NMRA DCC Reference Manual for QSI Quantum Equipped Locomotives

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NMRA DCC Explained

Digital Command Control (DCC) is the standard adopted by the National Model Railroad Association (NMRA) in 1994[1] to allow compatible operation of all engines and Command Stations regardless of manufacturer.

DCC differs from Analog control in that DCC applies full voltage to the track at all times and controls the speed and functions of different locomotives by addressing each engine separately using assigned engine ID numbers. The control method is similar to modems that send digital signals to remote computers. Because each engine can be addressed separately, it is possible to control speed, lights, and sounds on different engines independently on the same powered track. DCC provides features and opportunities that are not currently available under conventional Analog Control, but does require the user to commit to a new and more complex operating system.

Quantum equipped engines have been designed to operate directly out of the box under NMRA standards for either Analog conventional Analog DC operation or Digital Command Control. There are no switches in the locomotive that need to be set to select the type of control system. The Quantum System responds directly to the type of signal on the track.

This Manual

The Quantum DCC Reference Manual is divided into seven parts:

- the first covers basic operation under DCC and how to get started quickly with your Quantum equipped engine,
- the second covers programming Configuration Variables (CV's) that are used to customize your engine's performance,
- the third describes individual NMRA standard CV's supported by the Quantum System,
- the fourth deals with changing how features are assigned to different Function Keys,
- the fifth section describes CV's that are unique to the QSI Quantum Sound and Control System,
- the sixth section describes additional NMRA CV's and
- the appendices cover sound and features descriptions for each engine type, operation with different DCC Digital Command Stations, troubleshooting and Applications Notes.

Quantum is designed to operate all locomotive types using NMRA DCC control. The three most common locomotives are Steam, Diesel and Electric, although others, such as trolleys, powered commuter cars, subway, etc. can be operated under DCC as well.

Many operations of Quantum equipped engines, such as turning on and off the Bell, changing direction, blowing a Horn or a Whistle, are the same across all engine types. In addition, we have grouped some features that have a common function to operate in the same way using common terms across all model types. Special operations or behaviors for different types of Quantum equipped engines are described separately in the Operator's Manual that comes with the locomotive. Any special features included in this Reference Manual will be described in sidebars or notes and in the Appendix section, *Sounds Available Under DCC Operation*.

[1] The Electrical and Communication Standards were adopted by the NRMA in Portland OR in July, 1994. The basic Recommended Practices (RP's) were accepted in 1995 in Atlanta Georgia in 1995 and the Service Mode RP's were established in 1996.

Important Notes About Quantum DCC Operation

This is a complete reference manual for DCC features included in the QSI Quantum system. Although the Quick Start descriptions of DCC operation will allow you to begin operating your Quantum equipped engine immediately, this manual is not for the purpose of teaching you how to use DCC. We assume that you already have the working knowledge and experience to operate and program the different DCC features. If you are just getting started in DCC, there are several books listed in the Appendix to instruct you in the operation of DCC layouts, turnouts, accessories, programming, Configuration Variables (CV's), etc.

As new Quantum engines are introduced, they may have features not found in older locomotives. Since this reference manual is a complete description of all currently available features for DCC operation of the Quantum System, check your individual instruction manual that came with your locomotive to determine which features apply to your engine. This document will evolve over time as new information is added with the purpose of keeping it as complete and current as possible.

1. Locomotive Operation under DCC

1.1 Getting Started

Although DCC operation can be very complex, it does not have to be. We have preprogrammed the common and more popular features for your locomotive to operate with most DCC command stations. The following brief operation description will get you up and running quickly with your Quantum equipped locomotive.

These simple steps will allow you to start operating your Quantum equipped locomotive immediately.

- Select engine number 3
- Set your controller to 128 (preferred) or 28 (acceptable) speed step range[2]
- Start your locomotive by turning up the throttle

1.2 Direction Control

The direction of your locomotive will change when you press the direction key. If the engine was moving at the time you pressed the direction button, the engine will slow at a speed determined by the deceleration setting in CV 4, come to a complete stop and then accelerate in the other direction as determined by the C3 acceleration setting. Settings for C3 and C4 are described in the section on DCC Configuration Variables.

When you reduce the throttle setting to zero, and the engine has come to a complete stop, it will automatically enter Neutral with special background sounds appropriate to its resting state. If the engine was moving Forward, the Headlight will dim when it stops and enters Neutral, which was common practice for prototype locomotives under Rule 17[3]. You will also hear a short air release whenever the engine enters Neutral.

2 If you set your controller to 14 speed-step operation without reconfiguring your Quantum system to the same speed steps in CV 29, your directional lighting will not operate correctly.

3 Rule 17, followed by prototype railroads, states: The headlight will be displayed to the front of every train by night, but must be dimmed or concealed when a train turns out to meet another and the entire train has stopped clear of main track, or is standing to meet trains at the end of double track or at junctions.

Locomotive States under DCC Operation

Each Quantum locomotive has four distinct states under DCC operation described below:

Forward (FWD): If the engine is set to the Forward Direction and the engine is moving, it is in the "Forward" state . This is the same as any DCC operated locomotive.

Neutral from Forward (NFF): If the engine is set to the Forward Direction, and the throttle is turned down to zero speed step and the engine is stopped, it will be in a Neutral State called "Neutral from Forward".

Reverse (REV): If the engine is set to the reverse direction and the engine is moving, it is in the "Reverse" state. This is the same as any DCC operated locomotive.

Neutral from Reverse (NFR): If the engine is set to the reverse direction, and the throttle is turned down to zero speed step and the engine is stopped, it will be in a Neutral State called "Neutral from Reverse".

1.3 Function Keys

The following table lists features that have been pre-assigned to your DCC Function Keys for common operation across the different types of locomotives currently supported by Quantum. Operation of these keys can be different in the Neutral State (engine stopped) and the Motive State (engine moving in Forward or Reverse). Check the Operator's Manual that comes with each locomotive to see which of these common features are offered or what additional custom features have been included. Each of the common features is described in detail below the table.

Note: Quantum supports the new NMRA 0-12 Function Key standard as proposed; the current 0-8 standard is not supported[4].

1.3.1 Common Feature Function Key Assignments

Default F-Key	FWD/REV	NFF/NFR
FL(f)	Headlight Directional Lighting	Headlight Directional Lighting
FL(r)	Reverse Light Directional Lighting	Reverse Light Directional Lighting
F1	Bell	Bell
F2	Whistle/Horn	Whistle/Horn
F3	Coupler Crash-Coupler Fire	Coupler Arm (Enable) or Coupler Fire
F4	Steam Blower Hiss/ Diesel Fans and Louvers/ Electric Cooling Fans	Steam Blower Hiss/ Diesel Fans and Louvers/ Electric Cooling Fans
F5	Dynamic Brakes	Dynamic Brakes
F6	Doppler Shift	Engine Start Up
F7	Brake Squeal-Flanges	Reserved
F8	Audio Mute	Audio Mute
F9	Cruise Control	Shut Down[5]: Disconnect-Standby set-Total Shut Down
F10	Reserved	Reserved
F11	Reserved	Reserved
F12	Hazard Light/Cab Light	Hazard Light/Cab Light

4 The only Quantum equipped engine using the F0-F8 specification is the 2002 J1e Hudson by BLI, version ho300a02.
5 There are three stages to Shut Down. To operate Shut down, you will need to double click the F9 key for each stage.

- Reserved “common” feature will be assigned by QSI as the Quantum system evolves. On individual locomotive types, custom features may be assigned to the reserved positions. Consult your operator’s manual.
- The FL Key is sometimes labeled F0, Headlights, Lights or Directional Lighting on different DCC controllers.

1.3.2 Function Key Operation Explained

Most DCC hand held controllers have 9 to 13 Function Keys for operating various features. Before Sound Decoders became available, there was limited use for a large number of Function Keys. Usually, functions were applied to different lights and perhaps to some mechanical appliances such as a smoke units, etc. Sound decoders can require many more functions to operate the different sound features and also require a different use of the standard function key commands. In order to understand how we define the operation of our various sound features, it is worthwhile to understand how function commands operate.

Each function has two values, which were intended to operate features as follows: a “1” turns the feature on while a “0” turns the feature off. Many decoders show readouts of each function value, which allows the operator to know the status of the function without looking at or listening to the locomotive. For instance, if he sees that FL is “on” at the controller, he knows his directional lights are “on” in the locomotive.

Function Groups: Instead of the Function Commands being sent out as individual commands, they are sent out in groups to the selected locomotive. **Function Group One** sends out the commands for Functions F0 (or FL) and F1 – F4. **Function Group Two** sends out the commands for either Functions F5 – F 8 or F9 – F12.

Some decoders do not send out function groups until there is a change in any of the functions within that group. For instance, the controller may have Functions 1, 3 and 4 turned on (set to 1’s) while Functions 0 and 2 are off (set to 0’s). When the user changes Function 2 to on, then Function Group 1 is transmitted to the locomotive with the entire set of bits for all functions FL, and F1- F4.

This normally does not cause a problem if the engine had previously received all of the function settings at the last transmission. However, if the locomotive’s function states do not match the controller, the user can expect other functions to respond besides the one that is being changed.

For instance, if the FL command is registered as on (1) in the engine while it is shown as off (0) at the DCC controller, then sending a command to turn on the bell, F1, would have the additional effect of turning off the lights.

Understanding how function groups operate can explain a mystery about Quantum Directional Lighting.

Why does QSI choose to have the Directional Lights off by default?

If we assume that the user prefers to have his directional lights on during operation, why do we have Quantum Directional Lighting System off by default when an engine is selected? To understand this, consider the case where we have the lights on by default. If the lights were on in the controller and any other function key were pressed in Function Group One, then the lights would stay on; this is certainly good. However, if the lights were off in the controller, and the user pressed some other function key in Function Group One, then the lights would turn off. He would then need to turn the lights back on. This can be distracting, especially with steam engines that have a very distinctive turn on and turn off dynamo sound effect. The observer would see and hear the lights come on by default, then turn off when he pressed some other function key like the whistle, and then turn on again when he presses the FL Key– very unprototypical.

However, if the engine lights were off by default and the controller had the lights registered as on, then the lights would come on if any other function key were pressed – this is good. On the other hand, if the controller has the lights registered as off, then the lights stay off when another function command is sent in Function Group One – this is also good. The user could then send his light function command to turn the lights on.

To complicate the above problem, some controllers do not reset their function settings when a new engine is selected. Pressing any function key will send out a set of function commands that may not be what the operator wants.

In addition to the above problems with sending Function Group commands, sound decoders often need to operate sound effects in different ways than to simply turn on and off a particular feature.

1.4 Headlight and Reverse Light Operation (F0 or FL Key)

If the locomotive is moving Forward (or in Neutral From Forward (NFF)), the F0 Key will affect the Directional Lighting System. If F0 is "1", the Directional Lighting System will be on. If the F0 output is "0" the Directional Lighting System will be off. Once the Directional lighting system is turned on, Forward and Reverse lights will react to direction changes.

Some locomotives have "dim" headlight capability. If the engine enters Reverse or stops in Neutral From Reverse or stops in Neutral From Forward, the headlight will go to a dim setting. The Headlight will be at its bright setting only in Forward.

The table below is a summary of light operation in the different directional states for locomotives that have "dim" headlight option.

	Forward	Neutral from Forward	Reverse	Neutral from Reverse
Headlight	On	Dim	Dim	Dim
Reverse Light	Off	Off	On	On

The table below is a summary of light operation in the different directional states for locomotives that do not have "dim" headlight option.

	Forward	Neutral from Forward	Reverse	Neutral from Reverse
Headlight	On	On	Off	Off
Reverse Light	Off	Off	On	On

Some locomotives are equipped with special pulsing hazard light called a Mars Light mounted on the front of the locomotive. The table below is a summary of Mars Light, Headlight, and Reverse Light operation in the different directional states.

	Forward	Neutral from Forward	Reverse	Neutral from Reverse
Mars Light	Pulsing at Bright Setting	Dim non-pulsing	Dim non-Pulsing	Dim non-Pulsing
Headlight	On	Off	Off	Off
Reverse Light	Off	Off	On	On

Steam locomotives use a steam-powered generator, called a Dynamo, to supply electricity to the lights. When the lighting system is turned on, the steam generator revs up to full power over a couple of seconds as the brightness of the headlight comes on slowly. Check your Operator's manual to see if your model has this feature.

Note: If your F0 or FL key does not affect the headlight or Reverse Light, see the trouble shooting section in the appendix.
Note: Some base stations do not send the light toggle command when the engine is first turned on. To turn the directional lights on, press the F0 key once or twice after the engine is selected. Read the trouble shooting section for further information.
Note: The default for directional lighting is off. For an explanation, See *Why does QSI choose to have the Directional Lights off by default?* on page 8.

1.5 Horn and Bell Buttons (F2 Key and F1 Key)

For DCC controllers that have a bell button and a horn button, there are Function Keys that perform the same operations. The horn button is usually assigned to F2. If you press the F2 Key or the horn button, the Whistle or Horn will blow. The bell buttons might be assigned to F3 or F1 on your DCC controller.

- Pressing the F2 Key and releasing it will cause the Whistle or Horn to come on and stay on, until you press F2 again.
- Pressing the F1 Key and releasing it will cause the Bell to come on and stay on, until you press F2 again.

Note: If your DCC controller has assigned the Bell to F3, you can reassign Quantum Function 3 to the bell output (see CV 37). Remember to reassign the F1 Function to some other output besides 3 (see CV 35). Definitions and assignments of functions are described later in this manual.

Note: Pressing the F2 key and releasing will cause the Whistle or Horn to come on and stay on, and pressing it again will turn it off. On the other hand, if you have a horn button, it will blow the Whistle/Horn only as long as you are holding the horn button down. When you release the horn button, the Whistle/Horn will stop. There is no difference in operation between the bell button and its corresponding function key.

1.6 Throttle Control and Speed Control

There are three ways your engine can respond to your throttle.

- **Standard Throttle Control (STC) :** Under Standard Throttle Control, the "power" to the locomotive is controlled directly by the throttle setting and the speed changes under varying loads. This is the type of throttle control that almost all locomotives use. Its disadvantage is that the engine may easily stall at low speeds from minor gear binding, turnouts, and curves.

- **Speed Control (SC)**: Speed Control uses internal motor control electronics to maintain the same speed regardless of varying load conditions. Under speed control, the throttle setting (using 128 speed steps) selects the engine's speed in 1 smph (scale miles per hour) increments. For instance, if your throttle is set at 35, the model locomotive will go 35 smph on level track or up hill or down hill. If you use 14 or 28 speed steps, you will need to multiple your settings by 9 and 4.5 respectively to compute your scale speed. The disadvantage is that in Consists, the power is not shared evenly among all engines, if there is even slight mismatch is speed calibration. For further explanation, see CV 56.4.

- **Regulated Throttle Control (RTC)** : RTC combines the benefits of Standard Throttle Control and Speed Control and is the preferred method when multiple heading Quantum engines together because if equalizes power between locomotives. RTC, like Speed Control, will also allow you to run your locomotive very slowly without concern that it will abruptly stop from minor impediments such as misaligned track joints, tight curves, rough switches, etc. RTC operates your engine as though it has inertia; your engine will resist changes in speed once it is moving and will resist starting up quickly if at rest. For instance, if your locomotive under RTC encounters a grade, it will eventually slow down. Providing more throttle will slowly accelerate it back to speed.

Note: The default is “Speed Control”. If you prefer, change to Regulated Throttle Control in CV 56.4.

Important Legal Notice

Regulated Throttle Control and Speed Control features may not be included in your locomotive model under DCC operation. These two functions have been eliminated by some model railroad importers of Quantum equipped locomotives because of threats of litigation by Mikes Train House. QSI believes the claim by Mikes Train House is unfounded because these control features were developed by QSI and others and were in use long before Mikes Train House claims to have invented them. QSI does not believe that Quantum Sound System infringes any MTH patent.

1.7 Sound of Power™

Quantum locomotives will produce labored chuff sounds under acceleration and lighter drift chuff under deceleration but only if CV 3 and CV 4 and/or CV 23 and CV 24 are set to non-zero values. The level of labored sounds is proportional to the level or CV 3 and CV 4 and/or CV 23 and CV 24, and how much the throttle is increased or decreased.

1.8 Coupler Sound Effects (F3 Key)

There are two ways to use the F3 key.

- As your engine is about to couple up to a string of cars, press the F3 key to produce the crashing sound of engine coupling. Use the F3 key again as the engine moves to produce the same sound as the slack is taken up in the cars.
- Or use the F3 key in Neutral to produce uncoupling sounds as you disconnect cars over uncoupler magnets. Press the F3 key once to produce the sound of the lift bar and coupling pin being raised. This operation also arms the uncoupling sound effect. Press the F3 key again while moving or in Neutral to produce the sound of the coupler knuckle opening (fire the coupler) and the brake air-lines parting.

If you have armed the Coupler in Neutral and are now in Forward or Reverse, pressing the F3 Key will produce the coupler opening sound. Thereafter, as you continue in Forward or Reverse, the F3 Key will produce Coupler Crash Sounds.

1.9 Steam Blower Hiss and Cooling Fans (F4 Key)

Steam Blowers are used to increase the draft in the firebox by venting steam through the smoke stack. This creates a steam hiss sound heard quite often around idling steam locomotives. When

you press the F4 Key in Forward/Reverse or Neutral, Blower Hiss will toggle on or off. If it is turning on, you will hear the hiss sound increase in increments for each turn of the value as the fireman adjusts the blower. If it is turning off, you will hear the hiss sound decrease in increments.

For Diesels and Electrics, F4 toggles on the Vents and Cooling Fans. If the Cooling Fans are turned off, you will hear the fans gradually stop followed by the Vents and Louvers closing. If the Cooling Fans are being turned on, you will first hear the Vents and Louvers opening followed by the Fans coming on.

1.10 Dynamic Brakes (F5 Key)

Diesel Locomotives: The prototype Dynamic Brakes, found on most diesels, cause the train to slow down by using the traction motors in generator mode. This helps dissipate the energy of a moving train by applying electrical power from the traction motors to a large air-cooled resistor load in the locomotive. These resistor grids can get quite hot and require cooling by fans located on the roof of the locomotives.

- Pressing the F5 key in Forward will set the diesel motor sound to idle at the lowest Sound of Power setting and turn on the powerful Dynamic Brake Cooling Fans.
- Pressing the F5 key in Neutral will turn on the Dynamic Brake Fans while diesel motor sounds remain at idle.

Steam Locomotives: Prototype Steam Locomotives do not have Dynamic Brake sounds. However, the Dynamic Brake function has been included to make steam engines consistent with other Quantum equipped locomotives.

- Pressing the F5 key will set the Steam Exhaust Sound-of-Power to the lowest setting allowing the steam engine to behave consistently[6] with other engines that do have Dynamic Brake sounds in multiple unit Consists.

Electric Locomotives: Early Electric Locomotives did not have Dynamic Brakes. However, the Dynamic Brake function has been included to make Electric Locomotives consistent with other Quantum equipped locomotives.

- Pressing the F5 key will set the Electric Traction Motor Sound-of-Power to the lowest setting allowing these early Electric Locos to behave consistently[7] with other engines that do have Dynamic Brake sounds in multiple unit Consists.

If an Electric Locomotives has Dynamic Brakes with resistor grids and cooling fans, the engine will behave in a similar manner to Diesels.

Note: The Dynamic Brake function automatically turns off when entering or leaving Neutral, or the speed of the locomotive drops below 8 smph, or if the throttle is turned up. The Dynamic Brakes cannot be turned on in Forward or Reverse unless the engine is traveling over 9 smph.

1.11 Doppler Operation (F6 in Forward and Reverse)

There are two ways to control the Doppler effect. If your controller has a horn button in addition to the F2 key, use the horn button in the same way as it is used under conventional Analog control to trigger the Doppler effect.

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6 It would be inconsistent for the steam engines to be working at full Sound-of-Power while brakes are being applied in other locomotives within the same consist.

7 It would be inconsistent for the steam engines to be working at full Sound-of-Power while brakes are being applied in other locomotives within the same consist.

1.11.1 Horn Button Method

- While the engine is moving towards the observer, press the horn button to turn on the Whistle/Horn.
- Wait at least one second while the Whistle/Horn is blowing
- Release and re-press the horn button quickly so the Whistle/Horn does not shut off. Instead you will hear the Whistle/Horn and engine sounds increase in volume and shift in pitch as the engine passes by and then reduce in volume.
- Release the horn button at any time or continuing blowing long and short blasts. When you release the button and do not re-press the horn button for one second or more, the sounds will gradually return to normal.

Note: We have experienced that some base stations produce an intermittent and independent horn signal interruption that causes an unexpected Doppler shift. If this happens frequently, you may want to disable the automatic Doppler shift in CV 51.2.

Note: If the bell was on during the Doppler Shift, it will automatically turn off prior to the sounds returning to normal.

1.11.2 F6 Doppler Shift Operation Method:

- Start the whistle by pressing and releasing the F2 key.
- Press F6 Doppler shift key. All sounds, including the whistle will go through Doppler shift as the engine passes by.
- Press the F2 button to shut off the horn or continuing blowing long and short blasts by pressing and re-pressing the F2 button. If you shut off the horn for more than one second, the sounds will gradually return to normal.

Note: If Doppler shift is initiated without the horn blowing, the sounds will soon return to normal after the Doppler shift is finished. If the Bell is ringing, it will shut off automatically before the sounds return to normal.

Note: You might try using the F6 key to affect the chuffing sounds (sans Horn or Bell) to create interesting environmental effects.

Note: With some Command Stations, using the horn button to activate the Whistle/Horn, and then while this button is held down, activating the F6 Doppler Key will cause the whistle to shut off instead of causing a Doppler shift effect.

Note: Doppler is speed dependent. The greater the speed, the greater the amount of pitch change as the engine passes by. There is no Doppler shift at speeds less than 15 scale miles per hour (smph); instead you will hear a short air let-off when F6 is pressed.

1.13 Squealing Brakes and Flanges (F7 in Forward or Reverse)

Squealing brakes will occur automatically when the speed is reduced to 10 smph just before stopping. This effect only occurs if the engine has previously exceeded 40 smph prior to stopping. This prevents the automatic brakes from occurring too often for short switching maneuvers at low speeds.

However, squealing brakes can be manually activated anytime by pressing the F3 key when the engine is moving at any speed. The F3 Key can be pressed any number of times to start and continue brake sound effects without any dead period to continue the squealing sounds indefinitely.

- The F7 Key can be pressed any number of times while the squealing occurs to continue the brake effect.

With a little practice, you can extend brakes sounds to simulate long stops or the sound of locomotive flanges and car flanges as your train moves through long curves.

1.14 Audio Mute (F8 Key)

Quantum provides a way to quickly shut off or reduce in volume all engine sounds if you wish to talk on a phone or have a conversation with another person.

- Set F8 Function to “1” in Forward, Reverse or Neutral. All sounds, including the Whistle, Bells, Motors and Chuff will immediately go off.
- Set F8 Function to “0” in Forward, Reverse or Neutral. All sounds, including the Whistle, Bells, Motors and Chuff will immediately go on.

Note: CV 51.1 will allow you to set the Mute volume so the sound does not go complete off when Mute is activated. This will still allow you to reduce the volume to make a phone call or talk to a friend but does not have the effect of turning the sounds completely off. In addition, you can use this feature to increase sounds for engine that approach the front or foreground of your layout and reduce sounds for engines that are in the distance.

1.15 Cruise Control (F9 in Forward or Reverse)

Quantum Cruise Control behaves in much the same way as cruise control on a modern automobile.

- Press F9 and hear two short toots when Cruise Control is toggled on
- Press F9 and hear one short toot when Cruise Control is toggled off.

When Cruise Control is on, the engine will continue at its present speed regardless of grades, changes in load, or tight curves. Turning the throttle up or down will not affect engine speed, but will cause Sound-of-Power chuffing or diesel motor labor sounds to change in direct proportion to the throttle’s movement from the initial setting (where Cruise Control was turned on). You can increase the laboring motor sounds in Cruise Control as a train climbs a grade or decrease the Sound-of-Power effects as the train moves down the grade.

Return the throttle to its initial setting to avoid acceleration or deceleration when Cruise Control is toggled off.

Cruise Control is only available under Regulated Throttle Control or Speed Control.

Note: Cruise Control is automatically turned off when the speed step is reduced to zero or track power is turned off.

1.16 Three Stages of Shut Down: Disconnect, Standby and Total Shut Down (F9 in Neutral)

Engine Shut Down has three distinct stages, all controlled by the operator. Each stage is entered by double clicking or double pressing the F9 Key[8].

Stage One: Disconnect

- Double press the F9 key in Neutral to enter Disconnect. Hear a long air let-off.
- To leave Disconnect, either double press the F6 Start Up key described in the Start Up section or double press the F9 key again to reach the next stage of Shut Down, Standby.

If you double press the F9 Key in Neutral, the motor drive will be disconnected from the Quantum Sound system. You will hear a long air release after entering Disconnect, which represents the pneumatic reverse lever being placed in the Neutral position or the diesel transition level being placed in the off or disconnect position. Once in Disconnect, the throttle can be moved up and down without the locomotive moving. All function keys are active in Disconnect.

Note: If the throttle on a diesel is increased or decreased, the motor sounds will rev up and down but the engine will not move. If the Dynamic Brakes are activated, the motors sounds will be labored under Sound-of-Power control as the throttle is increased and decreased. Prototype Diesel Motor/Generator power output is often tested under Dynamic Brake load.

Note: If the throttle on a steam engine is increased or decreased, the hissing sound of venting steam will get louder and softer but the engine will not move. Prototype steam engines would sometimes vent steam in Neutral to clear rust debris from the super-heaters that can affect the throttle.

Note: For Electric Locomotives, there is no action or sound associated with moving the throttle up and down and no affect from having the Dynamic Brakes activated.

Stage Two: Standby

- Double press the F9 key while in Disconnect to enter Standby.
- To leave Standby, either double press the F6 Start Up key described in the Start Up section or double press the F9 key again to reach the final stage of Shut Down, Total Shut Down.

If you double press the F9 key while in Disconnect, the locomotive advances to Standby. You will hear a long air release followed by Directional Lighting shut down and Steam Blower shutting down. The motor will remain disconnected. Air Pumps will remain on. In Standby, the engine will not respond to throttle or function keys. The one exception is the F6 Start Up Function Key (described below).

Note: Standby in Diesels, called Low Idle, has more utility than Standby in Steam and Electric locomotives. It allows a diesel to be left on a siding inactive with only the motor running at its special “Low Idle” sounds. For Steam and Electrics, the locomotive will appear to be completely inactive except perhaps for occasional Air Pump sounds.

Stage Three: Total Shut Down

- Double press the F9 in Standby to enter Total Shut Down.

8 Double Clicking ensures that Shut Down stages are not entered or exited accidentally. Doubling Pressing is defined as two F9 presses within two seconds. Note that the F9 key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for F9.

- To leave Total Shut Down, double press the F6 key.

If you double press the F9 key while in Standby, the locomotive advances to Total Shut Down. The air pumps will turn off plus a few other engine-specific shut down sounds. Under Total Shut Down, Function Keys will have no affect. The one exception is the F6 Start Up Function Key (described below).

Total Shut Down procedures are different for different locomotives.

Steam Locomotive: The air pumps will turn off, followed by the sounds of Pop Off Operating for about ten seconds and finally the Blower hiss will shut off.

Diesel Locomotive: The air pumps will turn off, as will the Number Board Lights, followed by the sounds of the cooling fans shutting off, the louvers closing, the diesel motors shutting down and finally, the Engineer's door opening and shutting.

Electric Locomotive: The air pumps will turn off, Cab Lights will turn off, followed by the sounds of the louvers being closed and the Engineer's door being opened and shut.

Note: If power is turned off at any stage of Shut Down (Disconnect, Standby or Total Shut Down) or during a Shut Down procedure, the engine will remember its last Shut Down stage, and will power up in the same stage[9]. If Start Up is initiated during any of the above Shut Down procedures, Shut Down is aborted and the engine returns to normal operation.

1.17 Start Up (F6 in Neutral)

If your locomotive is in any of the Shut Down stages, you can return your locomotive to normal operation by double pressing[10] the F6 Key. Start Up will be different for each stage of Shut Down, but all will start up with a long air release and will enter normal operation[11].

Start Up from Disconnect

- Double press the F6 key in Disconnect, the locomotive will produce a long air let-off and enter normal operation.

Start Up from Standby

- Double press the F6 key in Standby, the locomotive will produce a long air let-off, the Directional Lighting will turn on and then the engine will enter normal operation.

Start Up from Total Shut Down

- Double press the F6 key in Total Shut Down; the locomotive will produce a long air let-off, and begin a full start up procedure.

Note: During the Start Up procedure, none of the function keys are active.

Start Up procedures are different for different locomotives.

Steam Locomotives: The Dynamo will rev up while the Headlight comes on gradually, then the Cab Lights (if available) will turn on, followed by the air pumps, the Steam Blower will turn on and then the locomotive will enter normal operation.

9 Total Shut Down allows you to take an engine "off-line" (turn off sounds, lights ignore throttle and function commands (except turn on)) independent of the operating session; that is, the engine will still be "off line" when power is reapplied for the next operating session.

10 Double pressing ensures that Start Up is not entered or exited accidentally. Doubling Pressing is defined as two F6 presses within two seconds. Note that the F6 Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for F6.

11 Locomotive enters neutral with long air release if speed step is zero. If speed step is non-zero, locomotive will enter either forward or reverse.

Diesel Locomotives: The engineer's door will open and close, then the Number Board Lights will turn on, followed by vents opening, the two diesel motors starting up one at a time (if two motor diesel), the air pumps starting up, and the locomotive entering normal operation.

Electric Locomotives: The engineer's door will open and close, then the Cab Lights will turn on, followed by the air pumps, directional lights, vents opening and then the locomotive will enter normal operation.

Note: If the throttle is turned up from zero during any of the above Start Up procedures, the Start Up procedure will abort and the engine will enter normal operation.

Note: Whenever a Start Up command is sent, regardless of whether the locomotive is in a Shut Down stage or operating normally, the Quantum System will automatically restore all Automatic Operations disabling all Take Control operations.

1.18 Automatic Features with "Take Control" Operation

Some sound features, like steam Blower Hiss, operate automatically by turning on in a few seconds after entering Neutral and off again in Forward or Reverse where it is no longer required. Automatic features may also have Function Keys for manual operation. Since there are two ways to control these special features, it is a potential conflict about which method actually wins, the automatic operation or the operator. We deal with this problem by using a concept called "take control". Once the operator "Takes Control", the feature will no longer have automatic operation and instead will be controlled by its associated function key commands. Automatic and Take Control operations are described in the table below for present Steam, Diesel and Electric locomotives.

Steam "Take Control" Operation

	Automatic Operation			Take Control	
	Forward	**Reverse**	**Neutral**	**Function Key**	**Operation**
Steam Blower	Off after 10 sec	Off after 10 sec	On after 10 sec	F4	Toggles Steam Blower

- Take Control of the Automatic Steam Blower with the F4 key to stop automatic operation and control whether the Steam Blower is On or Off.

Note: When you Take Control, you will change the state of the Steam Blower in addition to taking control of the feature. For instance, if the automatic Steam Blower is on, pressing the F4 key will toggle the Steam Blower to off and it will stay off.

Diesel "Take Control" Operation

	Automatic Operation			Take Control	
	Forward	**Reverse**	**Neutral**	**Function Key**	**Operation**
Mars Lights	Pulsing at Bright Setting	Dim non-pulsing	Dim non-Pulsing	F12	Advances from it current state to the next state in the sequence of "Off-Dim-Pulsing-Off-Dim-Pulsing, etc"
Vents & Cooling Fans	Non-operating	Non-operating	On and off at random times	F4	Toggles Vents/Fans operation between on or off.

- Take control of the Mars Light with the F12 key to stop automatic control of the Mars Light whether it is Pulsing, off or Dim.
- Take Control of Automatic Fans with the F4 key to stop automatic operation and control whether the Cooling Fans are on or off.

Note: When you Take Control, you will change the state of the Mars Light and/or Cooling Fans in addition to taking control of the feature. For instance, if the automatic Mars Light is Operating, pressing the F12 key will toggle the Mars Light to off and it will stay off, until you change the Take Control feature to the next state using the F12 Key.

Electric Locomotive "Take Control" Operation

	Automatic Operation		Take Control	
	Forward/Reverse	**Neutral**	**Function Key**	**Operation**
Cab Lights	Lights off after 5 sec	Lights on after 10 sec	F12	Toggles Cab Lights
Cooling Fans	On after 10 sec	Off after 10 sec	F4	Toggles Cooling Fans

- Take control of the Mars Light with the F12 key to stop automatic control of the Mars Light whether it is Pulsing, Dim or Off.
- Take Control of Automatic Fans with the F4 key to stop automatic operation and control whether the Cooling Fans are on or off.

Note: When you Take Control, you will change the state of the Cab Lights and/or Cooling Fans in addition to taking control of the feature. For instance, if the automatic Cab Light is on, pressing the F12 key will toggle the Cab Light to off and it will stay off while you operate the locomotive, until you toggle the Take Control feature to on using the F12 Key.

Note: Automatic operation will be restored if the power is shut down and reapplied or if the F6 Start Up key is double pressed in Neutral (see the description of Start Up above).

1.19 Neutral Sounds

Some of the same function keys used in Forward and Reverse will have different effects in either of the two Neutral States.

- The F7 Key produces Brake Squeal for a moving steam engine but activates the Boiler Water Injector if the engine is in Neutral.
- F6 results in Doppler shift for a moving engine but activates Start Up when in Neutral.
- F9 toggles Cruise Control when the engine is moving but activates Shut Down in Neutral.

Note: If a special Neutral Sound (i.e. Steam Water Injector, Steam Blow Down, Steam Pop-off, etc.) is occurring when you press one of the Function Keys that control any other special Neutral Sound, it will start the effect associated with that Function Key and will terminate the feature that was previously playing.

2. Programming

There are two types of operation for a DCC equipped engine: Operations Mode and Service Mode.

1. **Operations Mode**[12] (Ops Mode) is used to operate your train on a layout but it can also be used for programming the locomotive's decoder to customize it for your particular needs and operating preferences.
2. **Service Mode**[13] is used exclusively for programming your engine and, depending on your command station, can provide feedback on values entered into the decoder.

Service Mode is done on a special track called a "Programming Track" while Operations Mode Programming can be done anywhere on the layout. In either case, programming involves changing the values of parameters called Configuration Variables (CV's) that will change the operation of your engine. Both programming modes have their advantages and disadvantages. Which one you use will depend on your personal preferences, the layout you are operating on, and the capabilities of your command station. Both Service Mode and Operations Mode programming are described in detail in later sections.

2.1 Configuration Variables Explained

Configuration Variables or (CV's) are settings stored in the Quantum's non-volatile memory[14] that affects how your locomotive operates. These variables can be programmed and reprogrammed as often as needed by the user to customize the engine's behavior. The CV values will be maintained indefinitely in memory until they are reprogrammed or the Quantum System memory is reset.

There are over 70 standard CV's described by the NMRA that can be programmed by the user. The table below shows an example of the factory default CV (Configuration Variable) settings for some of the more important CV's for the Lionel Challenger locomotive. These CV's have been preset at the factory to provide the best operation right out of the box. Other locomotives may have different values and additional CV's. Programming of CV's is described in the following section.

Typical Factory Default Settings for Quantum Equipped Locomotives

Short Address	03
Speed Steps	28 or 128
Throttle Mode	Speed Control
V-Start	32
V-High	1 - disabled
Acceleration	0
Braking (Deceleration)	0
Consist Address	0
Speed Table	N/A
System Volume	100%
Doppler Effect with F6	Enabled
CV Verbal Feedback	Enabled

12 Both the short form and the long form of the CV access instructions are supported.
13 All four methods are supported: Address-Only Mode, Physical Register Addressing Mode, Paged CV Addressing Mode, and Direct CV Addressing Mode.
14 CV memory is retained even when the locomotive is stored without power for up to one hundred years.

Check the Operator's Manual supplied with your locomotive for a list of factory defaults and features that are supported.

2.2 Service Mode Programming

One method provided by the NMRA to program all CV's is called Service Mode. The locomotive is placed on an isolated track, called a Programming Track, that is electrically insulated from the main line and separately connected to a special output from your Command Station. There are advantages to programming in Service Mode.

1. No Engine Addresses are required to program your engine on the Programming Track. This is an advantage if you have forgotten your engines ID numbers or have programmed it incorrectly. This is also why this programming must be done on an isolated track section. Otherwise, all locomotives CV's on your layout would be programmed with the same value at once.

2. NMRA specified acknowledgements are available from the engine on the Programming Track. If your command station supports Service Mode Acknowledgements, you will be able to read back the current value in a CV. This is an advantage if you want to change a CV by some amount but need to know where you are starting from before you enter a new value. It is also reassuring to receive some feedback from your engine during CV programming to know that programming is actually happening. Verbal feedback is not available from Quantum equipped engines in Service Mode.

The NMRA specifications for Acknowledgements are that at least a 60 milliamp (mA) differential current load must be applied by the engine on the Programming Track when the Command Station requests an acknowledgement. Most decoders, including the Quantum System, turn on the motor briefly to produce this load. A differential current load means that the current must increase by at least 60 mA over the current that is normally applied to the engine on the Programming Track to operate the decoder. The command station can sense this current increase and register this as an acknowledgement to its query. **The Quantum System conforms to the NMRA standard for Service Mode programming.**

Note: Some Command Stations have restricted the amount of power that can be delivered to the Programming Track to prevent damage to improperly installed aftermarket decoders. If the decoder were wired correctly, the Programming Track would provide enough power to allow it to be programmed. If the decoder were wired incorrectly and a short circuit occurred, the limited current from the command station would not be enough to damage the decoder, allowing the operator another chance to wire it correctly.

In order to accommodate command stations that do restrict power during Service Mode programming, the Quantum System reduces its power consumption to a minimum by shutting off all lights, sound and other operations during Service Mode operation. Even so, the Quantum Sound Decoder will still require more current than most non-sound decoders. If your Quantum System will not program with your particular command station, you will need to program on the Main (Ops Mode Programming).

2.3 Operations Mode Programming

Operations Mode CV Programming is fully supported. Operations Mode is also called Ops Mode or Programming on the Main since no Programming Track is required.

Quantum System will allow the user to program all CV's including address CV's (CV 1, CV 17 and CV 18) in Operations Mode.

As with Service Mode, there are advantages and disadvantages to using Operations Mode Programming.

1) No advanced acknowledgement mechanism, as defined by the NMRA, is currently supported in Ops Mode Programming. If you are using a command station that provides readout for your CV's in Ops Mode, it can only indicate which CV you are addressing and the value you want to program. You will not be able to determine what value is already entered in that CV or that the new value has been accepted and is correct.

   Note: The Quantum System does provide verbal feedback when programming CV's in Ops mode. If a CV verbal acknowledgment (CV 62) is enabled, the CV number and the value written is announced over the Quantum sound system when a CV is programmed.

   Note: The Quantum System also provides a way to query any specified CV for its present value in Ops Mode (CV 64).

2) One disadvantage with Programming on the Main is that you will need to address your engine with its ID number before you can change CV values. The disadvantage is not that an extra step is required to enter the ID number; rather the problem is that you might enter a new ID number incorrectly or your might have forgotten your ID number altogether. Since we do support Ops Mode programming for changing any CV, it could happen that you find yourself unable to communicate with your locomotive. If this does happen, you can either move your engine to a Programming Track and change your ID using Service Mode Programming, or you can do a hardware reset by pulling the reset jumper on the circuit board (see Appendix IIIa).

   Note: Some command stations do not support programming ID's on the main. See notes in trouble shooting and related CV's (1, 17, 18, 56.129) for possible solutions to this problem.

3) On advantage of programming on the main is that you will be able to hear the actual System Volume or individual feature sound volumes change immediately as you enter new CV values. In Service Mode, you would have to remove the engine from the Service Mode Programming track and "test it out" on the Main to see if it is the value you want.

2.4 List of NMRA CV's Support by Quantum

The following table lists all CV's. The NMRA (2nd column) indicates whether these CV's are mandatory (M), recommended (R), or optional (O). The fifth column indicates if this CV is supported by QSI and the sixth column indicates the common default value.

CV#	CV Name	NMRA	QSI Supported	Default Value Decimal	Comment
1	Primary Address	M	Y	3	
2	V-Start	R	Y	32	This number may change from engine to engine.
3	Acceleration Rate	R	Y	0	
4	Deceleration Rate	R	Y	0	
5	V-High	O	Y	1	Either 1 or 0 in this CV will disable V-High
6	V-Mid	O	N	-	
7	Manufacturer Version No.	M	Y	-	See CV 56.128.nn for additional information on Quantum Specifications.
8	Manufacturer's ID	M	Y	113	
9	Total PWM Period15	O	N	-	Not needed with our motor control.
10	EMF Feedback Cutout2	O	N	-	Not needed with our BEMF detection.
11	Packet Time-Out Value	R	Y	1	About 1 second
12	Power Source Conversion	O	N	-	
13	Analog Mode Function Status	O	N	-	
14	Reserved by NMRA for future use	-	-	-	
15	Reserved by NMRA for future use	-	-	-	
16	Reserved by NMRA for future use	-	-	-	
17	Extended Address	O	Y	0	CV 17 and 18 form a paired CV. CV 17 must be written first followed by CV 18
18	Extended Address	O	Y	0	See above.
19	Consist Address	O	Y	-	
20	Reserved by NMRA for future use	-	-	-	
21	Consist Address Active for F1-F8	O	Y	0	
22	Consist Address Active for FL	O	Y	0	
23	Acceleration Adjustment	O	Y	0	
24	Deceleration Adjustment	O	Y	0	
25	Speed Table Selection	O	Y	2	Linear
26	Reserved by NMRA for future use	-	-	-	
27	Reserved by NMRA for future use	-	-	-	
28	Reserved by NMRA for future use	-	-	-	
29	Configuration Data #1	M	Y	2	28 speed step mode.
30	Error Information	O	N	-	May be used in the future but not currently needed.
31	Configuration Data #2	O	N	-	Reserved by NMRA for future use.
32	Configuration Data #3	O	N	-	Reserved by NMRA for future use.
33	Output Function Location for FL(f)	O	Y	1	Preset to directional lighting.
34	Output Function Location for FL(r)	O	Y	3	Preset to directional lighting.
35	Output Function Location for F1	O	Y	4	Preset to bell output
36	Output Function Location for F2	O	Y	8	Preset to whistle output.
37	Output Function Location for F3	O	Y	16	

15 Changes are not allowed. The PWM is already optimized for Quantum equipped locomotives.

38	Output Function Location for F4	O	Y	4	
39	Output Function Location for F5	O	Y	8	
40	Output Function Location for F6	O	Y	16	
41	Output Function Location for F7	O	Y	32	
42	Output Function Location for F8	O	Y	64	
43	Output Function Location for F9	O	Y	16	
44	Output Function Location for F10	O	Y	32	
45	Output Function Location for F11	O	Y	64	
46	Output Function Location for F12	O	Y	128	
47	Reserved by NMRA for future use	-	-		
48	Reserved by NMRA for future use	-	-		
49	QSI Primary Index	O	Y	0	
50	QSI Secondary Index	O	Y	0	
51	QSI System Sound Control	O	Y		
52	QSI Individual Sound Volume Control	O	Y		
53	QSI Function Output Feature Assignment	O	Y		
54	Reserved by QSI for future use	-	-		
55	Reserved by QSI for future use	-	-		
56	QSI Configuration	O	Y		
57	Reserved by QSI for future use	-	-		
58	Reserved by QSI for future use	-	-		
59	Reserved by QSI for future use	-	-		
60	Reserved by QSI for future use	-	-		
61	Reserved by QSI for future use	-	-		
62	QSI Control	O	Y	1	
63	Reserved by QSI for future use	-	-		
64	Verbal CV Inquiry	O	Y		
65	Kick Start	O	N	-	Not needed.
66	Forward Trim	O	Y	128	
67	Speed Step 1	O	Y	0	
68	Speed Step 2	O	Y	9	
69	Speed Step 3	O	Y	18	
70	Speed Step 4	O	Y	28	
71	Speed Step 5	O	Y	37	
72	Speed Step 6	O	Y	47	
73	Speed Step 7	O	Y	56	
74	Speed Step 8	O	Y	66	
75	Speed Step 9	O	Y	75	
76	Speed Step 10	O	Y	85	
77	Speed Step 11	O	Y	94	
78	Speed Step 12	O	Y	103	
79	Speed Step 13	O	Y	113	
80	Speed Step 14	O	Y	122	
81	Speed Step 15	O	Y	132	
82	Speed Step 16	O	Y	141	
83	Speed Step 17	O	Y	151	
84	Speed Step 18	O	Y	160	
85	Speed Step 19	O	Y	170	
86	Speed Step 20	O	Y	179	
87	Speed Step 21	O	Y	188	
88	Speed Step 22	O	Y	198	
89	Speed Step 23	O	Y	207	

90	Speed Step 24	O	Y	217	
91	Speed Step 25	O	Y	226	
92	Speed Step 26	O	Y	236	
93	Speed Step 27	O	Y	245	
94	Speed Step 28	O	Y	255	
95	Reverse Trim	O	Y	128	
96	Reserved by NMRA for future use	-	-		
97	Reserved by NMRA for future use	-	-		
98	Reserved by NMRA for future use	-	-		
99	Reserved by NMRA for future use	-	-		
100	Reserved by NMRA for future use	-	-		
101	Reserved by NMRA for future use	-	-		
102	Reserved by NMRA for future use	-	-		
103	Reserved by NMRA for future use	-	-		
104	Reserved by NMRA for future use	-	-		
105	User Identifier #1	O	N		
106	User Identifier #2	O	N		
107	Reserved by NMRA for future use	-	-		
:	:	-	-		
512	Reserved by NMRA for future use	-	-		

3. CV Descriptions - Overview

This section provides detailed descriptions of each CV supported by the QSI Quantum System. Each CV on the following pages shows the default value, a pictorial of the CV data register and notes regarding its use, limitations, explanations and operational hints, when appropriate.

The data for each bit shown in the pictorial data registers are classified as:

"**A**" for Address data

"**D**" for general data

"**F**" for Function Designation value

"**Sign**" for plus or minus sign.

"**N/A**" for Not Applicable meaning the user is not to enter data in these bits.

"**Output**" for assigning different Output locations for Function Inputs.

"**P**" for QSI Primary Index values

"**S**" for QSI Secondary Index values

"**V**" for audio volume data

In addition, QSI or NMRA pre-assigned data for individual bits in CV registers are shown as their binary value, "1" or "0".

Examples:

CV 1: Primary Address Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**A6**	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**

Bits 0-6 are data bits, which specify the engines seven bit Primary Address. A zero means, "do not attempt to write a 1 to this bit".

CV 49: Primary Index Register

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
P7	**P6**	**P5**	**P4**	**P3**	**P2**	**P1**	**P0**

Bits 0-7 are data bits, which specify any of the possible eight bit Primary Index values.

CV 40: F6 Output Function Location for F6 Register (with Factory Default Features)

Cruise Control (Disconnect-Standby-Shut Down)	Mute	Squealing Brakes (Special)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Whistle/Horn
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 11	**Output 10**	**Output 9**	**Output 8**	**Output 7**	**Output 6**	**Output 5**	**Output 4**

The "**Output 4**" means that bit 0 specifies whether Output 4 is controlled by Function Key 6.

Gray background for an Output bit means that it is the default setting.

3.1 CV 1 Primary Address Control

Programs Quantum Short or Primary Address from 1 to 127 decimal.

Default Value: **3**

CV 1: Primary Address Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**A6**	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**

- Writing to this CV sets Quantum's Primary Address to any value between 1 and 127. The Quantum System will process any valid command sent by the base station with an address that matches the address stored in this register.
- Any attempt to set this CV to any value outside the range of 1 to 127 will be ignored and the previous address in this register will remain.
- The Primary Address can be set either in Service Mode or Operations Mode. Remember to change bit 5 of CV 29 to "0" to enable the Primary Address.

Note: Some Command Stations will not operate Quantum Systems in Service Mode due to insufficient power output or timing problems. (Check Appendix II for a listing of recommended command stations). If you cannot operate in Service Mode, use Ops Mode programming.

If your command station will not allow setting ID numbers in Ops Mode, use QSI CV 56.129.

3.2 CV 2 V-Start

V-Start defines the voltage drive level applied to the motor at the first throttle speed step.

Default Value: **32**

CV 2: V-Start Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- This register sets a start voltage for the motor to any value between 0 and 255 (0 – 0xFF). A value of 0 provides no offset while a value of 255 provides maximum starting voltage with no throttle range left.

  This register specifies how much of the available track voltage will be applied to the motor at the start of the throttle range. While the "0" speed step still provides no motor drive, the "2" speed step provides a starting voltage to the motor defined by the following equation:

  Start Voltage = (Track Voltage) x (CV2/255)

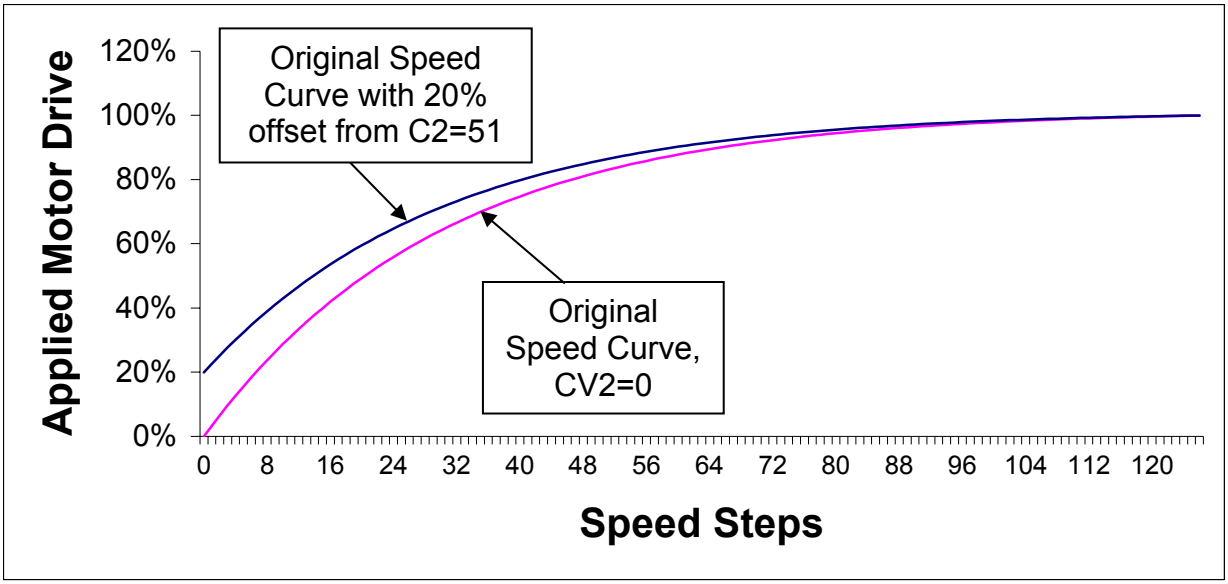
  Note that the value of this register is not an offset to the speed step. For instance, a value of "5" does not mean that the throttle speed step is offset by five and represents a speed step of six for the first speed step.

- The value of motor drive (as a percentage of total track voltage) is computed according to the formula below:

$$\%\ \text{Applied Motor Voltage} = \{CV\,2 + (CV5 - CV\,2) * \left(\frac{\text{Speed Table Value for speed step}}{255}\right)\} * \frac{100}{255}$$

  This produces an offset percentage equal to {CV2/255}*100% plus the percentage increase from the speed table curve reduced by the offset percentage. The result is that this curve starts at the desired offset but ends up at the same maximum value (CV 5). The graph below shows the original curve plus the effect of an offset of 20% (CV 2 = 51 and CV 5, V-High, is set at its maximum value of 255).

  If CV 5 is less than or equal to CV 2, or CV 5 set to 0 or 1, then 255 is used for CV 5 in the above equations.



- DCC V Start is not related to V Start for Analog Operation.
- V-Start is not used when Throttle Mode = Speed Control .
- See CV 5 for more information.

3.3 CV 3 Acceleration Rate[16]

Sets Quantum value of Inertia Under Acceleration

Default Value: **0**

CV 3: Acceleration Rate Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Acceleration rate register can have any rate between 0 and 255. A value of "0" provides no inertia and gives the fastest response to changes in throttle position.
- When any number except "0" is entered in CV 3, the power applied to the motor increases linearly as a function of time between speed steps. The inertia in "seconds per speed step" is based on the value of CV 3 as provided by the formula below.

$$\textbf{Acceleration Inertia (Seconds/speed step)} = \frac{\textbf{(CV 3) * 0.896}}{\textbf{Number of Speed Steps}}$$

- Note that the value of CV 3 will provide the same inertia for all speed step choices (14, 28, and 128) for the same percentage change in throttle position. In other words, for the same value of CV 3, it will take the same amount of time to go from a dead stop to full speed for a throttle change from minimum to maximum regardless of the speed step choice. The acceleration rate can vary from a quick response measured in seconds for CV 3=0 to as long as 3.8 minutes (228 seconds) for CV 3 = 255.
- The actual acceleration is the inverse of the above inertia formula.

$$\textbf{Acceleration (speed steps/second)} = \frac{\textbf{Number of speed steps}}{\textbf{(CV 3)* 0.896}}$$

- The acceleration and deceleration rate values in CV 3 and CV 4 will apply if you change the direction on a moving engine. The locomotive will slow to a stop at a rate set by CV 4 and then accelerate in the opposite direction at a rate set by CV 3.

16 This NMRA CV is more aptly entitled "Inertia under Acceleration" since higher values for this CV result in higher inertia values but lower acceleration rates. Using the term "Momentum" to describe CV 3 is not correct since a non-moving train has no momentum even if CV 3 is set to the maximum value. Inertia is the property of an object that resists any change to its state of rest or motion.

3.4 CV 4 Deceleration Rate[17]

Sets Quantum Inertia Under Deceleration.

Default Value: **0**

CV 4: Deceleration Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Deceleration rate register can have any rate between 0 and 255. A value of "0" provides no inertia and gives the fastest response to changes in throttle position.
- When any number except "0" is entered in CV 4, the power applied to the motor decreases linearly as a function of time between speed steps. The amount of seconds per speed step is based on the value of CV 4 as provided by the formula below.

$$\textbf{Deceleration Inertia (Seconds/speed step)} = \frac{\textbf{(CV 4) * 0.896}}{\textbf{Number of Speed Steps}}$$

- Note that the value of CV 4 will provide the same inertia for all speed step choices (14, 28, and 128) for the same percentage change in throttle position. In other words, for the same value of CV 4, it will take the same amount of time to go from full speed to a dead stop for a throttle change from maximum to minimum regardless of the speed step choice. The deceleration rate can vary from the time it takes the model engine running at full speed to stop (a second or so) for CV 4 = 0, to as long as 228 seconds (3.8 minutes) for CV 4 = 255.
- The actual deceleration is the inverse of the above formula.

$$\textbf{Deceleration (speed steps/second)} = \frac{\textbf{Number of speed steps}}{\textbf{(CV 4)* 0.896}}$$

- The acceleration and deceleration rate values in CV 3 and CV 4 will apply if you change the direction of a moving engine. The locomotive will slow to a stop at a rate set by CV 4 and then accelerate in the opposite direction at a rate set by CV 3.

17 This NMRA name is more aptly entitled "Inertia under Deceleration" since higher values for this CV result in higher inertia values but lower acceleration rates. Using the term "Momentum" to describe CV 3 is not correct since a non-moving train has no momentum even if CV 3 is set to the maximum value. Inertia is the property of an object that resists any change to its state of rest or motion.

3.5 CV 5 V-High"

V-High defines the voltage drive level applied to the motor at maximum throttle. Use CV 5 to reduce the maximum speed of locomotives that operate too fast at maximum throttle.

Default Value: **1**

CV 5: V-High Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- This register sets a maximum voltage for the motor to any value between 2 and 255 (0 – 0xFF). A value of 0 or 1 or 255 provides maximum motor voltage at maximum throttle.

  The value of this register determines the maximum motor drive as a fraction of the applied voltage as defined by the following equation:

  Maximum Motor Voltage = (Track Voltage) x (CV5/255)

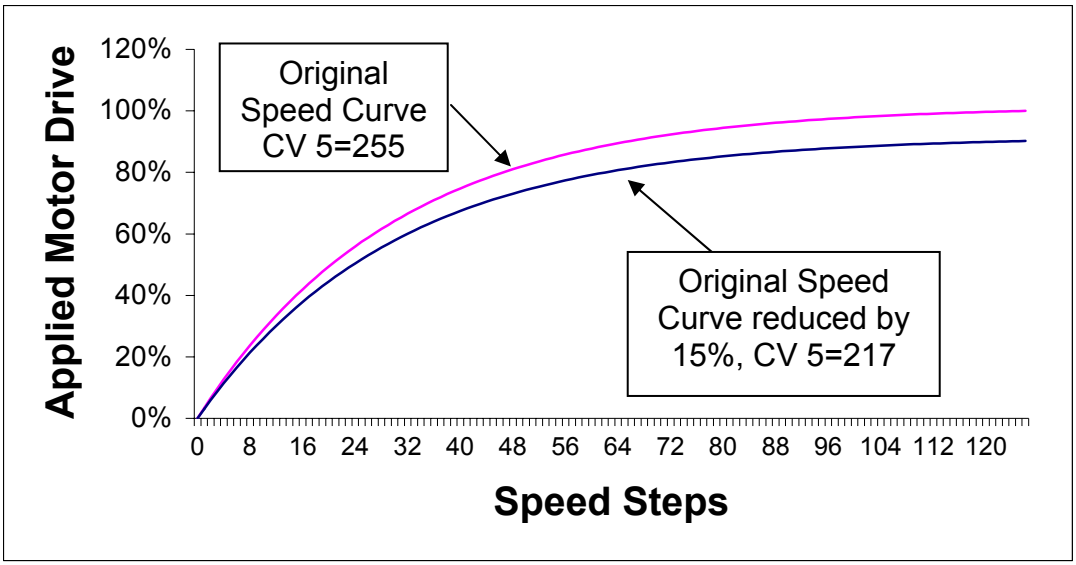
  For instance, a value of "200" for CV 5 means that the maximum voltage will be 217/255 or 85% of the applied track voltage.

  The value of motor drive (as a percentage of total track voltage) is computed according to the formula below:

$$\%\ \text{Applied Motor Voltage} = \{CV\,2 + (CV\,5 - CV\,2) * \left(\frac{\text{Speed Table Value for speed step}}{255}\right)\} * \frac{100}{255}$$

  While CV 2 determines the offset percentage, CV 5 determines the maximum percentage of the track voltage applied to the motor. The result is that the shape of the original speed curve from the speed table is preserved but compressed to fit between V-Start and V-High. The graph below shows the effect of only CV 5 (CV 2 =0) on the original curve. Here a value of CV 5 = 217 reduces the original speed curve by 15% over the entire speed step range.

  If CV 5 is less than or equal to CV 2, or CV 5 set to 0 or 1, then 255 is used for CV 5 in the above equations.



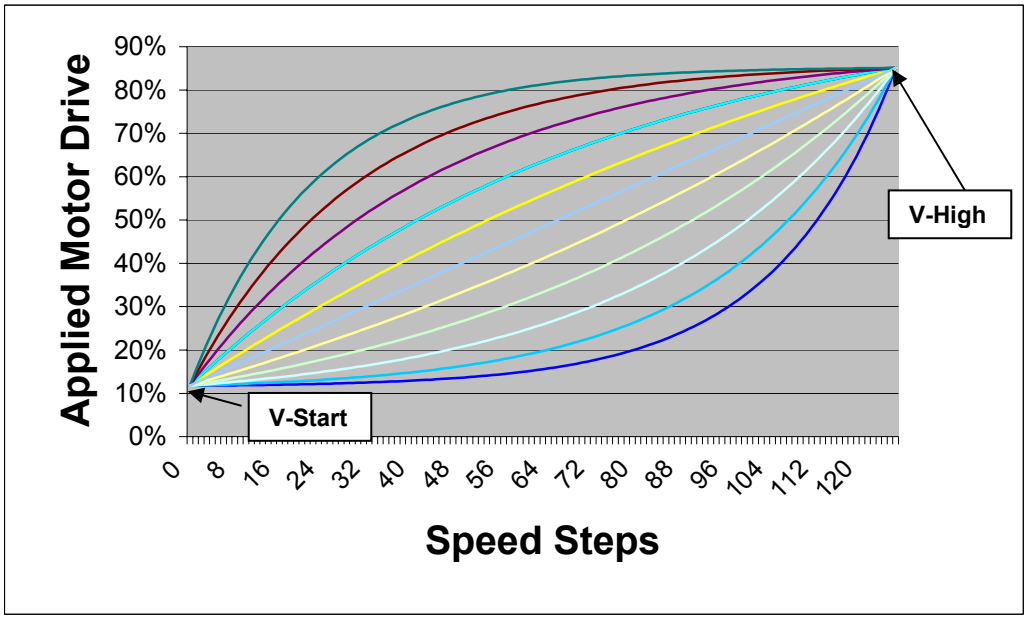
V-High is not related to V Max for Analog Operation.
V-High is not used when Throttle Mode = Speed Control.

Recommendations for specifying speed curves, V-Start and V-High.

The following is a method we have used to program an engine to match the speed of other engines at QSI. This method uses Ops mode programming since it will let you program your locomotive's speed characteristics while the engine is operating.

1. Set CV 56.4 to 0 or 1which will set the throttle control mode to either Standard Throttle Control or Regulated Throttle Control.
2. Set CV 29, bit 4, to 1 to enable speed curves.
3. Set different engine ID numbers for engine A and engine B.
4. Place your engine to be programmed (call it engine A) on a fairly large loop of track. Also place your standard engine[18] (call it engine B) that you use as your speed reference on the same loop of track but on the opposite end. Both engines should have different ID's.
5. Select and start your standard engine, B, moving at speed step 1 and select and start your engine A to be programmed, also moving at speed step 1.
6. Enter in Ops mode programming for engine A. Set CV 2 values until engine A is moving at the same speed as engine B.
7. Leave Ops mode programming. Select and run your standard engine at full throttle and quickly do the same with engine B. You may have to temporarily restrain one of the engines if they get too close to each other.
8. Enter in Ops mode programming for engine A. Set CV 5 values until engine A is moving at the same speed as engine B.
9. Leave Op mode programming. Set both engine A and engine B to speed step 128. Enter Ops mode programming for engine A and select CV 25. Choose speed curves from the list of QSI speed from CV 25 until both engines are running at a similar speed. These speed curves will be compressed to fit between V-High and V-Start as shown in the graph below.

18 You may have a number of standard engines for different speed classifications. For instance, you might have a standard engine for yard operations with a top speed of 35 smph, a standard freight engine with a top speed of 65 smph and a third standard engine for passenger service with a top speed of 100 smph.



QSI Speed Curves with V-Start set to 30 (10% of applied voltage) and V-High set to 217 (85% of applied voltage).

10. If none of the QSI speed curves are acceptable, set CV 25 to 1 and make you own custom speed curve using CV 67 through CV 94. Your custom speed curve will also be compressed to fit within the limits set by V-Start and V-High. Set both engines at 28 speed-step selection so your custom changes are at the speed step the engine is operating. Start both engines at speed step 1; enter Ops mode programming for engine A and set CV 67 to match engine B speed. Leave Ops mode programming, and set both engines to operate at speed step 2, enter Ops mode programming for engine B and set CV 68 to match engine B speed. Repeat this procedure until you have entered speed curve values for all CV's between 67 and CV 94.

3.6 CV 7 Manufacturer's Version Number

This is a read only CV that provides information regarding the version number of the software released for this locomotive.

Default Value: **N/A**

CV 7: Manufacturer's Version Number Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Version releases start with 1. If you have a 1 in this register, this is the first version of Quantum HO software released. If you have a "2" it is the second version of Quantum HO software released.

3.7 CV 8 Manufacturer's ID

This read-only CV identifies QSI as the manufacturer or developer of the software used in the Quantum System.

Default Value: **113**

CV 8: Manufacturer's ID Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**1**	**1**	**1**	**0**	**0**	**0**	**1**

- The value of this read only register is 113, which is the official NMRA designation for QSI as a manufacturer of DCC decoders.

3.8 CV 11 Packet Time-Out Value

The value in CV 11 is the maximum time Quantum will maintain its current speed without receiving a valid DCC packet.

Default Value: **1**

CV 11: Packet Time-Out Value Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
N/A	**N/A**	**N/A**	**D4**	**D3**	**D2**	**D1**	**D0**

- If CV 11 has a non-zero value, and the engine receives no DCC packets addressed to the engine for that number of seconds then the engine will decelerate to a stop at a rate specified by CV 4 and CV 24 and will enter Neutral. The usual Neutral Sounds will then be heard.
- When DCC packets addressed to the engine are again received, the engine will respond to the DCC packet commands addressed to the engine. It will remain in Neutral until a new speed packet is received at which time it will accelerate at the rate set in CV 3 and CV 23.
- A value of zero will disable the time-out function and the engine will continue to run at its last speed setting when it stops receiving packets addressed to the engine.
- The factory default is “1” which is interpreted as 1 second.
- The maximum value for CV 11 is 20, interpreted as 20 seconds[19]. Any value greater than 20 will be ignored and the
- If both Power Source Conversion (CV 29, bit 2) and Packet time-out Value are enabled, Power Source Conversion takes precedence, since it will always have the shorter time-out period.

19 Twenty seconds is the maximum time specified in NMRA Recommended Practice RP-9.2.4.

3.9 CV 17, 18 Extended Address

CV 17 and CV 18 together provide a larger (14 bit) alternative for engine ID numbers from 0 to 10,239.

CV 17 Default Value:	0[20]
CV 18 Default Value	0

CV 17: Extended Address Most Significant Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	**1**	**A13**	**A12**	**A11**	**A10**	**A9**	**A8**

CV 18: Extended Address Least Significant Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
A7	**A6**	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**

- CV 17 and CV 18 Extended or Long Address allows the operator to enter one of 10,240 addresses from 0 to 10,239 although most Command Stations will only allow entering ID's up to 9,999. The advantage of the Extended Address is that ID's can be identical to the engine cab numbers, which rarely exceed four digits.

- Placing the Extended Address in CV 17 and CV 18 does not eliminate the Primary Address in CV 1. Since there is overlap in the range between Primary Addresses and Extended Addresses, a Primary Address may have the same number as an Extended Address but these addresses are not the same and are addressed differently from your Command Stations (see your Command Station Instructions).

- The Extended Address can be set either in Service Mode or Operations Mode. Remember to change bit 5 of Configuration CV 29 to "1" to enable the Extended Address.

- **Entering Extended Address into CV 17 and CV 18 Directly:** Most modern Command Stations allow the operator to input an Extended Address from 0 to 9999 directly in decimal format without having to individually enter data into CV 17 and CV 18. However, if you have an older Command Station and need to program these CV's directly, the following information will be helpful.

  CV 17 and 18 form a paired CV and it makes a difference how data is entered. CV 17, the most significant byte, must be written first followed by CV 18, the least significant byte. If the order is reversed, the Quantum decoder will not accept the values entered.

  Bits A15 and A14 must both be assigned "1" which adds 192 to the value of the byte in CV 17. The remaining 6 bits of C17 and the 8 bits of C18 allow addresses to be assigned between 0 and 10,239 inclusive. Any attempt to program an extended ID above 10,239 will be ignored.

20 The default for CV 17 is actually "192" which is an artifact of how these ID numbers are specified by the NRMA where 192 is added to the MSB (Most Significant Byte) of the address you want to enter. If you have a modern Command Station that programs your ID numbers directly, you will enter your ID number equal to the Extended Address you intend to use; however, if you program the extended address CV directly, a zero address must be entered as 192. See example in this section on directly programming CV 17 and CV 18.

If your Command Station will not allow you to enter Extended Addresses as a decimal number, you will need to enter CV 17 and 18 by direct programming. To enter your extended ID, first divide the decimal address you intend to enter by 256, and convert the quotient to binary and add the two leading 1's for bits A14 and A15 and write to CV 17. Convert the remainder to binary and write this number to CV 18. If you enter either number in hex or decimal, make sure you convert C17 with the two leading binary 1's in bits A14 and A15.

Example1 Decimal Entry: Program CV 17 and CV 18 to Extended Address 5343.

Divide 5343 by 256 to get 20 as quotient and 223 as remainder.

Note: If you use a calculator, you will get 20.8711. Note the integer value n = 20, which is the quotient.

Add 192 to this quotient to get 212 and store this value in CV 17:

CV17 = n + 192

CV 17 = 20 + 192 = 212

Computer the remained integer value by multiplying 20 by 256 and subtract from the engine value to get remainder and store in CV 18:

CV 18 = Engine Number – (n X 256)

CV 18 = 5343 – (20 X 256) = 223

Remember to change CV 29, bit 5 to "1" to allow the Extended Address operation (see CV 29).

Example2 Binary or Hex Entry: Program CV 17 and CV 18 to Extended Address 5343.

Convert 212 from previous example to binary 11010100 or hex 0xD4. Enter this number in CV 17.

Convert 223 from previous example to binary 11011111 or hex 0xDF and enter in CV 18.

Remember to change CV 29, bit 5 to "1" to allow the Extended Address operation (see CV 29).

To check: Compute (CV 17 – 192)*(256) + CV 18 where 192 is the decimal equivalent of CV 17 with only the leading 1's (11000000)

Decimal: (212 – 192)*(256) + 223 = **5343**

Binary: (11010100 –11000000)*(100000000) + 11011111 = 1010011011111 = **5343** decimal.

Hex: (0xD4– 0xC0)*0x100 + 0xDF = 0x14DF = **5343** decimal, where 0xC0 is the hex equivalent of 192.

The following table shows examples for some common train numbers. Just follow the procedure below.

1) Find out if your command station accepts Decimal, Binary or Hex inputs for CV entries.
2) First enter CV 17 (Most Significant Byte) from the table below as a Decimal, Binary or Hex number shown.
3) Next enter CV 18 (Least Significant Byte) from the table below as a Decimal, Binary or Hex number shown.

4) Change CV 29, bit 5 to “1” to allow operation with your new Extended Address.

Challenger Engine Numbers:

Loco Number	CV 17 (Dec)	CV 18 (Dec)	CV 17 (Hex)	CV 18 (Hex)	CV 17 (Binary)	CV 18 (Binary)
3985	207	145	CF	91	11001111	10010001
3989	207	149	CF	95	11001111	10010101
3708	206	124	CE	7C	11001110	01111100
3710	206	126	CE	7E	11001110	01111110
3976	207	136	CF	88	11001111	10001000
3983	207	143	CF	8F	11001111	10001111
3980	207	140	CF	8C	11001111	10001100
3984	207	144	CF	90	11001111	10010000
3801	206	217	CE	D9	11001110	11011001
3805	206	221	CE	DD	11001110	11011101
671	194	159	C2	9F	11000010	10011111
673	194	161	C2	A1	11000010	10100001

Note: If you command station allows entering in decimal format, but requires separate entries for both CV 17 and CV18, then you should follow the above procedure. However, if your Command Station will allow you to enter the ID's in decimal form in either CV 17 or CV 18 as a single four-digit number, do not follow the above procedure; simply enter your four-digit number as explained in your command station instruction manual.

Note: Some command stations will not operate Quantum Systems in Service Mode due to insufficient power output or timing problems. (Check Appendix II for a listing of recommended command stations). If you cannot operate in Service Mode, use Ops mode programming.

If your command station will not allow setting ID numbers in Ops Mode, use QSI CV 56.129 to enter your ID numbers.

3.10 CV 19 Consist Address

Sets an engine to a Consist[21] address in addition to setting the locomotive's direction within the Consist.

Default Value: **0**

CV 19: Consist Address Active for FL and F9-F12 Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**A6**	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**

- Bits A0-A6 set the Consist address to any value from 0 to 127.
- Bit D7 sets the engine's direction. "0" in D7 sets the engine to a normal Forward and "1" sets engine to Reverse Direction within the Consist.
- If the seven bit address in bits 0-6 is 0000000 the locomotive is not in the Consist. If any other address is entered and decoder receives a command packet that matches this Consist Address, the packet will be processed as any other packet except,
    - The direction bit in a speed/direction or advanced operation packet is inverted if D7=1.
    - Function Key behavior can be modified via CV's 21 and 22.
    - Long Form CV Access instructions will be ignored.
    - Only Short Form CV Access instructions for CV's 23 and 24 are allowed.
- If you intend to use an engine in a Consist and need to configure it for compatible operation in the Consist (e.g. setting the acceleration CV to be the same as other intended Consist engines, etc.), you can either change the appropriate CV's to their new values before you give it a Consist Address or you can address the individual engine within the Consist by its Primary or Extended Address and then change the appropriate CV's.
- If an engine has the same Consist ID as its Primary Address, it will respond to commands as through it were being addressed by its Engine Address without the restrictions set in CV 21 and CV 22.
- Take care not to use an address for a Consist that is the same as an enabled Primary Address in an individual locomotive somewhere else on your layout. Since there is no difference in the form of packet addresses sent to a Consist or an individual engine, both the Consist and isolated engine will process the commands and both will respond at the same time.

[21] Consists are also know as Multiple Heading, Lashups or Multiple Unit Trains (MU's) .

3.11 CV 21 Consist Address Active for F1-F8[22]

Sets which Function Keys are enabled when an engine is addressed by its Consist ID.

Default Value: **0**

CV 21: Consist Address Active for FL and F9-F12 Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
F8	**F7**	**F6**	**F5**	**F4**	**F3**	**F2**	**F1**

- If zeros are placed in any bit, that function key is disabled when the locomotive is addressed by its Consist ID. If a one is placed in any bit, that function key is enabled when the locomotive is addressed by its Consist ID.

This CV and CV 22 are useful for disabling certain features for helper locomotives within the Consist. For instance, only the lead engine should have its Horn/ Whistle and Bell enabled. If the F2 key controls the Horn and the F3 key controls the Bell, then all slave engines should have "0" in Bit 1 and Bit 2, while the lead engine should have “1” in these bits.

The following recommended values are for engines that have factory default features assigned to Functions Outputs (see CV 53) . Features that are different in the Neutral State are shown with parentheses (i.e. Doppler (Start Up) means Doppler is only operable in Forward and Reverse and Start Up is operable only in Neutral). Features shown that do not indicate a special Neutral Option, will operate in all states (Forward, Neutral and Reverse).

Recommended value of CV 21 for a Lead Engine in a Consist.

(The QSI default features assignments are shown for Forward/Reverse operation in the top row and for Neutral in parenthesis).

Audio Mute	Brake Squeal*	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Whistle/Horn	Bell
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	**1**	**1**	**1**	**1**	**0**	**1**	**1**

22 Write bit operation is supported for CV 21.

Recommended value of CV 21 for a Mid[23] Helper engine in a Consist.

(The QSI default features assignments are shown for Forward/Reverse operation in the top row and for Neutral in parenthesis).

Audio Mute	Brake Squeal*	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash	Whistle/Horn	Bell
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	**0**	**1**	**1**	**1**	**0**	**0**	**0**

Recommended value of CV 21 for an End[24] Helper engine in a Consist.

(The QSI default features assignments are shown for Forward/Reverse operation in the top row and for Neutral in parenthesis).

Audio Mute	Brake Squeal*	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash	Whistle/Horn	Bell
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	**0**	**1**	**1**	**1**	**1**	**0**	**0**

*Squealing Brakes is not recommend for helpers since in Neutral, this function key also controls the Boiler Water Injector sounds on steam engines which might cause some confusion with all engines doing this operation at once. Automatic brake squeal at low speeds would still be operable for all engines in the Consist.

23 A Mid Helper is any engine between the Lead and the last or End helper in a Consist.
24 An End Helper is the last helper in a consist.

3.12 CV 22 Consist Address Active for FL and F9-F12[25]

Sets whether the FL(r) or FL(f) keys and F9-F12 keys are enabled when an engine is addressed by its Consist ID.

Default Value: **0**

CV 22: Consist Address Active for FL and F9-F12 Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**F12**	**F11**	**F10**	**F9**	**FL(r)**	**FL(f)**

- If “0’s”are placed in any of bits 0 through 5, the FL key is disabled when the locomotive is addressed by its Consist ID. If a “1” is placed in any of bits 0 through 5, that function key is enabled when the locomotive is addressed by its Consist ID. FL in the Forward Direction is controlled by bit 0, FL in the Reverse Direction is controlled by bit 1.
- Any "1" placed in bits 6 or 7 will be ignored.

This CV and CV 21 are useful for disabling certain features for slave locomotives within the Consist. For instance, only the Lead Engine should have its front headlight operational. If the F0 key controlled the Directional Lighting, then all slave engines should have "0" in Bit 1.

If FL is mapped to the Headlight and Reverse Light (see CV 33 and CV 34), CV 22 is useful in Consists to control the lights of the Lead and End engines. The Lead Engine Headlight can be enabled with "1" in bit 0 and "0" in bit 1. This allows the Headlight to be turned on and off for the Lead Engine but not the Reverse Light since it would only illuminate the engine behind it and not the track. On the other hand, the last engine in the Consist could have it Reverse Light enabled with "1" in bit 1 and have its Headlight disabled with "0" in bit 0. All other engines within the Consist could have both lights disabled with "0's" in bits 0 and 1. This Consist would act as a single unit with the FL key only toggling the Lead engine Headlight on or off when the Consist was moving Forward and only toggling the Reverse Light when the Consist was moving in Reverse.

F9, Cruise Control and Shut Down are recommended for all Helper types in a Consist since Cruise Control should apply to all engines or none at all; otherwise there would be fighting between engines that have Cruise control enabled and those that do not. Similarly, the F9 Shut Down key should apply to all engines in Consist or none at all.

Features for F keys 10,11 and 12 are usually reserved for custom appliance sounds or operations for the different engine types (Steam, Diesel or Electric) such as steam Blow Down, Diesel Mars Lights, Electric locomotive Cab Lights, etc. It is recommended that these functions be disabled for all Helper types except the Lead engine to avoid confusion.

The following recommended values are for engines that have factory default values assigned to FL Function Outputs (see CV 53). Features that are different in the Neutral State are shown with parentheses (i.e. Cruise Control (Shut Down) means Cruise Control is only operable in Forward and Reverse and Shut Down is operable only in Neutral).

25 Write bit operation is supported for CV 22.

Recommended value of CV 22 for a Lead Engine in a Consist:

N/A	N/A	Custom	Custom	Custom	Cruise Control (Shut Down)	Reverse Light	Headlight
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**0**	**0**	**1**	**0**	**1**

Recommended value of CV 22 for a Mid Helper engine in a Consist:

N/A	N/A	Custom	Custom	Custom	Cruise Control (Shut Down)	Reverse Light	Headlight
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**0**	**0**	**1**	**0**	**0**

Recommended value of CV 22 for an End Helper engine in a Consist:

N/A	N/A	Custom	Custom	Custom	Cruise Control (Shut Down)	Reverse Light	Headlight
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**0**	**0**	**1**	**1**	**0**

3.13 CV 23 Acceleration Adjustment

Increases or decreases the Acceleration from the base Acceleration Rate in CV 3.

Default Value: **0**

CV 23: Acceleration Adjustment Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Sign	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- CV 23 can have any value from –127 to +127 where positive values will increase the acceleration time and negative values will decrease the acceleration time. A positive value is indicated by a 0 in bit 7 while a “1” indicates a negative value.
- The value of CV 23 adds directly to the value of C3 by the formula below:

$$\textbf{Seconds/speed step} = \frac{\textbf{(CV 3 + CV 23) * 0.896}}{\textbf{Number of Speed Steps}}$$

The purpose of CV 23 is to allow the operator to simulate differing train lengths/loads, most often when operating in Consists. It can, however, apply to single locomotives as well.

3.14 CV 24 Deceleration Adjustment

Increases or decreases the Deceleration from the base Deceleration Rate in CV 4.

Default Value: **0**

CV 24: Deceleration Adjustment Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Sign	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- CV 24 can have any value from –127 to +127 where positive values will increase the deceleration time and negative values will decrease the deceleration time. A positive value is indicated by a 0 in bit 7 while a “1” indicates a negative value.
- The value of CV 24 adds directly to the value of C4 by the formula below:

$$\text{Seconds/speed step} = \frac{(\text{CV 4} + \text{CV 24}) * 0.896}{\text{Number of Speed Steps}}$$

The purpose of CV 24 is to allow the operator to simulate differing train lengths/loads, most often when operating in Consists. It can, however, apply to single locomotives as well.

3.15 CV 25 Quantum Speed Table Selection

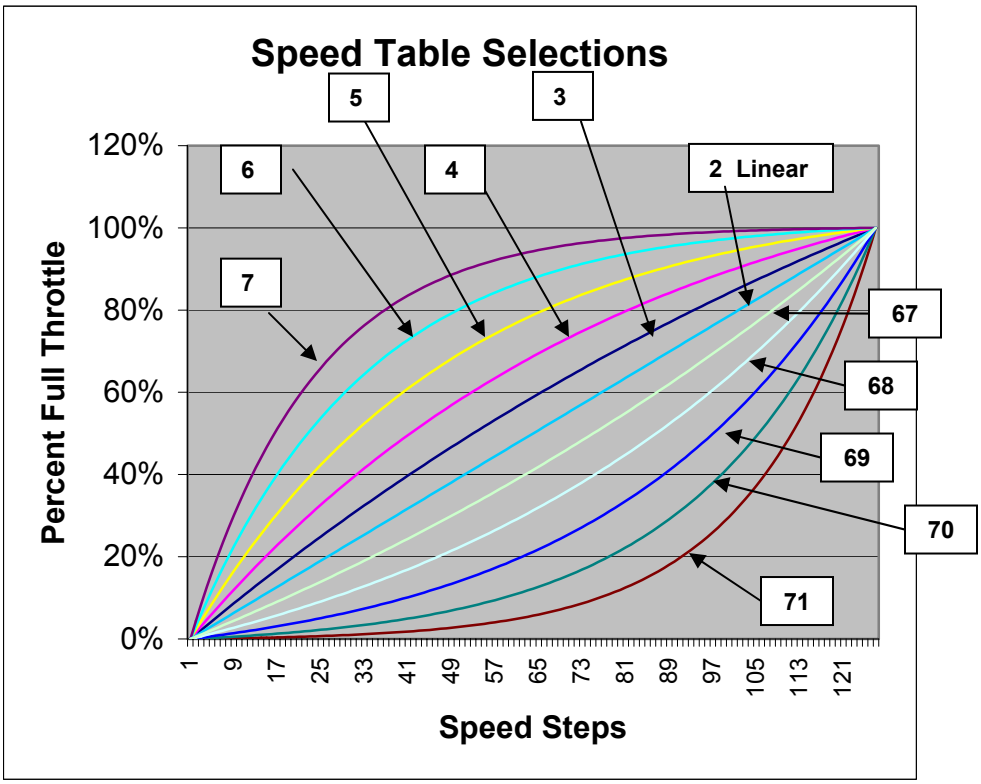
User selection of one of 11 speed curves.

Default Value: **2**

CV 25: Quantum Speed Table Selection Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**N/A**	**N/A**	**D5**	**0**	**D2**	**D1**	**D0**

- A number of speed tables are included with your Quantum system that can be directly used in place of the linear default table or user specified tables. The user is able to select from 11 different predefined speeds as shown in the graph below. The upper five convex curves show a choice of different “fast start” speed tables while the lower five concave curves are “slow start” speed tables. The “fast start” curves will compensate for engines that are less responsive getting started while the “slow start” curves compensate for engines than tend to “rocket out” when the throttle is barely turned on.



0 – QSI Standard Speed Table
1 - User Defined
Any other number – Linear

- To enable any speed curve shown above, set CV 25 to the value shown in the table or set it to 1 to enable a User Defined Curve (see CV 67 – 94) or set it to any other number to those shown on the graph to enable the Linear Curve.
- Bit 4 of CV 29 must be set to 1 to enable any of the above speed curves. If CV 29 bit 4 is set to "0", then a linear straight-line response is enabled.

Additional Information for the Curious Regarding QSI Speed Curves:

- The assignment of bits to this register follows a logical sequence:

Bits 0-2: Determines how much curvature. For low values the curves are closer to linear while higher values provide greater curvature. Bits 0-2 set to 000 or 001 indicates that speed table is not used regardless of the setting in bit 6. Bits 0-2 set to 010 indicate a linear speed table.

Bit 3-5: Reserved for future QSI expansion of speed curves. Any value entered for these bits will automatically result in a Linear Response regardless of what is entered in other bits.

Bit 6: Determines if it is convex "Fast Start" or concave "Slow Start" curve.
0 = "Fast Start" Convex Curve
1 = "Slow Start" Concave Curve

Bit 7: This bit specifies the mid-range Speed Step and is not supported by Quantum. Set the value to 0. Either a "1" or a "0" is ignored.

The decimal value for each curve from the table below is shown on the above speed graph.

- Curve Tables in order of value for CV 25:

Value of CV 25 (Decimal)	Value of CV 25 Bits 7-0 (Binary)	Resulting Speed Table
Convex "Fast Start" Curves		
0	0 0 0 0 0 0 0 0	Reverts to User Defined Speed Table (CV 67-94)
1	0 0 0 0 0 0 0 1	Reverts to User Defined Speed Table (CV 67-94)
2	0 0 0 0 0 0 1 0	Linear Curve
3	0 0 0 0 0 0 1 1	Fast Start 1 (close to linear)
4	0 0 0 0 0 1 0 0	Fast Start 2
5	0 0 0 0 0 1 0 1	Fast Start 3
6	0 0 0 0 0 1 1 0	Fast Start 4
7	0 0 0 0 0 1 1 1	Fast Start 5 (greatest curvature)
Concave "Slow Start" Curves		
65	0 1 0 0 0 0 0 0	Reverts to Linear Curve
66	0 1 0 0 0 0 0 1	Reverts to Linear Curve
67	0 1 0 0 0 0 1 1	Slow Start 1 (close to linear)
68	0 1 0 0 0 1 0 0	Slow Start 2
69	0 1 0 0 0 1 0 1	Slow Start 3
70	0 1 0 0 0 1 1 0	Slow Start 4
71	0 1 0 0 0 1 1 1	Slow Start 5 (greatest curvature)

- If any of the “Reverts to User Defined Table” values are set in CV 25, then the user specified speed table programmed into CV’s 67-94 will be enabled.

- Quantum Speed Tables are complete for a full 128 speed steps. They are also enabled for 14 and 28 speed steps; Quantum simply skips speed table values for the larger step sizes. However, these intermediate steps are still used under acceleration and deceleration to provide smoother operation at 14 and 28 speed steps settings.

- V-Start and V-High settings will apply to these and all curve tables as described in the section for CV 2 and CV 5. When selecting a speed table, it is recommended that you first select your V-Start offset based on a linear curve and enter this value into CV 2, particularly for concave “slow start” curves where the V-Start point may not be obvious. Setting V-Start for a linear curve will be much more discernible; then select the type of curve you want.

3.16 CV 29 Configuration Data[26]

Each bit in CV 29 controls some basic operational setting for DCC decoders.

Default Value: **00000010 = 2**

CV 29: Configuration Data Register (with NMRA Assigned Features)

Accessory Decoder	Reserved for Future Use	Extended Addressing	Speed Table Enable	Advanced Decoder Acknowledgement	Power Source Conversion	FL Location	Locomotive Direction
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**N/A**	**D5**	**D4**	**N/A**	**D3**	**D2**	**D1**

- Bit 0 = Locomotive Direction:

  "0" = normal Forward Direction
  "1" = Reversed Direction.

  This bit controls the locomotive's Forward and Reverse direction. With Bit 0 set to 1, the engine will start out in the Reverse Direction even though the Command Station indicates a Forward Direction. Directional sensitive functions, such as Headlights (FL(f) and FL(r)), will also be reversed to be consistent with the locomotive's new Reverse Direction.

- Bit 1 = FL location:

  "0" = Bit 4 in Speed and Direction instructions controls FL (14 Speed Step Mode).
  "1" = Bit 4 in Function Group 1 instruction controls FL (28 and 128 Speed Step Mode).

  Normally in 14 Speed Step Operation, the speed and direction instruction is in one byte of transmitted data that tells the engine what direction to go, what speed to travel and whether the lights should be on or off. For 28-speed step operation, the bit for turning off or on the directional lights was used to increase the number of speed steps instead of lighting. When in 28-speed step mode, information about the light function, FL, on or off state must be transmitted by a separate packet, the Function Group 1 Instruction. Setting Bit 1 in CV 29 to "1" specifies that the FL bit in Function Group One controls the lights. Similarly, to use128 speed step mode, bit 1 of CV 29 must be set to "1" since 128-speed-step mode control byte does not contain information about the directional lighting state, so that a Function Group 1 instruction be sent to control lighting.

- Bit 2 = Power Source Conversion.

  "0" = Power Source Conversion disabled
  "1" = Power Source Conversion enabled.

  If CV 29 bit 2 is "1", and a period of approximately 200mSec[27] elapses in which no DCC packet is detected, then the engine will convert to Analog power.

26 Write bit operation is supported for CV 29.
27 NMRA Spec RP-9.2.4 specifies that Power Source Conversion should take place when DCC packets are absent for more than 30 mSec. However Quantum requires approximately 200mSec to determine the Analog track polarity.

If the polarity of the track would result in the engine moving in the same direction that it was last moving in DCC mode, then the engine will continue to move at the speed corresponding to the last received speed step packet. The usual FWD/REV engine sound will be heard.

If the polarity of the track would result in the engine moving the opposite direction that it was last moving in DCC mode, then the engine will decelerate to a stop at a rate determined by CV 4 and CV 24, and will enter Neutral. The usual Neutral sounds will be heard.

After analog power conversion, switching the polarity of the track will either start the engine moving or bring it to a stop.

If the engine is moving and the polarity is reversed, the engine will decelerate to a stop at a rate determined by CV 4 and CV 24 and will enter Neutral.

If the engine is stopped in Neutral and the polarity is reverse, the engine will accelerated at a rate determined by CV 3 and CV 23 to a speed corresponding to the last received speed step packet.

The actual engine speed under Analog power may differ from its speed under DCC power depending on the Analog track voltage and whether the engine is using Speed Control, or Standard Throttle Control (e.g. the engine may jerk upon switching to analog power).

- Bit 3 = Advanced Decoder Acknowledgement: (not used)

- Bit 4 = Speed Table set by configuration variables.

  “0” Speed Table not used.
  “1” Speed Table set by CV 25, Quantum Speed Table selection.

  When bit 4 of CV 29 is set to “0” a linear Speed Table is used by default.

- Bit 5 = Extended Address Mode enable

  “0” = Quantum responds to one byte Primary Address (see CV 1).
  “1” = Quantum responds to a two byte Extended Address (see CV 17 and CV 18)

- Bit 6 = Reserved for NMRA future use.

- Bit 7 = Accessory Decoder.

  “0” = Multifunction locomotive decoder.
  “1” = Accessory Decoder.

  Quantum is a Multifunction Decoder; this bit cannot be changed.

Command stations will either allow you to change bits directly one at a time, or you will need to enter the value of CV 29 as a complete 8-bit word (Byte) . The table below shows features designated with an “X” for CV 29 along with the Binary, Decimal, and Hex values. Choose the features you want and enter the number into CV 29 using the format recommended by your command station. The more common selections for CV 29 are shown with gray background. The default for Quantum is shown in bold type.

CV 29 Common Settings

Extended Addressing	Speed Tables	Power Conversion	28/ 128 speed step	Reversed Direction	Decimal Value	Binary Value	Hex Value
					0	00000000	0x0
				X	1	00000001	0x1
			X		**2**	**00000010**	**0x2**
			X	X	3	00000011	0x3
		X			4	00000100	0x4
		X		X	5	00000101	0x5
		X	X		6	00000110	0x6
		X	X	X	7	00000111	0x7
	X				16	00010000	0x10
	X			X	17	00010001	0x11
	X		X		18	00010010	0x12
	X		X	X	19	00010011	0x13
	X	X			20	00010100	0x14
	X	X		X	21	00010101	0x15
	X	X	X		22	00010110	0x16
	X	X	X	X	23	00010111	0x17
X					32	00100000	0x20
X				X	33	00100001	0x21
X			X		34	00100010	0x22
X			X	X	35	00100011	0x23
X		X			36	00100100	0x24
X		X		X	37	00100101	0x25
X		X	X		38	00100110	0x26
X		X	X	X	39	00100111	0x27
X	X				48	00110000	0x30
X	X			X	49	00110001	0x31
X	X		X		50	00110010	0x32
X	X		X	X	51	00110011	0x33
X	X	X			52	00110100	0x34
X	X	X		X	53	00110101	0x35
X	X	X	X		54	00110110	0x36
X	X	X	X	X	55	00110111	0x37

4 CV 33-46, Output Locations

4.1 Overview

The NMRA standard currently provides for fourteen Function Inputs, which are transmitted to the locomotive decoder to control the different Outputs. These fourteen Function Inputs are generally operated by thirteen[28] Function Keys (FL,F1,F2,F3,F4,F5,F6,F7,F8,F9,F10,F11 and F12) on the command station or the hand held throttle. The FL[29] Function Key can produce two different Function Inputs**,** called FL(r) and FL(f)**,** depending on the direction of the engine.

The NMRA standard provides for fourteen Outputs, numbered from 1 to 14.

CV's 33 through 46 specify which Function Input is connected to which Output.

The table below shows Output numbers across the top and Function Inputs along the side. The CV number associated with each Function Input is shown in the first column. Each of these CV's Consists of an eight bit register with a "1" or "0" in each bit location, specifying which Outputs are controlled by that Function Input. The default value for each CV is shown.

CV #	Function Inputs	Output Numbers and Pre-assigned Features													
					Cruise Control (Shut Down)	Mute	Squealing Brakes (Reserved)	Doppler Shift (Engine Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler	Whistle/Horn	Bell	Reverse Light	Headlight
		14	13	12	11	10	9	8	7	6	5	4	3	2	1
33	Headlight FL(f)							0	0	0	0	0	0	0	**1**
34	Reverse Light FL(r)							0	0	0	0	0	0	**1**	**1**
35	Function 1							0	0	0	0	0	**1**	0	0
36	Function 2							0	0	0	0	**1**	0	0	0
37	Function 3							0	0	0	**1**	0	0	0	0
38	Function 4				0	0	0	0	0	**1**	0	0			
39	Function 5				0	0	0	0	**1**	0	0	0			
40	Function 6				0	0	0	**1**	0	0	0	0			
41	Function 7				0	0	**1**	0	0	0	0	0			
42	Function 8				0	**1**	0	0	0	0	0	0			
43	Function 9	0	0	0	**1**	0	0	0	0						
44	Function 10	0	0	**1**	0	0	0	0	0						
45	Function 11	0	**1**	0	0	0	0	0	0						
46	Function 12	**1**	0	0	0	0	0	0	0						

A "**1**" with gray background specifies that the Output for that column is controlled by that Input for that row. For example, CV 36 has a "1" in the column for Output 4, indicating that Function 2 controls Output 4.

[28] Some earlier command stations only support the original NMRA specification of 10 functions using 9 Function Keys.
29 For Command Stations that do not have an FL key, the F0 Function key usually controls this function.

Each Input Function can control up to 8 Outputs. For instance, the F4 key (Function Input 4) can control only Outputs 4-11. You can chose to have the F4 Key operate Output 10 or a combination of Outputs 11,9, 7, and 6 all at once, but you cannot have it operate Output 12.

For many non-sound decoders, the Outputs are literally wires that are connected to different features such as Headlights and Reverse Lights, overhead blinking lights, smoke generators, and couplers. All the Outputs are "hardwired" to the features, meaning you cannot change which feature corresponds to an Output. Such decoders are limited to fourteen different features.

For Sound Decoders like the Quantum System, few of the Outputs are "hardwired" to a particular feature. Many of the features require no external wires. Examples of these internal features are bells, whistles, air let-offs, blower hiss, and flange sounds. Even those features, which do require external wires, such as lights and couplers, are not necessarily "hardwired" to any particular Output. With a few exceptions, you can change which feature is associated with an Output. For QSI Quantum Sound Decoders, this is done in CV 53.

CV 53 also allows Outputs to be redirected to different features depending on the state of the locomotive. For example, Output 8 might be assigned to Doppler Shift in Forward and Reverse but be assigned to "Engine Start Up" in Neutral. Mapping an Output to two different features, one feature for the Forward/Reverse State (Motive State) and a different feature for the Neutral State, increases the number of features that can be operated. Neutral Features are shown in parenthesis in the table.

The table above shows the feature associated by default with each Output for a Quantum Sound Decoder. The features associated with Outputs 1-4 have a gray background, indicating that these Outputs are fixed or "hardwired" to the Headlight, Reverse Light, Bell, and Horn. You cannot assign different features to these Outputs. The remaining Outputs 5-14, however, are not "hardwired" to any feature. You can change the feature associated with any of these Outputs.

Advanced Sound Decoders like the Quantum Decoders allow great flexibility in choosing which function keys operate which features. However, this flexibility can get you into trouble if misused. For technical reasons too complicated to discuss here[30], we recommend you follow the rules below to avoid having your decoder behave in a confusing manner.

- In CV's 33-46, do not attempt to control the same output with two or more function keys. This means, in the table above, only one row in each column should have a "1". Yes, we violated this rule for Output 1, where we have both FL(f) and FL(r) operating the Headlight. This is an exception which does work for the Headlight and FL(f) and FL(r). In general, it does not work.

- Do not use FL(f) and FL(r) to control any Outputs other than Outputs 1 and 2, the Forward and Reverse Lights; i.e., leave CV 33 and 34 to their default values. If you are adventurous, you might experiment with different values for CV 33 and 34, and might discover an interesting and useful locomotive behavior. But more often than not, the behavior will be unpredictable and annoying.

- In CV 53, do not assign the same feature to two or more Outputs.

[30] See Appendix V *Interaction of Function Keys, Function Groups, Function Inputs and Outputs and Feature Assignments* for additional technical explanation.

4.2 CV 33 Output Location for FL(f)[31]

This CV specifies whether outputs 1 thru 8 are controlled by FL(f) .

A '1' in a bit location specifies the output is controlled by FL(f), while a '0' specifies the output is not controlled by FL(f).

Default Value: **00000001 = 1**

CV 33: Output Location for FL(f) (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Whistle/Horn	Bell	Reverse Light	Bright Headlight (Dim Headlight)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 8	**Output 7**	**Output 6**	**Output 5**	**Output 4**	**Output 3**	**Output 2**	**Output 1**

- Any feature can be assigned to any output in CV 53 except for fixed features (shown with gray back-ground in top row). In CV 53, the default setting for Output 1 is the Directional Headlight. Therefore, by default FL(f) controls the Directional Headlight in Forward or Neutral From Forward.
- You can specify that FL(f) controls any of Outputs 2 thru 8 in addition to or instead of Output 1.
- Assuming the default CV 53 settings (shown in the top row)[32], you can specify that FL(f) controls the following features.

Bit 0 Output 1: Directional Headlight

"0" The Headlight is unaffected[33] by FL(f).
"1" The Headlight is affected by FL(f).

Bit 1 Output 2: Directional Reverse Light

"0" The Reverse Light is unaffected by FL(f).
"1" The Reverse Light is unaffected by FL(f).

Bit 2 Output 3; Bell

"0" The Bell is unaffected by FL(f).
"1" The Bell is affected by FL(f).

31 Write bit operation is supported for CV 33.
32 Features that are different in the neutral state are shown in parentheses
33 "Unaffected" means that the output condition cannot be changed by the Function Key; if a feature is on, it state or toggled feature is on, it will stay on and if a state or toggle feature is off, it will stay off, regardless of the state or changes in the Function.

Bit 3 Output 4; Whistle/Horn

"0" The Whistle/Horn is unaffected by FL(f)
"1" The Whistle/Horn is affected by FL(f).

Bit 4 Output 5: Coupler Crash, Coupler Arm, Coupler Fire.

"0" The Coupler Sound Effects are unaffected by FL(f).
"1" The Coupler Sound Effects are affected by FL(f).

Bit 5 Output 6: Steam Engine Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower Hiss/Fans are unaffected by FL(f).
"1" Blower Hiss/Fans are affected by FL(f).

Bit 6 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by FL(f)
"1" Dynamic Brakes are affected by FL(f).

Bit 7 Output 8: Doppler, Start Up

"0" Doppler or Start Up features are unaffected by FL(f)
"1" Doppler or Start Up are affected by FL(f).

4.3 CV 34 Output Location for FL(r)[34]

This CV specifies whether outputs 1 thru 8 are controlled by FL(r).

A '1' in a bit location specifies the output is controlled by FL(r), while a '0' specifies the output is not controlled by FL(r).

Default Value: **00000011 = 3**

CV 34: Output Location for FL(r) (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Whistle/Horn	Bell	Reverse Light	Bright Headlight (Dim Headlight)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 8	**Output 7**	**Output 6**	**Output 5**	**Output 4**	**Output 3**	**Output 2**	**Output 1**

- Any feature can be assigned to any output in CV 53 except for fixed features (shown with gray back-ground in top row). In CV 53, the default setting for Output 1 is the Directional Dim Headlight and Output 2 is the Reverse Light. Therefore, by default FL(r) controls the Directional Dim Headlight and Reverse Light in Reverse or Neutral from Reverse.

- You can specify that FL(r) control any of Outputs 3 thru 8 in addition to or instead of Outputs 1 and 2.

- Assuming the default CV 53 settings (shown in the top row)[35], you can specify that FL(r) control the following features.

Bit 0 Output 1: Headlight

"0" The Headlight is unaffected[36] by FL(r).
"1" The Headlight is affected by FL(r).

Bit 1 Output 2: Reverse Light

"0" The Reverse Light is unaffected by FL(r).
"1" The Reverse Light is affected by FL(r).

Bit 2 Output 3; Bell

"0" The Bell is unaffected by FL(r).
"1" The Bell is affected by FL(r).

34 Write bit operation is supported for CV 34.
35 Features that are different in the neutral state are shown in parentheses
36 "Unaffected" means that the output condition cannot be changed by the Function Key; if a feature is on, it state or toggled feature is on, it will stay on and if a state or toggle feature is off, it will stay off, regardless of the state or changes in the Function.

Bit 3 Output 4; Whistle/Horn

"0" The Whistle/Horn is unaffected by FL(r)
"1" The Whistle/Horn is affected by FL(r).

Bit 4 Output 5: Coupler Crash, Coupler Arm, Coupler Fire.

"0" The Coupler Sound Effects are unaffected by FL(r)
"1" The Coupler Sound Effects are affected by FL(r).

Bit 5 Output 6: Steam Engine Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower Hiss/Fans are unaffected by FL(r).
"1" Blower Hiss/Fans are affected by FL(r).

Bit 6 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by FL(r)
"1" Dynamic Brakes are affected by FL(r).

Bit 7 Output 8: Doppler, Start Up

"0" Doppler or Start Up features are unaffected by FL(r)
"1" Doppler or Start Up are affected by FL(r).

4.4 CV 35 Output Location for F1[37]

This CV specifies whether outputs 1 thru 8 are controlled by F1.

A '1' in a bit location specifies the output is controlled by F1, while a '0' specifies the output is not controlled by F1.

Default Value: **00000100 = 4**

CV 35: Output for F1 (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Whistle/Horn	Bell	Reverse Light	Bright Headlight (Dim Headlight)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 8	**Output 7**	**Output 6**	**Output 5**	**Output 4**	**Output 3**	**Output 2**	**Output 1**

- Any feature can be assigned to any output in CV 53 except for fixed features (shown with gray back-ground in top row). In CV 53, the default setting for Output 3 is the Bell. Therefore, by default F1 controls the Bell.
- You can specify that F1 control any of Outputs 1-2 and 4-8 in addition to or instead of Output 3.
- Assuming the default CV 53 settings (shown in the top row)[38], you can specify that F1 control the following features.

Bit 0 Output 1: Headlight

"0" The Headlight is unaffected[39] by F1.
"1" The Headlight is affected by F1.

Bit 1 Output 2: Reverse Light

"0" The Reverse Light is unaffected by F1.
"1" The Reverse Light is affected by F1.

Bit 2 Output 3; Bell

"0" The Bell is unaffected by F1.
"1" The Bell is unaffected by F1.

37 Write bit operation is supported for CV 35.
38 Features that are different in the neutral state are shown in parentheses
39 "Unaffected" means that the output condition cannot be changed by the Function Key; if a feature is on, it state or toggled feature is on, it will stay on and if a state or toggle feature is off, it will stay off, regardless of the state or changes in the Function.

Bit 3 Output 4; Whistle/Horn

"0" The Whistle/Horn is unaffected by F1
"1" If F1 is on, Whistle/Horn is on.

Bit 4 Output 5: Coupler Crash, Coupler Arm, Coupler Fire.

"0" The Coupler Sound Effects are unaffected by F1.
"1" If F1 is changed when engine is moving, coupler crash sounds are produced.
If F1 is changed when engine is in Neutral, Coupler Arm or Fire occurs.

Bit 5 Output 6: Steam Engine Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower Hiss/Fans are unaffected by F1.
"1" If F1 is changed, Blower Hiss/Fans will toggle on or off.

Bit 6 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F1.
"1" If F1 is changed, Dynamic Brakes will toggle on or off.

Bit 7 Output 8: Doppler, Start Up

"0" Doppler or Start Up features are unaffected by F1.
"1" If F1 is changed, Doppler shift will occur in a moving engine.
In Neutral, if F1 is double pressed[40], Quantum will produce engine start up sounds and clear all "Take Control" operations.

40 Double pressing ensures that Start Up is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

4.5 CV 36 Output Location for F2[41]

This CV specifies whether outputs 1 thru 8 are controlled by F2.

A '1' in a bit location specifies the output is controlled by F2, while a '0' specifies the output is not controlled by F2.

Default Value: **00001000 = 8**

CV 36: Output Location for F2 (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Whistle/Horn	Bell	Reverse Light	Bright Headlight (Dim Headlight)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 8	**Output 7**	**Output 6**	**Output 5**	**Output 4**	**Output 3**	**Output 2**	**Output 1**

- Any feature can be assigned to any output in CV 53 except for fixed features (shown with gray back-ground in top row). In CV 53, the default setting for Output 4 is the Whistle or Horn. Therefore, by default F2 controls the Whistle or Horn.
- You can specify that F1 control any of Outputs 1-3 and 5-8 in addition to or instead of Output 4.
- Assuming the default CV 53 settings (shown in the top row)[42], you can specify that F2 control the following features.

Bit 0 Output 1: Headlight

"0" The Headlight is unaffected[43] by F2.
"1" If F2 is on, Headlight Light comes on Bright in Forward, and Dim in Reverse and Neutral.

Bit 1 Output 2: Reverse Light

"0" The Reverse Light is unaffected by F2.
"1" If F2 is on, the Reverse Light is on. Headlight is unaffected by F2.

Bit 2 Output 3; Bell

"0" The Bell is unaffected by F2.
"1" If F2 is on, Bell turns on.

41 Write bit operation is supported for CV 36.
42 Features that are different in the neutral state are shown in parentheses
43 "Unaffected" means that the output condition cannot be changed by the Function Key; if a feature is on, it state or toggled feature is on, it will stay on and if a state or toggle feature is off, it will stay off, regardless of the state or changes in the Function.

Bit 3 Output 4; Whistle/Horn

"0" The Whistle/Horn is unaffected by F2
"1" If F2 is on, Whistle/Horn is on.

Bit 4 Output 5: Coupler Crash, Coupler Arm, Coupler Fire.

"0" The Coupler Sound Effects are unaffected by F2.
"1" If F2 is changed when engine is moving, coupler crash sounds are produced.
If F2 is changed when engine is in Neutral, Coupler Arm or Fire occurs.

Bit 5 Output 6: Steam Engine Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower Hiss/Fans are unaffected by F2.
"1" If F2 is changed, Blower Hiss/Fans will toggle on or off.

Bit 6 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F2.
"1" If F2 is changed, Dynamic Brakes will toggle on or off.

Bit 7 Output 8: Doppler, Start Up

"0" Doppler or Start Up features are unaffected by F2.
"1" If F2 is changed, Doppler shift will occur in a moving engine.
In Neutral, if F2 is double pressed[44], Quantum will produce engine start up sounds and clear all "Take Control" operations.

44 Double pressing ensures that Start Up is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

4.6 CV 37 Output Location for F3[45]

This CV specifies whether outputs 1 thru 8 are controlled by F3.

A '1' in a bit location specifies the output is controlled by F3, while a '0' specifies the output is not controlled by F3.

Default Value: **00010000 = 16**

CV 37: Output Location for F3 (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Whistle/Horn	Bell	Reverse Light	Bright Headlight (Dim Headlight)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 8	**Output 7**	**Output 6**	**Output 5**	**Output 4**	**Output 3**	**Output 2**	**Output 1**

- Any feature can be assigned to any output in CV 53 except for fixed features (shown with gray back-ground in top row). In CV 53, the default setting for Output 5 is the Coupler Crash, Coupler Fire and Coupler Arm. Therefore, by default F3 controls the Coupler Sounds.
- You can specify that F3 control any of Outputs 1-4 and 6-8 in addition to or instead of Output 5.
- Assuming the default CV 53 settings (shown in the top row)[46], you can specify that F3 control the following features.

Bit 0 Output 1: Headlight

"0" The Headlight is unaffected[47] by F3.
"1" If F3 is on, Headlight Light comes on Bright in Forward, and Dim in Reverse and Neutral.

Bit 1 Output 2: Reverse Light

"0" The Reverse Light is unaffected by F3.
"1" If F3 is on, the Reverse Light is on.

Bit 2 Output 3; Bell

"0" The Bell is unaffected by F3.
"1" If F3 is on, Bell turns on.

45 Write bit operation is supported for CV 37.
46 Features that are different in the neutral state are shown in parentheses
47 "Unaffected" means that the output condition cannot be changed by the Function Key; if a feature is on, it state or toggled feature is on, it will stay on and if a state or toggle feature is off, it will stay off, regardless of the state or changes in the Function.

Bit 3 Output 4; Whistle/Horn

"0" The Whistle/Horn is unaffected by F3
"1" If F3 is on, Whistle/Horn is on.

Bit 4 Output 5: Coupler Crash, Coupler Arm, Coupler Fire.

"0" The Coupler Sound Effects are unaffected by F3.
"1" If F3 is changed when engine is moving, coupler crash sounds are produced.
If F3 is changed when engine is in Neutral, Coupler Arm or Fire occurs.

Bit 5 Output 6: Steam Engine Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower Hiss/Fans are unaffected by F3.
"1" If F3 is changed, Blower Hiss/Fans will toggle on or off.

Bit 6 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F3.
"1" If F3 is changed, Dynamic Brakes will toggle on or off.

Bit 7 Output 8: Doppler, Start Up

"0" Doppler or Start Up features are unaffected by F3.
"1" If F3 is changed, Doppler shift will occur in a moving engine.
In Neutral, if F3 is double pressed[48], Quantum will produce engine start up sounds and clear all "Take Control" operations.

Example: Change F3 to Bell Operation (Output 3), and change F1 to Output 5 (Coupler Sounds).
The Bell is permanently set to Output 3. Output 5 is set by QSI to the Coupler Sound Feature by default.

1. Set CV 37 (F3) to "4" (bit 2 = output 3 = Bell)
2. Set CV 35 (F1) to "16" (bit 4 = output 5 = Coupler Sounds)

After these changes, F3 will toggle the bell, and F1 will activate Coupler Sounds.

48 Double pressing ensures that Start Up is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

4.7 CV 38 Output Location for F4[49]

This CV specifies whether outputs 4 thru 11 are controlled by F4.

A '1' in a bit location specifies the output is controlled by F4, while a '0' specifies the output is not controlled by F4.

Default Value: **00000100 = 4**

CV 38: Output Location for F4 Register (with Factory Default Features)

Cruise Control (Disconnect-Standby-Shut Down)	Mute	Squealing Brakes (Special)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Whistle/Horn
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 11	**Output 10**	**Output 9**	**Output 8**	**Output 7**	**Output 6**	**Output 5**	**Output 4**

- Any feature can be assigned to any output in CV 53 except for fixed features (shown with gray back-ground in top row). In CV 53, the default setting for Output 6 is Blower Hiss/Fans. Therefore, by default F4 controls the Blower Hiss/Fans Sound.
- You can specify that F4 control any of Outputs 4-5 and 7-11 in addition to or instead of Output 6.
- Assuming the default CV 53 settings (shown in the top row)[50], you can specify that F4 control the following features.

Bit 0 Output 4; Whistle/Horn

"0" The Whistle/Horn is unaffected[51] by F4
"1" If F4 is on, Whistle/Horn is on.

Bit 1 Output 5: Coupler Crash, Coupler Arm, Coupler Fire.

"0" The Coupler Sound Effects are unaffected by F4.
"1" If F4 is changed when engine is moving, coupler crash sounds are produced.
If F4 is changed when engine is in Neutral, Coupler Arm or Fire occurs.

Bit 2 Output 6: Steam Engine Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower Hiss/Fans are unaffected by F4.
"1" If F4 is changed, Blower Hiss/Fans will toggle on or off.

49 Write bit operation is supported for CV 38.
50 Features that are different in the neutral state are shown in parentheses
51 "Unaffected" means that the output condition cannot be changed by the Function Key; if a feature is on, it state or toggled feature is on, it will stay on and if a state or toggle feature is off, it will stay off, regardless of the state or changes in the Function.

Bit 3 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F4.
"1" If F4 is changed, Dynamic Brakes will toggle on or off.

Bit 4 Output 8: Doppler, Start Up

"0" Doppler or Start Up features are unaffected by F4.
"1" If F4 is changed, Doppler shift will occur in a moving engine.
In Neutral, if F4 is double pressed[52], Quantum will produce engine start up sounds and clear all "Take Control" operations.

Bit 5 Output 9: Squealing Brakes, Short Air Let-off or Special Feature

"0" The Squealing Brakes are unaffected by F4.
"1" If F4 is changed, Squealing Brake Sounds are triggered for a moving engine.
If F4 is changed when engine is in Neutral, Special[53] Sounds occurs.

Bit 6 Output 10: Audio Mute or

"0" Audio Mute is unaffected by F4.
"1" If F4 is on, engine sounds are reduced to "Mute Volume".

Bit 7 Output 11: Cruise Control, Disconnect-Standby-Total Shut Down

"0" Cruise Control, Disconnect-Standby-Total Shut Down are unaffected by F4.
"1" If F4 is changed, Cruise Control will toggle on or off for a moving engine.
In Neutral, each time F4 is double pressed[54], Quantum will go through a series of shut down effects, starting with Disconnect, followed by Standby and finally Total Shut Down.

52 Double pressing ensures that Start Up is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.
53 Special Sounds usually denote sounds specific to a particular type of engine such as Water Injector Sounds for a steam engine.
54 Double pressing ensures that Shut Down is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

4.8 CV 39 Output Location for F5[55]

This CV specifies whether outputs 4 thru 11 are controlled by F5.

A '1' in a bit location specifies the output is controlled by F5, while a '0' specifies the output is not controlled by F5.

Default Value: **00001000 = 8**

CV 39: Output Location for F5 Register (with Factory Default Features)

Cruise Control (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes (Special)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Whistle/Horn
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 11	**Output 10**	**Output 9**	**Output 8**	**Output 7**	**Output 6**	**Output 5**	**Output 4**

- Any feature can be assigned to any output in CV 53 except for fixed features (shown with gray back-ground in top row). In CV 53, the default setting for Output 7 is Dynamic Brakes. Therefore, by default F5 controls the Dynamic Brake Sounds.
- You can specify that F5 control any of Outputs 4-6 and 8-11 in addition to or instead of Output 7.
- Assuming the default CV 53 settings (shown in the top row)[56], you can specify that F5 control the following features.

Bit 0 Output 4; Whistle/Horn

"0" The Whistle/Horn is unaffected[57] by F5
"1" If F5 is on, Whistle/Horn is on.

Bit 1 Output 5: Coupler Crash, Coupler Arm, Coupler Fire.

"0" The Coupler Sound Effects are unaffected by F5.
"1" If F5 is changed when engine is moving, coupler crash sounds are produced.
If F5 is changed when engine is in Neutral, Coupler Arm or Fire occurs.

Bit 2 Output 6: Steam Engine Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower Hiss/Fans are unaffected by F5.
"1" If F5 is changed, Blower Hiss/Fans will toggle on or off.

55 Write bit operation is supported for CV 39.
56 Features that are different in the neutral state are shown in parentheses
57 "Unaffected" means that the output condition cannot be changed by the Function Key; if a feature is on, it state or toggled feature is on, it will stay on and if a state or toggle feature is off, it will stay off, regardless of the state or changes in the Function.

Bit 3 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F5.
"1" If F5 is changed, Dynamic Brakes will toggle on or off.

Bit 4 Output 8: Doppler, Start Up

"0" Doppler or Start Up features are unaffected by F5.
"1" If F5 is changed, Doppler shift will occur in a moving engine.
In Neutral, if F5 is double pressed[58], Quantum will produce engine start up sounds and clear all "Take Control" operations.

Bit 5 Output 9: Squealing Brakes, Short Air Let-off or Special Feature

"0" The Squealing Brakes are unaffected by F5.
"1" If F5 is changed, Squealing Brake Sounds are triggered for a moving engine.
If F5 is changed when engine is in Neutral, Special[59] Sounds occurs.

Bit 6 Output 10: Audio Mute

"0" Audio Mute is unaffected by F5.
"1" If F5 is on, engine sounds are reduced to "Mute Volume".

Bit 7 Output 11: Cruise Control, Disconnect-Standby-Total Shut Down

"0" Cruise Control, Disconnect-Standby-Total Shut Down are unaffected by F5.
"1" If F5 is changed, Cruise Control will toggle on or off for a moving engine.
In Neutral, each time F5 is double pressed [60], Quantum will go through a series of shut down effects, starting with Disconnect, followed by Standby and finally Total Shut Down.

58 Double pressing ensures that Start Up is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.
59 Special Sounds usually denote sounds specific to a particular type of engine such as Water Injector Sounds for a steam engine.
60 Double pressing ensures that Shut Down is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

4.9 CV 40 Output Location for F6[61]

This CV specifies whether outputs 4 thru 11 are controlled by F6.

A '1' in a bit location specifies the output is controlled by F6, while a '0' specifies the output is not controlled by F6.

Default Value: **00010000 = 16**

CV 40: F6 Output Location for F6 Register (with Factory Default Features)

Cruise Control (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes (Special)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Whistle/Horn
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 11	**Output 10**	**Output 9**	**Output 8**	**Output 7**	**Output 6**	**Output 5**	**Output 4**

- Any feature can be assigned to any output in CV 53 except for fixed features (shown with gray back-ground in top row). In CV 53, the default settings for Output 8 are Doppler Shift for a moving engine and Engine Start Up in Neutral. Therefore, by default F6 controls Doppler Shift and Start Up.
- You can specify that F6 control any of Outputs 4-7 and 9-11 in addition to or instead of Output 8.
- Assuming the default CV 53 settings (shown in the top row)[62], you can specify that F6 control the following features.

Bit 0 Output 4; Whistle/Horn

"0" The Whistle/Horn is unaffected[63] by F6
"1" If F6 is on, Whistle/Horn is on.

Bit 1 Output 5: Coupler Crash, Coupler Arm, Coupler Fire.

"0" The Coupler Sound Effects are unaffected by F6.
"1" If F6 is changed when engine is moving, coupler crash sounds are produced.
If F6 is changed when engine is in Neutral, Coupler Arm or Fire occurs.

61 Write bit operation is supported for CV 40.
62 Features that are different in the neutral state are shown in parentheses
63 "Unaffected" means that the output condition cannot be changed by the Function Key; if a feature is on, it state or toggled feature is on, it will stay on and if a state or toggle feature is off, it will stay off, regardless of the state or changes in the Function.

Bit 2 Output 6: Steam Engine Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower Hiss/Fans are unaffected by F6.
"1" If F6 is changed, Blower Hiss/Fans will toggle on or off.

Bit 3 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F6.
"1" If F6 is changed, Dynamic Brakes will toggle on or off.

Bit 4 Output 8: Doppler, Start Up

"0" Doppler or Start Up features are unaffected by F6.
"1" If F6 is changed, Doppler shift will occur in a moving engine.
In Neutral, if F6 is double pressed[64], Quantum will produce engine start up sounds and clear all "Take Control" operations.

Bit 5 Output 9: Squealing Brakes, Short Air Let-off or Special Feature

"0" The Squealing Brakes are unaffected by F6.
"1" If F6 is changed, Squealing Brake Sounds are triggered for a moving engine.
If F6 is changed when engine is in Neutral, Special[65] Sounds occurs.

Bit 6 Output 10: Audio Mute

"0" Audio Mute is unaffected by F6.
"1" If F6 is on, engine sounds are reduced to "Mute Volume".

Bit 7 Output 11: Cruise Control, Disconnect-Standby-Total Shut Down

"0" Cruise Control, Disconnect-Standby-Total Shut Down are unaffected by F6.
"1" If F6 is changed, Cruise Control will toggle on or off for a moving engine.
In Neutral, each time F6 is double pressed [66], Quantum will go through a series of shut down effects, starting with Disconnect, followed by Standby and finally Total Shut Down.

64 Double pressing ensures that Start Up is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.
65 Special Sounds usually denote sounds specific to a particular type of engine such as Water Injector Sounds for a steam engine.
66 Double pressing ensures that Shut Down is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

4.10 CV 41 Output Location for F7[67]

This CV specifies whether outputs 4 thru 11 are controlled by F7.

A '1' in a bit location specifies the output is controlled by F7, while a '0' specifies the output is not controlled by F7.

Default Value: **00100000 = 32**

CV 41: Output Location for F7 Register (with Factory Default Features)

Cruise Control (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes (Special)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Whistle/Horn
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 11	**Output 10**	**Output 9**	**Output 8**	**Output 7**	**Output 6**	**Output 5**	**Output 4**

- Any feature can be assigned to any output in CV 53 except for fixed features (shown with gray back-ground in top row). In CV 53, the default settings for Output 9 are Squealing Brakes for a moving engine and Special or Custom Sound in. Therefore, by default F7 controls Squealing Brakes and a customer or special Neutral Sound..

- You can specify that F7 control any of Outputs 4-8 and 10-11 in addition to or instead of Output 9.

- Assuming the default CV 53 settings (shown in the top row)[68], you can specify that F7 control the following features.

  Bit 0 Output 4; Whistle/Horn

  "0" The Whistle/Horn is unaffected[69] by F7
  "1" If F7 is on, Whistle/Horn is on.

  Bit 1 Output 5: Coupler Crash, Coupler Arm, Coupler Fire.

  "0" The Coupler Sound Effects are unaffected by F7.
  "1" If F7 is changed when engine is moving, coupler crash sounds are produced.
  If F7 is changed when engine is in Neutral, Coupler Arm or Fire occurs.

  Bit 2 Output 6: Steam Engine Blower Hiss or Diesel or Electric Loco Vents and Fans

  "0" Blower Hiss/Fans are unaffected by F7.
  "1" If F7 is changed, Blower Hiss/Fans will toggle on or off.

67 Write bit operation is supported for CV 41.
68 Features that are different in the neutral state are shown in parentheses
69 "Unaffected" means that the output condition cannot be changed by the Function Key; if a feature is on, it state or toggled feature is on, it will stay on and if a state or toggle feature is off, it will stay off, regardless of the state or changes in the Function.

Bit 3 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F7.
"1" If F7 is changed, Dynamic Brakes will toggle on or off.

Bit 4 Output 8: Doppler, Start Up

"0" Doppler or Start Up features are unaffected by F7.
"1" If F7 is changed, Doppler shift will occur in a moving engine.
In Neutral, if F7 is double pressed[70], Quantum will produce engine start up sounds and clear all "Take Control" operations.

Bit 5 Output 9: Squealing Brakes, Short Air Let-off or Special Feature

"0" The Squealing Brakes are unaffected by F7.
"1" If F7 is changed, Squealing Brake Sounds are triggered for a moving engine.
If F7 is changed when engine is in Neutral, Special[71] Sounds occurs.

Bit 6 Output 10: Audio Mute

"0" Audio Mute is unaffected by F7.
"1" If F7 is on, engine sounds are reduced to "Mute Volume".

Bit 7 Output 11: Cruise Control, Disconnect-Standby-Total Shut Down

"0" Cruise Control, Disconnect-Standby-Total Shut Down are unaffected by F7.
"1" If F7 is changed, Cruise Control will toggle on or off for a moving engine.
In Neutral, each time F7 is double pressed [72], Quantum will go through a series of shut down effects, starting with Disconnect, followed by Standby and finally Total Shut Down.

70 Double pressing ensures that Start Up is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.
71 Special Sounds usually denote sounds specific to a particular type of engine such as Water Injector Sounds for a steam engine.
72 Double pressing ensures that Shut Down is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

4.11 CV 42 Output Location for F8[73]

This CV specifies whether outputs 4 thru 11 are controlled by F8.

A '1' in a bit location specifies the output is controlled by F8, while a '0' specifies the output is not controlled by F8.

Default Value: **01000000 = 64**

CV 42: Output Location for F8 Register (with Factory Default Features)

Cruise Control (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes (Special)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Whistle/Horn
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 11	**Output 10**	**Output 9**	**Output 8**	**Output 7**	**Output 6**	**Output 5**	**Output 4**

- Any feature can be assigned to any output in CV 53 except for fixed features (shown with gray back-ground in top row). In CV 53, the default setting for Output 10 is Audio Mute. Therefore, by default F8 controls Audio Mute.
- You can specify that F8 control any of Outputs 4-9 and 11 in addition to or instead of Output 10.
- Assuming the default CV 53 settings (shown in the top row)[74], you can specify that F8 control the following features.

Bit 0 Output 4; Whistle/Horn

"0" The Whistle/Horn is unaffected[75] by F8
"1" If F8 is on, Whistle/Horn is on.

Bit 1 Output 5: Coupler Crash, Coupler Arm, Coupler Fire.

"0" The Coupler Sound Effects are unaffected by F8.
"1" If F8 is changed when engine is moving, hear coupler crash sounds.
If F8 is changed when engine is in Neutral, Coupler Arm or Fire occurs.

Bit 2 Output 6: Steam Engine Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower Hiss/Fans are unaffected by F8.
"1" If F8 is changed, Blower Hiss/Fans will toggle on or off.

73 Write bit operation is supported for CV 42.
74 Features that are different in the neutral state are shown in parentheses
75 "Unaffected" means that the output condition cannot be changed by the Function Key; if a feature is on, it state or toggled feature is on, it will stay on and if a state or toggle feature is off, it will stay off, regardless of the state or changes in the Function.

Bit 3 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F8.
"1" If F8 is changed, Dynamic Brakes will toggle on or off.

Bit 4 Output 8: Doppler, Start Up

"0" Doppler or Start Up features are unaffected by F8.
"1" If F8 is changed, Doppler shift will occur in a moving engine.
In Neutral, if F8 is double pressed[76], Quantum will produce engine start up sounds and clear all "Take Control" operations.

Bit 5 Output 9: Squealing Brakes, Short Air Let-off or Special Feature

"0" The Squealing Brakes are unaffected by F8.
"1" If F8 is changed, Squealing Brake Sounds are triggered for a moving engine.
If F8 is changed when engine is in Neutral, Special[77] Sounds occurs.

Bit 6 Output 10: Audio Mute

"0" Audio Mute is unaffected by F8.
"1" If F8 is on, engine sounds are reduced to "Mute Volume".

Bit 7 Output 11: Cruise Control, Disconnect-Standby-Total Shut Down

"0" Cruise Control, Disconnect-Standby-Total Shut Down are unaffected by F8.
"1" If F8 is changed, Cruise Control will toggle on or off for a moving engine.
In Neutral, each time F8 is double pressed [78], Quantum will go through a series of shut down effects, starting with Disconnect, followed by Standby and finally Total Shut Down.

76 Double pressing ensures that Start Up is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.
77 Special Sounds usually denote sounds specific to a particular type of engine such as Water Injector Sounds for a steam engine.
78 Double pressing ensures that Shut Down is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

4.12 CV 43 Output Location for F9[79]

This CV specifies whether outputs 7 thru 14 are controlled by F9.

A '1' in a bit location specifies the output is controlled by F9, while a '0' specifies the output is not controlled by F9.

Default Value: **00010000 = 16**

CV 43: Output Location for F9 Register (with Factory Default Features)

Short Air Let Off or Special	Short Air Let Off or Special	Short Air Let Off or Special	Cruise Control (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes (Short Air Let-Off or Special)	Doppler (Start Up)	Dynamic Brakes
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 14	**Output 13**	**Output 12**	**Output 11**	**Output 10**	**Output 9**	**Output 8**	**Output 7**

- Any feature can be assigned to any output in CV 53[80]. In CV 53, the default settings for Output 11 are Cruise Control for a moving engine and Disconnect-Standby-Shut Down for an engine in Neutral. Therefore, by default F9 controls Cruise Control and Disconnect-Standby-Shut Down.
- You can specify that F9 control any of Outputs 7-10 and 12-14 in addition to or instead of Output 11.
- Assuming the default CV 53 settings (shown in the top row)[81], you can specify that F9 control the following features.

Bit 0 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F9.
"1" If F9 is changed, Dynamic Brakes will toggle on or off.

Bit 1 Output 8: Doppler, Start Up

"0" Doppler or Start Up features are unaffected by F9.
"1" If F9 is changed, Doppler shift will occur in a moving engine.
In Neutral, if F9 is double pressed[82], Quantum will produce engine start up sounds and clear all "Take Control" operations.

79 Write bit operation is supported for CV 43.
80 Although fixed features (Direction Headlight, Directional Reverse Light, Horn and Bell) can be assigned to any output, they are also assigned permanently assigned to Outputs FL(f), FL(r), F1 and F2, which may cause conflicts over which output has precedence.
81 Features that are different in the neutral state are shown in parentheses
82 Double pressing ensures that Start Up is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

Bit 2 Output 9: Squealing Brakes, Short Air Let-off or Special Feature

"0" The Squealing Brakes are unaffected by F9.
"1" If F9 is changed, Squealing Brake Sounds are triggered for a moving engine. If F9 is changed when engine is in Neutral, a Short Air Let-off or Special[83] Sounds occurs.

Bit 3 Output 10: Audio Mute

"0" Audio Mute is unaffected by F9.
"1" If F9 is on, engine sounds are reduced to "Mute Volume".

Bit 4 Output 11: Cruise Control, Disconnect-Standby-Total Shut Down

"0" Cruise Control, Disconnect-Standby-Total Shut Down are unaffected by F9.
"1" If F9 is changed, Cruise Control will toggle on or off for a moving engine. In Neutral, each time F9 is double pressed [84], Quantum will go through a series of shut down effects, starting with Disconnect, followed by Standby and finally Total Shut Down.

Bit 5 Output 12: Short Air Let-off or Special Feature

"0" The feature assigned to Output 12 is unaffected by F9.
"1" The feature assigned to Output 12 is affected by F9.

Bit 6 Output 13: Short Air Let-off or Special Feature

"0" The feature assigned to Output 13 is unaffected by F9.
"1" The feature assigned to Output 13 is affected by F9.

Bit 7 Output 14: Short Air Let-off or Special Feature

"0" The feature assigned to Output 14 is unaffected by F9.
"1" The feature assigned to Output 14 is affected by F9.

83 Special Sounds usually denote sounds specific to a particular type of engine such as Water Injector Sounds for a steam engine.
84 Double pressing ensures that Shut Down is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

4.13 CV 44 Output Location for F10[85]

This CV specifies whether outputs 7 thru 14 are controlled by F10.

A '1' in a bit location specifies the output is controlled by F10, while a '0' specifies the output is not controlled by F10.

Default Value: **00100000 = 32**

CV 44: Output Location for F10 Register (with Factory Default Features)

Short Air Let Off or Special	Short Air Let Off or Special	Short Air Let Off or Special	Cruise Control (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes (Short Air Let-Off or Special)	Doppler (Start Up)	Dynamic Brakes
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 14	**Output 13**	**Output 12**	**Output 11**	**Output 10**	**Output 9**	**Output 8**	**Output 7**

- Any feature can be assigned to any output in CV 53[86]. In CV 53, the default settings for Output 12 is a Short Air Let-off, or are special for specific types of locomotives such as Pop Off for steam engines.

- You can specify that F10 control any of Outputs 7-11 and 13-14 in addition to or instead of Output 12.

- Assuming the default CV 53 settings (shown in the top row)[87], you can specify that F10 control the following features.

  Bit 0 Output 7: Dynamic Brakes

  "0" Dynamic Brakes are unaffected by F10.
  "1" If F10 is changed, Dynamic Brakes will toggle on or off.

  Bit 1 Output 8: Doppler, Start Up

  "0" Doppler or Start Up features are unaffected by F10.
  "1" If F10 is changed, Doppler shift will occur in a moving engine.
  In Neutral, if F10 is double pressed[88], Quantum will produce engine start up sounds and clear all "Take Control" operations.

85 Write bit operation is supported for CV 44.
86 Although fixed features (Direction Headlight, Directional Reverse Light, Horn and Bell) can be assigned to any output, they are also assigned permanently assigned to Outputs FL(f), FL(r), F1 and F2, which may cause conflicts over which output has precedence.
87 Features that are different in the neutral state are shown in parentheses
88 Double pressing ensures that Start Up is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

Bit 2 Output 9: Squealing Brakes, Short Air Let-off or Special Feature

"0" The Squealing Brakes are unaffected by F10.
"1" If F10 is changed, Squealing Brake Sounds are triggered for a moving engine. If F10 is changed when engine is in Neutral, a Short Air Let-off or Special[89] Sounds occurs.

Bit 3 Output 10: Audio Mute

"0" Audio Mute is unaffected by F10.
"1" If F10 is on, engine sounds are reduced to "Mute Volume".

Bit 4 Output 11: Cruise Control, Disconnect-Standby-Total Shut Down

"0" Cruise Control, Disconnect-Standby-Total Shut Down are unaffected by F10.
"1" If F10 is changed, Cruise Control will toggle on or off for a moving engine. In Neutral, each time F10 is double pressed [90], Quantum will go through a series of shut down effects, starting with Disconnect, followed by Standby and finally Total Shut Down.

Bit 5 Output 12: Short Air Let-off or Special Feature

"0" The feature assigned to Output 12 is unaffected by F10.
"1" The feature assigned to Output 12 is affected by F10.

Bit 6 Output 13: Short Air Let-off or Special Feature

"0" The feature assigned to Output 13 is unaffected by F10.
"1" The feature assigned to Output 13 is affected by F10.

Bit 7 Output 14: Short Air Let-off or Special Feature

"0" The feature assigned to Output 14 is unaffected by F10.
"1" The feature assigned to Output 14 is affected by F10.

89 Special Sounds usually denote sounds specific to a particular type of engine such as Water Injector Sounds for a steam engine.
90 Double pressing ensures that Shut Down is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

4.14 CV 45 Output Location for F11[91]

This CV specifies whether outputs 7 thru 14 are controlled by F11.

A '1' in a bit location specifies the output is controlled by F11, while a '0' specifies the output is not controlled by F11.

Default Value: **01000000 = 64**

CV 45: Output Location for F11 Register (with Factory Default Features)

Short Air Let Off or Special	Short Air Let Off or Special	Short Air Let Off or Special	Cruise Control (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes (Short Air Let-Off or Special)	Doppler (Start Up)	Dynamic Brakes
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 14	**Output 13**	**Output 12**	**Output 11**	**Output 10**	**Output 9**	**Output 8**	**Output 7**

- Any feature can be assigned to any output in CV 53[92]. In CV 53, the default settings for Output 13 is a Short Air Let-off, or are special for specific types of locomotives such as Boiler Blow Down for steam engines.
- You can specify that F11 control any of Outputs 7-12 and 14 in addition to or instead of Output 13.
- Assuming the default CV 53 settings (shown in the top row)[93], you can specify that F11 control the following features.

Bit 0 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F11.
"1" If F11 is changed, Dynamic Brakes will toggle on or off.

Bit 1 Output 8: Doppler, Start Up

"0" Doppler or Start Up features are unaffected by F11.
"1" If F11 is changed, Doppler shift will occur in a moving engine.
In Neutral, if F11 is double pressed[94], Quantum will produce engine start up sounds and clear all "Take Control" operations.

91 Write bit operation is supported for CV 45.
92 Although fixed features (Direction Headlight, Directional Reverse Light, Horn and Bell) can be assigned to any output, they are also assigned permanently assigned to Outputs FL(f), FL(r), F1 and F2, which may cause conflicts over which output has precedence.
93 Features that are different in the neutral state are shown in parentheses
94 Double pressing ensures that Start Up is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

Bit 2 Output 9: Squealing Brakes, Short Air Let-off or Special Feature

"0" The Squealing Brakes are unaffected by F11.
"1" If F11 is changed, Squealing Brake Sounds are triggered for a moving engine. If F11 is changed when engine is in Neutral, a Short Air Let-off or Special[95] Sounds occurs.

Bit 3 Output 10: Audio Mute

"0" Audio Mute is unaffected by F11.
"1" If F11 is on, engine sounds are reduced to "Mute Volume".

Bit 4 Output 11: Cruise Control, Disconnect-Standby-Total Shut Down

"0" Cruise Control, Disconnect-Standby-Total Shut Down are unaffected by F11.
"1" If F11 is changed, Cruise Control will toggle on or off for a moving engine. In Neutral, each time F11 is double pressed [96], Quantum will go through a series of shut down effects, starting with Disconnect, followed by Standby and finally total Shut Down.

Bit 5 Output 12: Short Air Let-off or Special Feature

"0" The feature assigned to Output 12 is unaffected by F11.
"1" The feature assigned to Output 12 is affected by F11.

Bit 6 Output 13: Short Air Let-off or Special Feature

"0" The feature assigned to Output 13 is unaffected by F11.
"1" The feature assigned to Output 13 is affected by F11.

Bit 7 Output 14: Short Air Let-off or Special Feature

"0" The feature assigned to Output 14 is unaffected by F11.
"1" The feature assigned to Output 14 is affected by F11.

95 Special Sounds usually denote sounds specific to a particular type of engine such as Water Injector Sounds for a steam engine.
96 Double pressing ensures that Shut Down is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

4.15 CV 46 Output Location for F12[97]

This CV specifies whether outputs 7 thru 14 are controlled by F12.

A '1' in a bit location specifies the output is controlled by F12, while a '0' specifies the output is not controlled by F12.

Default Value: **10000000 = 128**

CV 46: Output Location for F12 Register (with Factory Default Features)

Short Air Let Off or Special	Short Air Let Off or Special	Short Air Let Off or Special	Cruise Control (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes (Short Air Let-Off or Special)	Doppler (Start Up)	Dynamic Brakes
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 14	**Output 13**	**Output 12**	**Output 11**	**Output 10**	**Output 9**	**Output 8**	**Output 7**

- Any feature can be assigned to any output in CV 53[98]. In CV 53, the default settings for Output 14 is a Short Air Let-off, or are special for specific types of locomotives such as Boiler Blow Down for steam engines.
- You can specify that F12 control any of Outputs 7-13 in addition to or instead of Output 14.
- Assuming the default CV 53 settings (shown in the top row)[99], you can specify that F12 control the following features.

Bit 0 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F12.
"1" If F12 is changed, Dynamic Brakes will toggle on or off.

Bit 1 Output 8: Doppler, Start Up

"0" Doppler or Start Up features are unaffected by F12.
"1" If F12 is changed, Doppler shift will occur in a moving engine.
In Neutral, if F12 is double pressed[100], Quantum will produce engine start up sounds and clear all "Take Control" operations.

97 Write bit operation is supported for CV 46.
98 Although fixed features (Direction Headlight, Directional Reverse Light, Horn and Bell) can be assigned to any output, they are also assigned permanently assigned to Outputs FL(f), FL(r), F1 and F2, which may cause conflicts over which output has precedence.
99 Features that are different in the neutral state are shown in parentheses
100 Double pressing ensures that Start Up is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

Bit 2 Output 9: Squealing Brakes, Short Air Let-off or Special Feature

"0" The Squealing Brakes are unaffected by F12.
"1" If F12 is changed, Squealing Brake Sounds are triggered for a moving engine. If F12 is changed when engine is in Neutral, a Short Air Let-off or Special[101] Sounds occurs.

Bit 3 Output 10: Audio Mute

"0" Audio Mute is unaffected by F12.
"1" If F12 is on, engine sounds are reduced to "Mute Volume".

Bit 4 Output 11: Cruise Control, Disconnect-Standby-Total Shut Down

"0" Cruise Control, Disconnect-Standby-Total Shut Down are unaffected by F12.
"1" If F12 is changed, Cruise Control will toggle on or off for a moving engine. In Neutral, each time F12 is double pressed [102], Quantum will go through a series of shut down effects, starting with Disconnect, followed by Standby and finally Total Shut Down.

Bit 5 Output 12: Short Air Let-off or Special Feature

"0" The feature assigned to Output 12 is unaffected by F12.
"1" The feature assigned to Output 12 is affected by F12.

Bit 6 Output 13: Short Air Let-off or Special Feature

"0" The feature assigned to Output 13 is unaffected by F12.
"1" The feature assigned to Output 13 is affected by F12.

Bit 7 Output 14: Short Air Let-off or Special Feature

"0" The feature assigned to Output 14 is unaffected by F12.
"1" The feature assigned to Output 14 is affected by F12.

101 Special Sounds usually denote sounds specific to a particular type of engine such as Water Injector Sounds for a steam engine.
102 Double pressing ensures that Shut Down is not entered or exited accidentally. Doubling Pressing is defined as two Function Key presses within two seconds. Note that the Function Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for the Function.

5 CV 49-64, QSI Configuration Variables

5.1 Overview

Many of the available CV's have been reserved by the NMRA to provide standardized and compatible operation by all manufacturers with each other's products.

The NMRA specified CV specifications relate to the operation of functions that must be standard to all DCC products such as ID numbers, number of speed steps, and acceleration and deceleration values.

However, many model railroad products today, and a much larger number in the future, will require manufacturer unique CV's to configure their product's special features. The command structure and protocols for operation of non-specified features are standardized through the NMRA, but the individual manufacturers will specify the actual behavior and configuration. An example is the system volume for the Quantum Sound System. This feature is not specified by the NMRA and it is left to the discretion of the product designer to determine how it will be implemented and what parameters are necessary to customize its performance. For this reason, the NMRA has provided a number of CV's for the manufacturers to allow configuring of their own products, using CV's 49 through 64. Additional CV's 112-128 have recently been made available for manufacturers as well.

Unfortunately the total number of manufacturer unique CV's made available may not be sufficient for future needs. Also, the grouping of the CV's may not be as well organized as new features are added. For instance, if we included CV's for particular sound effects followed by CV's to set their volume levels, we could easily consume a large number of the available allocated CV's. If at a later date, we decided to add configuration variables to enhance some sound feature, that CV may have to be placed at the end of the list, far from the CV's related to that feature.

5.1.1 Primary and Secondary Indices

Instead of filling up the manufacturer unique CV's in a linear or chronological order, we have elected to use a table indexing system that allows the user to change the operation and behavior of each customizable feature in a consistent way. We have included both a Primary Index set by CV 49 and a Secondary Index (SI) set by CV 50. Numbers or values placed in these two indices do not, by themselves, have any effect on the operation of the Quantum System. Rather, they are used along with CV's that do affect some Quantum characteristic. They simply act as a pointer to individual sounds, features, outputs or whatever that will be affected by the CV under consideration.

5.1.1.1 Primary Index

The Primary Index is used as a table index to expand the number of choices available for a CV.

For example, consider QSI CV 52, which controls the volume levels for different sound features. CV 52 can have any of sixteen volume-settings as specified by the first four bits. Although 52 does specify a volume level, it does not know which feature to apply that volume setting to unless there is a way to point at the desired sound feature. That "pointing" is accomplished by using the Primary Index (PI), which is set in CV 49. The user first selects the sound he wants to affect from a table of the different sound features available and enters its corresponding number into the Primary Index, CV 49. He then uses CV 52 to change that particular sound volume. He can enter one value after another into CV 52 until he gets the desired volume for the feature selected. The user can then select a new sound from the table, write its corresponding value into CV 49 and then use CV 52 to change the volume of this second sound.

We use a shorthand notation when writing a CV that has a Primary Index. The CV is first written followed by a decimal point followed the Primary Index value. For instance, if we had set CV 52 to a volume level of 6 for the Bell (Sound Identifier Number[103] = 8), we would write CV 52.8 = 6.

5.1.1.2 Secondary Index

The Secondary Index is used as a second table index where there is a secondary choice of behavior that can apply. For instance, CV 53 is used to assign features to both an output and a motive state of the engine. When we assign a feature in CV 53, we need a pointer (Primary Index) to select the desired output and another pointer (Secondary Index) to specify the state (Forward/Reverse or Neutral).

A useful way to help understand this concept is to picture assigning Secondary and Primary Indexes as row and column values in a two dimensional table for a particular CV (shown as CV X in this case). The Primary Index (PI) is shown as row values and the Secondary Index (SI) is shown as column values. The value of the CV for each PI and SI is shown as a table entry where the row and column (PI and SI) values are included (i.e. “CV Value 1,3” means the Values of CV X assigned for PI = 1 and SI = 3).

CV X Date Register

Primary Index set by CV 49	**Secondary Index set by CV 50**					
	0	1	2	3	:	255
0	CV Value 0,0	CV Value 0,1	CV Value 0,2	CV Value 0,3	CV Value 0,n	CV Value 0,255
1	CV Value 1,0	CV Value 1,1	CV Value 1,2	CV Value 1,3	CV Value 1,n	CV Value 1,255
2	CV Value 2,0	CV Value 2,1	CV Value 2,2	CV Value 2,3	CV Value 2,n	CV Value 2,255
3	CV Value 3,0	CV Value 3,1	CV Value 3,2	CV Value 3,3	CV Value 3,n	CV Value 3,255
:	CV Value m,0	CV Value m,1	CV Value m,2	CV Value m,3	CV Value m,n	CV Value m,255
255	CV Value 255,0	CV Value 255,1	CV Value 255,2	CV Value 255,3	CV Value 255,n	CV Value 255,255

Not all of the 256 row and 256 columns are shown. The row labeled “m” and column labeled “n” indicate any row or column between 3 and 255. Although there is only one CV (shown as CV X in this case), a different value can be stored for each row and column choice, providing up to 256 X 256 possible choices for the CV.

To use CV X, first select the PI and SI you want and assign these values to CV 49 and CV 50 respectively. Now when you enter a value into CV X, it will only apply to that particular selection of CV X for the choices you made for the SI and PI values.

To see how this works in practice, consider CV 53 as an example. The table below shows how different QSI Features have been assigned to different outputs and locomotive states for our factory defaults. The Primary Index column has 14 choices for the 14 different Outputs. The Secondary Index is shown across the top and has only two values (0 for a Motive State, and 1 for Neutral); an N/A means there are no other directional states available and hence no other Secondary ID’s besides 0 and 1.

103 See the list of Individual Sound Identifiers in CV 52.

Each Feature ID (see listing of Feature ID's in CV 53) to be controlled by an output is shown as a location in the table corresponding to the desired output and the desired directional state in which it will be active. For instance, we have assigned Mute (ID 64) to Output 10 and to operate in all states (Forward and Reverse, and Neutral). Doppler (ID 65) has been assigned to Output 8 but only in Forward and Reverse. A completely different feature, Engine Start Up (ID 144) has been assigned to Neutral. This means that a moving engine will produce a Doppler Shift Effect when Output 8 is activated, but will produce an Engine Start up Sound if in Neutral when Output 8 is activated.

Feature Assignments using CV 53 Primary and Secondary Indexes:

		Secondary Index set by CV 50					
		0	**1**	**2**	**3**	**……**	**255**
Primary Index set by CV 49		Forward/ Reverse only	Neutral only	N/A	N/A		N/A
0	N/A						
1	Output 1	96	96				
2	Output 2	97	97				
3	Output 3	3	3				
4	Output 4	1	1				
5	Output 5	211	211				
6	Output 6	8	8				
7	Output 7	5	5				
8	Output 8	65	144				
9	Output 9	215	14				
10	Output 10	64	64				
11	Output 11	177	145				
12	Output 12	10	10				
13	Output 13	10	10				
14	Output 14	10	10				
15	N/A						
:							
255	NA						

Let's say you wanted to assign a Short Air Let-Off (QSI Feature[104] Number 10) into CV 53 to operate only in Neutral in Output 7. Currently, Output 7 is already assigned "Dynamic Brakes" for both Forward/Reverse and Neutral. To place Short Air Let-off in the Neutral Position for Output 7, first set CV 49 to 7 (Output 7) and then set CV 50 to 1 (Neutral). Now set 10 (Short Air Let-Off) into CV 53.

In summary, to assign a feature to an output, we first chose which output it would apply to, followed by the motive state it will operate in. We use the Primary Index (PI) to select the Output followed by the Secondary Index (SI) to select the motive state and then enter the Feature ID number into CV 53. We then select the next SI for the other motive state and enter the next Feature ID into CV 53.

We use a shorthand notation when writing a CV that has a Primary and Secondary Index. The CV is first written followed by a decimal point followed by the Primary Index value followed by a decimal point followed by the Secondary Index. For instance, in the above example where we entered the Short Air Let-off (10) into CV 53 to be active in Output 7 (PI = 7) and to operate in the Neutral Position (SI = 1), we would write "CV 53.7.1 = 10. When CV's are spoken out in Ops Mode Programming, the same shorthand method

104 See CV 53 listing of QSI Feature ID's).

is used. If you inquired about the value in CV 53 for this example, you would hear “CV five three point seven point one equals ten”.

5.2 CV 49 QSI Primary Index

Use CV 49 to specify the Primary Index or Row Number for CV's that use a table index to expand the number of choices.

Default Value: **0**

CV 49: Primary Index Register (PI)

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
P7	**P6**	**P5**	**P4**	**P3**	**P2**	**P1**	**P0**

CV 49 is used as an index into a table of up to 256 related values.

Primary Index	Table of Values
0	Value[0]
1	Value[1]
2	Value[2]
3	Value[3]
…	…

For example, using CV 49 as an index for CV 52 allows specifying the volume for up to 256 Individual Sounds.

Primary Index	Table of Volumes
0	Volume for Individual Sound[0]
1	Volume [1]
2	Volume [2]
3	Volume [3]
…	…

- In this document the terms CV 49 and Primary Index mean the same thing. PI is the abbreviation for Primary Index.

- We use a shorthand notation to simplify description of a CV that is composed of a table of values. The elements of the table are referred to as CV NN.PI, where NN is the CV number. For example, Individual Sound Volume 5 is written CV 52.5. During verbal acknowledgement or during CV Numeric Verbal Readout (CV 64) from the locomotive, it is spoken out as "CV five two point five".

5.3 CV 50 QSI Secondary Index

Use CV 50 to specify the Secondary Index for CV's that use two pointers or table indices to expand the number of available choices.

Default Value: **0**

CV 50: Secondary Index Register (SI)

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
S7	**S6**	**S5**	**S4**	**S3**	**S2**	**S1**	**S0**

CV 50 is used along with CV 49 as an index into a 2-dimensional table of up to 256x256 related values. CV 49 is the row index and CV 50 is the column index.

	Secondary Index				
Primary Index	**0**	**1**	**2**	**3**	…
0	Value[0,0]	Value[0,1]	Value[0,2]	Value[0,3]	…
1	Value[1,0]	Value[1,1]	Value[1,2]	Value[1,3]	…
2	Value[2,0]	Value[2,1]	Value[2,2]	Value[2,3]	…
3	Value[3,0]	Value[3,1]	Value[3,2]	Value[3,3]	…
…	…	…	…	…	…

- Where Value [n,m] represents the data entered in each position with PI =n, and SI =m.
- In this document the terms CV 50 and Secondary Index mean the same thing. SI is the abbreviation for Secondary Index.
- To simplify description of a CV that is a 2-dimensional table of values, the elements of the table are referred to as CV NN.PI.SI, where NN is the CV number, PI is the Primary Index and SI is the Secondary Index. During verbal acknowledge of CV's or during CV Numeric Verbal Readout (CV 64), the value of data in a 2-dimensional table is spoken out with the word "point" to distinguish between the CV number, the Primary Index and the Secondary Index. For example, the location of the Feature Assigned to Output 5 in NFF/NFR is written CV 53.5.1 and spoken out as "CV five three point five point 1".

See Example Next Page:

For example, CV 53, using CV 49 as a row index (1..14) and CV 50 as a column index (0..1) allows assigning different QSI Features to each of fourteen outputs for two states: Forward/Reverse, and NFF/NFR.

	Secondary Index	
Primary Index	**0**	**1**
1	Feature Assigned to Output 1 in FWD/REV	Feature Assigned to Output 1 in NFF/NFR
2	Feature Assigned to Output 2 in FWD/REV	Feature Assigned to Output 2 in NFF/NFR
3	Feature Assigned to Output 3 in FWD/REV	Feature Assigned to Output 3 in NFF/NFR
4	Feature Assigned to Output 4 in FWD/REV	Feature Assigned to Output 4 in NFF/NFR
5	Feature Assigned to Output 5 in FWD/REV	Feature Assigned to Output 5 in NFF/NFR
6	Feature Assigned to Output 6 in FWD/REV	Feature Assigned to Output 6 in NFF/NFR
7	Feature Assigned to Output 7 in FWD/REV	Feature Assigned to Output 7 in NFF/NFR
8	Feature Assigned to Output 8 in FWD/REV	Feature Assigned to Output 8 in NFF/NFR
9	Feature Assigned to Output 9 in FWD/REV	Feature Assigned to Output 9 in NFF/NFR
10	Feature Assigned to Output 10 in FWD/REV	Feature Assigned to Output 10 in NFF/NFR
11	Feature Assigned to Output 11 in FWD/REV	Feature Assigned to Output 11 in NFF/NFR
12	Feature Assigned to Output 12 in FWD/REV	Feature Assigned to Output 12 in NFF/NFR
13	Feature Assigned to Output 13 in FWD/REV	Feature Assigned to Output 13 in NFF/NFR
14	Feature Assigned to Output 14 in FWD/REV	Feature Assigned to Output 14 in NFF/NFR

5.4 CV 51 QSI System Sound Control

Use CV 51 to control the Quantum Sound System, Mute Volume and Special Sound Effects

5.4.1 CV 51.0 Operations Mode System Volume (PI = 0)

Use CV 51.0 to change the overall System Volume.

Default Value: **127**

CV 51.0: Ops Mode System Volume Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**V6**	**V5**	**V4**	**V3**	**V2**	**V1**	**V0**

- Set CV 49 to "0" to specify the Primary Index for **Operations Mode System Volume**.
- The System Volume can be set to any value between 0 (no sound) and 127 (100%). The upper bit is reserved and should be 0. The default Operations Mode Volume is 127 **(100%)**. A "0" in this CV will reduce all sound effects to zero volume.

Example: Set the Operations Mode System volume to 64 (50% of max).
1) Set CV 49 to 0. 2) Set CV 51 to 64.

The Operations Mode System Volume is the overall sound volume when the engine is in normal operation on the main (Operations Mode). When you change the Operations Mode System Volume on the main, you will immediately hear the change in volume.

All sound is turned off in Service Mode because of the limited power usually available for the programming track. If your Command Station supports programming Quantum in Service Mode, you can program the System Volume. You just won't hear the change in volume until you enter Operations Mode.

Note: Setting the system volume in this CV will also apply to the system volume during conventional Analog operation. The converse is also true. Setting the Analog System Volume using Analog program options described in the Analog Operation section of your locomotive's instruction manual will affect the system volume in DCC operation.

5.4.2 CV 51.1 Operations Mode Mute Volume (PI = 1)

Use CV 51.0 to change the Mute Volume. Mute is one of the Quantum features that can be selected by a Function Key. When Mute is activated the overall volume reduces to the volume set by CV 51.1.

Default Value: **0**

CV 51.1: Ops Mode Mute Volume Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**V5**	**V4**	**V3**	**V2**	**V1**	**V0**

- Set CV 49 to "1" to specify the Primary Index for **Operations Mode System Volume**.

- The Mute Volume can be set to any value between 0 (no sound) and 63 (50%). If the Mute Volume is set over 50% of the System Volume set in CV 51.0, the applied Mute Volume will be 50% of the System Volume setting. The upper bit is reserved and should be 0. The default Mute Volume is 0 **(0%)**. A "0" in this CV will mute all sound effects to zero volume.

Example: Set the Operations Mode System volume to 32 (25% of max).
1. Set CV 49 to 1 2. Set CV 51 to 32

The Mute Volume applies when the engine is in normal operation on the main (Operations Mode). When you change the Mute Volume on the main and "Mute" has been activated by its assigned Function Key, you will immediately hear the change in volume.

If your Command Station will support programming Quantum in Service Mode, you can program the Mute Volume. You just won't hear the change in Mute volume until you enter Operations Mode and activate the Mute feature.

5.4.3 CV 51.2 Special Sound Effects Enable [105] (PI = 2)

Use CV 51.2 to turn on/off special sound effects.

Default Value: **1**

CV 51.2: Special Sound Effects Enable Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved for future use	Reserved for future use	Reserved for future use	Reserved for future use	Reserved for future use	Reserved for future use	Reserved for future use	Horn Triggered Doppler

- Write 2 to CV 49 to specify the Primary Index for **Special Sound Effects Enable.**
- If Horn Triggered Doppler is enabled, you can obtain a Doppler effect by first blowing the Horn for a least one second. Any time thereafter, briefly interrupt the horn signal by releasing the function key and reapplying to produce the Doppler effect.
- Set data in Bit 1 as follows:

  "0" = Horn Triggered Doppler Effect is disabled
  "1" = Horn Triggered Doppler Effect is enabled.

- All other bits are reserved. Data in bits 1-7 are not used. Any data entered in these bits will be ignored.
- Default is "1", Horn Triggered Doppler enabled.

Example: Disable Horn Triggered Doppler.
1) Set CV 49 to 2. 2) Set CV 51 to 0.

105 Write bit operation is supported for Special Sound Effects Enable.

5.5 CV 52.PI QSI Individual Sound Volume Control

Use CV 52 to specify volumes levels for individual Quantum sounds.

CV 52.PI: Individual Sound Volume Registers

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**0**	**V3**	**V2**	**V1**	**V0**

To change the volume level of an individual sound, do the following:

1. Set CV#49 to the identifier for the individual sound (see table below).
2. Set data in Bits 0-3 of CV#52 as follows:

   "0" = No sound
   "1 – 15" = Sets volume level from the lowest level at "1" to the highest level at "15"

- 4 bits of volume are used, providing 16 volume levels. The volume levels are in 2db increments.
- All other bits are reserved. Data in bits 4-7 are not used. Any data entered in these bits will be ignored.

Example: Set the bell volume to the 6th volume level and then set the Whistle volume to 10th level (i.e. set CV 52.8 to 6 followed by setting CV 52.0 to 11)
1. Set CV 49 to 8 to select the Bell sound. 2. Set CV 52 to 6 to select the 6th volume level for the Bell. 3. Set CV 49 to 0 select the Whistle/Horn sound. 4. CV 52 to 10 to select the 10th volume level for the Whistle/Horn.

Example: For dual pump steam engines, turn the volume off on one pump to create single pump action.
1. Set CV 49 to 17 to select the second pump sound. 2. CV 52 to zero to select no volume.

5.5.1 Individual Sound Identifiers

Primary Index (CV 49 value)	Sound	Typical Defaults Levels[106]
0	**Whistle/Horn[107]**	11
8	**Bell**	11
10	**Chuff/Diesel Motor/Traction Motor[108]**	11
16	**Air Pump 1**	11
17	**Air Pump 2**	11
19	**Steam Blower (hiss)/ Fans[109]**	8
21	**Long Air Let-off**	11
22	**Short Air Let-off**	11
24	**Squealing Brakes**	11
26	**Steam Dynamo**	8
28	**Dynamic Brakes**	8
29	**Boiler Pop-off**	11
30	**Blow down**	11
31	**Injector**	11
34	**Coupler Sounds**	11

106 Default levels for individual sounds may be set to different levels at the factory then are shown here depending on the acoustic nature of each locomotive. Check the value of your default settings in your individual locomotive's instruction manual.
107 Whistle in Steam Locomotives; Horn in Diesel and Electric Locomotive.
108 Chuff in Steam Locomotives; Diesel Motor in Diesel Locomotives; Traction Motor in Electric Locomotives.
109 Steam Blower in Steam Locomotives; Cooling Fans in Diesel and Electric Locomotives.

5.6 CV 53.PI.SI Output Feature Assignment

Use CV 53 to assign QSI features to the 14 decoder outputs.

CV 53.PI.SI: Output Feature Assignment Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Write the Decoder Output Number (5…14) to CV 49. Outputs 1…4 are pre-assigned and cannot be changed.
- Write the Engine State (0 for Forward/Reverse, 1 for Neutral (NFF/NFR) to CV 50. Certain features can only be assigned to an output for a specific state.
- Write the QSI Feature Identifier Number to CV 53.
- Never assign the same feature to two or more outputs; it is unclear what the effect will be since both outputs may have different states. For instance, if you assign the Blower Hiss to Output 5 and to Output 7, and Output 5 is off but Output 7 is on, would Blower Hiss be on or off?

Example: Set Long Air Let-Off to Output 5 to operate in Forward and Reverse and set Short Air Let-Off to Output 5 to operate in Neutral (i.e. set CV 53.5.1 to 9 and set CV 53.5.2 to 10).

1) Set Primary Index CV 49 to “5” to select output 5.
2) Set Secondary Index CV 51 to “0” to select Forward/Reverse.
3) Set CV 53 to “9” (00000101) for Long Air Let-Off.
4) Set Secondary Index CV 51 to “1” to select Neutral. (CV 49 is already set to output 5.)
5) Set CV 53 to “10” (00001010) for Short Air Let-Off.

Now when the engine is in Neutral, the Function key mapped to output 5 will produce a Short Air-Let-Off a Long Air Let-Off when the engine is moving in Forward and Reverse.

5.6.1 QSI Feature Identification Numbers

The following table lists the QSI Features, which may be assigned to function key outputs.

The third column shows the directional states (All, Forward/Reverse, Neutral) for which the feature may be assigned to an output. Some features, like Blower Hiss or Mute, apply to all states; some features, like Doppler and Squealing Brakes, only apply to a moving engine; some features, like Pop-off or Blow-Down, only apply to Neutral. The Quantum System allows you to assign, say, squealing brakes to Output 7 in Neutral but when the F5 Key is pressed to activate this feature in Neutral, it will produce no effect.

Feature ID	Feature	Allowed Directional States	Comments
0	Null Output	All	No feature, no sound effect.
1	Whistle/Horn	All	Pre-assigned to output 4.
3	Bell	All	Pre-assigned to output 3.
5	Dynamic Brakes	All	Dynamic Brakes are usually applied to diesel or electric locomotives. Even though it has no meaning for a steam engine, it has some utility when the steam engine is in a Consist. Here Dynamic Brakes cause the chuff sound to lower in labor or volume to be consistent with other engines that have Dynamic Brakes. Dynamic Brakes can also be applied in Neutral for diesels in “Disconnect” which will allow the motor to rev up under Dynamic Brake loading.
8	Blower Hiss/Diesel Cooling Fans	All	Blowers are used on steam engines to vent steam through the smoke stack to provide extra draft for the fire when engine is idle. It produces a familiar hissing sound. Diesel and Electric Cooling Fans are used to keep diesels and/or traction motors from overheating. Cooling fans are accompanied by vents opening and closing.
9	Long Air Let-off	All	Use a long air let-off to simulate operating some steam appliances like power reverse.
10	Short Air Let-off	All	Short air let-off for turn on or turn off of some appliances. Combine with brakes to simulate venting air prior to brake sounds.
12	Pop-off	NFF/NFR	This is the sound of the boiler Pop-off values venting excess steam. Although this can be applied to all directional states, it occurs more typically in Neutral.
13	Blow down	NFF/NFR	This is venting of residue that collects at the bottom of the boiler, usually in Neutral.
14	Injector	NFF/NFR	This is the sound effect of water being injected into the boiler. This can happen anytime but it is more obvious in Neutral.
64	Mute	All	Ideal for muting sounds of a running engine when the phone rings. When an engine is muted, all sounds go silent. We have added a feature in CV 51.1 that provides a custom mute volume; when Mute is engaged, the sounds go to a lower sound but not completely off.
65	Doppler Shift	FWD/REV	Doppler, when activated, produces volume increase and pitch change on a moving train to simulate the sound a train makes when passing close to an observer. Doppler has no meaning or utility in Neutral.
96	Headlight	All	Pre-assigned to output 1. Steam Loco’s Directional Lights also include Dynamo Start Up Sounds.
97	Reverse Light	All	Pre-assigned to output 2. Steam Loco’s Directional Lights also include Dynamo Start Up Sounds.
101	Cab Lights		May not be available for all models.

102	Mars Light	All	Usually found on diesels. Three position feature that proceeds successively through the stages of 1) Off 2) Dim non-pulsing and 3) Bright pulsing.
105	Number Board Lights	All	May not be available for all models.
144	Start Up	NFF/NFR	The Start Up feature produces engine start up sound effects for an engine that has been Shut Down (see 145).
145	Shut Down	NFF/NFR	Shut Down features Consists of three parts that proceeds successively with each use of the Function Key to the stages of: 1) “Disconnect” which allow a diesel motor to rev or steam engine to vent steam without engaging the motor, 2) “Standby” which produces low background sounds of an idling engine, and 3) Total Shut Down.
177	Cruise Control	FWD/REV	Cruise control locks the engine into its current speed when activated. Cruise control works only in Regulated Speed Control and Speed Control, and not Standard Throttle Control. Cruise Control has no meaning or utility in Neutral.
211	Coupler Effect	All	Although this feature can be applied to all directional states, it has different effects depending on when it is used. If only assigned to FWD/REW it will produce a coupler crash sound. If also enabled in Neutral, it will arm and fire a coupler sound. If it is armed in Neutral, it can be also be fired in FWD/REV.
215	Squealing Brakes	FWD/REV	This feature can be re-triggered over and over again anywhere in the record to extend the brake squeal sound. Do not waste this feature in Neutral where squealing brakes have no meaning.
217	Pumps	NFF/NFR	This can be two or one compressor depending on the locomotive. Note that when two pumps are available, each one can be assigned different volumes in CV 52.

Note: Do not confuse the above table with the Individual Sound Identifiers Table shown in CV 52. The above table lists ID’s of Features while CV 52 table lists ID’s of Individual Sounds.

5.6.2 Factory Default Settings

		Secondary Index (SI) (CV 50 Value)		
		0	**1**	**2 …… 255**
Primary Index (PI) (CV 49 Value)		**Forward/Reverse only**	**Neutral only**	**N/A**
1	**Output 1**	Headlight (96)*	Headlight (96)*	
2	**Output 2**	Reverse Light (97)*	Reverse Light (97)*	
3	**Output 3**	Bell (3)*	Bell (3)*	
4	**Output 4**	Whistle/Horn (1)*	Whistle/Horn (1)*	
5	**Output 5**	Coupler (211)	Coupler (211)	
6	**Output 6**	Blower Hiss/Fans (8)	Blower Hiss/Fans (8)	
7	**Output 7**	Dynamic Brakes (5)	Dynamic Brakes (5)	
8	**Output 8**	Doppler Shift (65)	Start Up (13)	
9	**Output 9**	Squealing Brakes (215)	Special**	
10	**Output 10**	Mute 64)	Mute (64)	
11	**Output 11**	Cruise Control (177)	Shut Down (145)	
12	**Output 12**	Special**	Special**	
13	**Output 13**	Special**	Special**	
14	**Output 14**	Special**	Special**	

* These output designations are pre-assigned by QSI to the features indicated and cannot be changed.

** "Special" means that there is no current feature assigned to this output or that "special" or custom features have been assigned depending on the engine type. Check you locomotive instruction manual to determine if special features have been assigned to these outputs. If no feature is assigned, a Short Air Let-off (10) is usually used as a placeholder. In other words, Outputs that have no standard or special features will activate a Short Air Let-off sound when their assigned Function Keys are pressed.

5.7 CV 56.PI QSI Configuration

Use CV 56 to specify Quantum Configuration settings. Use CV 49 to select among the configuration bytes.

5.7.2 CV 56.4: QSI Throttle Mode (PI = 4)

Default Value: **1**

CV 56.4: QSI Throttle Mode Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**0**	**0**	**0**	**D1**	**D0**

- Use this configuration byte to control Quantum Engine behavior.
- Set data in Bits 0 and 1as follows:

  "0" = Standard Throttle Control.
  "1" = Speed Control.
  "2" = Regulated Throttle Control.

Standard Throttle Control (STC) is the common way to control the power delivered to the model locomotive's motor. Under STC, the "power" to the motor is controlled by the throttle setting (speed step) as specified in a speed table. Under throttle control, the speed of the locomotive will change under load such as climbing grades, pulling a heavy train, binding wheels or gears and poor track conditions. In addition, under throttle control, the speed of the locomotive will vary from changes in track voltage, due to power pack resistance, track resistance, inconsistent or intermittent pickups and changes in motor load current.

Speed Control (SC) uses internal motor control electronics to maintain the same speed regardless of varying load or track voltage conditions. Under speed control, the throttle setting (in 128 speed step mode) sets the engines speed in scale miles per hour equal to the throttle setting[110]. Default resolution is in 1-smph increments. If your throttle is set at 35, the engine will go 35 smph (scale miles per hour) . At 14 or 28 speed steps, you will need to multiple your throttle settings by 9 and 4.5 respectively to determine the locomotive speed.

Under Speed control, CV 2 (V-Start), CV 25 (speed tables), Forward Trim CV 66, Reverse Trim 95, and User Defined Speed Tables CV 67 – CV 94, have no meaning and are ignored.

Note: Although some prototype engines can achieve 128 miles per hour, most were not designed for these speeds. Hence, increasing the speed setting above the fastest speed obtainable by the model will have no effect. In addition, if your command station cannot supply sufficient voltage for your engine to reach its highest speed value, high speed settings will not produce the indicated speed.

Although Speed Control is a big improvement over Standard Throttle Control, it can cause problems when engines are in Consists or used as mid train helps or pushers. The problem occurs because engines can be slightly mismatched in speed. An engine that wants to go 36 mph wants to pull the

110 Because of the way the NMRA has set up speed steps, the actual scale speed is 1 smph less than the speed step (i.e. Speed Step 2 = smph, Speed Step 3 = 2 smph, etc.). Most Command Stations display the throttle setting as 1 less than the speed step (i.e. Speed Step 2 = Throttle Setting 1, Speed Step 3 = Throttle Setting 2, etc.) For those command stations, the throttle setting is equal to scale miles per hour.

engine that is going 35 mph up to speed and will continue to apply more power to do so. The engine going 35 mph wants to slow the engine going 36 mph and continues to reduce power to do. This can cause a huge mismatch in engine power. Under these conditions, something must give which usually means that wheels will slip. If traction is good for all locomotives, the motor power can be very high for some locomotives in the Consist while others are barely working.

Regulated Throttle Control (RTC) combines the best of both Standard Throttle Control and Speed Control. The engine still uses speed control circuitry to maintain the engine's speed but the speed is allowed to increase or decrease slowly in response to loading. Under RTC, if the engine encounters a grade, it does not stop immediately but instead decreases speed slowly in response to the extra loading. If an engine encounters a tight curve or if it has to climb a bad track joint at low speed, it passes through or over these obstacles with little change in speed, just like the prototype. The speed step command in RTC is a requested power setting just like Standard Throttle Control except that the engine acts like it weights thousands of pounds in response to changing speed.

This is not the same as inertia settings where the engine throttle settings vary slowly over time. Under Inertia[111] settings with Standard Throttle Control, the model locomotive would still stop suddenly if it encountered an obstacle since there is no speed control circuitry to maintain its motion.

RTC provides an advantage when operating Consists. Now if engines are slightly mismatched in speed and feel unequal loading, they respond to equalize the loading. Within a very short time, all engines are working together.

RTC uses all CV's pertaining to throttle, including V-Start, V-High, and all QSI pre-programmed speed curves and user definable speed curves.

- All other bits are reserved. The values of these bits are ignored.
- Default is "1", Speed Control.

Example: Select Regulated Throttle Control
1. Write 4 to CV 49.
2. Write 2 to CV 56.

5.7.3 CV 56.10: Speed Step to Scale MPH Scale Factor (PI = 10)

Default Value: **64**

CV 56.10: Speed Step to Scale MPH Scale Factor Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- This byte specifies a Scale Factor used with **Speed Control** to change the amount that smph speed changes as a function of speed steps. The value of this byte is interpreted as N/64, which means N = 64 is equivalent to a Scale Factor of 1.0. Some examples of Speed Control with different scale factors are:

[111] Refer to CV 3, CV 4, CV 23 and CV 24 for Inertia Settings.

CV 56.10	Scale Factor	Slowest possible speed at Speed Step 2	Fastest possible speed at Speed Step 127.
32 (0x20)	0.5	0.5 smph	63 smph
64 (0x40)	1.0	1 smph	126 smph
128 (0x80)	2.0	2 smph	252 smph

Change the Scale Factor when you want a more useful throttle range for an engine under Speed Control. This Scale Factor will have no effect if the engine is under Throttle Control or Regulated Throttle Control.

You can also use the Scale Factor to increase the accuracy of its speed. If your engine actual scale miles per hour are running a little under the speed step settings, you can change the scale factor to slightly increase all speeds. This is also useful when trying to match engines in Consists when all are operating under speed control.

A Scale Factor less than 1.0 is useful when the top speed of the engine is much less than 126 smph. For example, suppose an engine has a top speed of 60 smph. With a Scale Factor of 1.0, all speed steps from 61 through 127 will result in a speed of 60 smph. If the Scale Factor is set to 0.5, then the top speed of 60 smph will correspond to speed steps 121 and above.

A Scale Factor greater than 1.0 is useful when the top speed of the engine is much greater than 126 smph. For example, suppose an engine has a top speed of 200 smph. With a Scale Factor of 1.0 the engine would only go up to 126 smph. If the Scale Factor were set to 2.0, then the top speed of 200 smph would be obtained at speed stepsS 101 and above.

The advantage of a Scale Factor of "1" for command stations with an LCD display is to easily know the engine's speed. If you do not have a visual readout, it is best to set the Scale Factor to provide the best throttle range.

5.7.4 CV 56.128: Reset to Factory Default (PI = 128)

Default Value: **NA**

CV 56.128: Reset to Factory Default Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**0**	**0**	**0**	**0**	**D0**

- Use this configuration byte to reset CV's to factory default values.
- Use the Secondary Index to select a range of CV's. Only those CV's in the selected range will be reset; those CV's outside the range are left unchanged.

SI	Reset Operations:
51	Reset CV 51, System Sound Control
52	Reset CV 52, Individual Sounds
53	Reset CV 53, Function Output Mappings
56	Reset CV 56, QSI Configuration
253	Reset all standard NMRA CV's
254	Reset all QSI CV's
255	Reset all CV's

- Write the QSI Manufacturer Number, 113, to CV 56, to execute the reset operation.
- In Operations Mode you will hear 3 whistle hoots when the reset operation completes.

Note: "Reset all CV's" may not work correctly in Service Mode on some command stations, because the command station may turn off the track power before the operation is complete. If this happens, reset CV's in separate groups or use Ops Mode Programming.

Example: Reset Quantum to original factory defaults (i.e. Reset all CV's)
1. Set CV 49 to 128. 2. Set CV 50 to 255. 3. Set CV 56 to 113.

Example: Reset the Individual Sound Volumes to factory defaults
1. Set CV 49 to 128. 2. CV 50 to 52. 3. Set CV 56 to 113.

5.7.5 CV 56.129: Engine ID Access (PI = 129)

Default Value: **N/A**

CV 56.129: Engine ID Access Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Use this index with CV 56 if your controller will not allow you to program your engine's ID on the main, and programming on the programming track is impossible due to insufficient power from your command station.
- This index is only supported during Operations Mode programming. It will not work during Service Mode programming.
- Use CV 50 to select between Short Address (CV 50 = 1), High Byte Extended Address (CV 50 = 17) and Low Byte Extended Address (CV 50 = 18).
- When CV 56.129.1 is written, the data byte is written to CV 1, and bit 5 of CV 19 is cleared to 0, making the engine's ID the data byte just written, If programming acknowledgement is enabled, you will hear "CV 1 equals <short address>". The data byte must be in the range 1 to 127.
- When CV 56.129.17 is written, the data byte is merely stored in temporary memory. If programming acknowledgement is enabled, you will hear "CV 56 point 129 point 17" but will not hear the value entered. The data byte must be in the range of 0xC0 to 0xE7.

  When CV 56.129.18 is written, the data byte is written to CV 18, making the engine's ID the 2 byte address consisting of the byte written to CV 56.129.17 and the byte written to CV 56.129.18. If programming acknowledgement is enabled, you will hear "CV 17 equals <long address>".

  When programming the Extended Address, you must set CV 56.129.17 before you set CV 56.129.18.

  See the CV17and CV 18 documentation for description of how to compute and enter the MSB (most significant byte) and the LSB (least significant byte) of your Extended Addresses.

Step-by-Step procedure for entering your short (Primary) address in CV 56.129 in Ops Mode.

1) Find out if your command station accepts Decimal, Binary or Hex[112] inputs for CV entries.
2) Set CV 49 to 129.
3) Set CV 50 to 1.
4) Set CV 56 to your short address. Hear the address spoken back.
5) Change CV 29, bit 5 to "0" to allow operation with your new primary address address (see CV 29).

Example: Set your engine's ID to the short address "**23**"
1. Set CV 49 to 129 decimal (10000001, 0x81). 2. Set CV 50 to 1. 3. Set CV 56 to 23 decimal (00010111, 0x17). Hear "CV One equals two, three". 4. Set CV 29 to 2 decimal (00000010, 0x02) for Primary Address Enable and 28/128 Speed Step.
Your engine's short ID is now 23 and ready to operate.

112 Hex and Binary numbers are not shown in the following examples. If you require Hex or Binary, use the conversion table in Appendix V.

Step-by-Step procedure for entering your long in CV 56.129 in Ops Mode.

1. Find out if your command station accepts Decimal, Binary or Hex inputs for CV entries.
2. Determine the MSB and LSB for your Extended Address (See CV 17/18 instructions and example).
3. Set CV 49 to 129.
4. Set CV 50 to 17.
5. Enter CV 17 (Most Significant Byte) as a Decimal, Binary or Hex number required by your command station. You will hear no verbal response.
6. Next enter CV 18 (Least Significant Byte) as a Decimal, Binary or Hex number. Hear the new full address spoken back.
7. Change CV 29, bit 5 to "1" to allow operation with your new Extended Address (see CV 29).

The following table shows examples for some common train numbers. Just follow the procedure above when entering CV17 and CV 18.

ID Number	CV 17 (MSB) (Dec)	CV 18 (LSB) (Dec)	CV 17 (MSB) (Hex)	CV 18 (LSB) (Hex)	CV 17 (MSB) (Binary)	CV 18 (LSB) (Binary)
3985	207	145	CF	91	11001111	10010001
3989	207	149	CF	95	11001111	10010101
3708	206	124	CE	7C	11001110	01111100

Example 1: Set your engine's long address to "**3985**" (Also see example under CV 17 and 18.)

1. Set CV 49 to 129 decimal (10000001, 0x81).
2. Set CV 50 to 17 decimal (00010001, 0x11).
3. Set CV 56 to 207 decimal (11001111, 0xCF), which is the MSB for your address (you will hear no verbal feedback).
4. Set CV 50 to 18 decimal (00010010, 0x12).
5. Set CV 56 to 145 decimal (10010001, 0x91), which is the LSB for your address. Hear "CV one, seven equals three, nine, eight, five".
6. Set CV 29 to 34 decimal (00100010, 0x22) for Extended Address Enable and 28/128 Speed Step.

Your engine's Long ID is now 3985 and ready to operate.

Example 2: Set your engine's long address to "**5344**" (See example under CV 17 and 18.)

1. Set CV 49 to 129 decimal (10000001, 0x81).
2. Set CV 50 to 17 decimal (00010001, 0x11).
3. Set CV 56 to 212 decimal (11010100, 0xD4), which is the MSB for your address (you will hear no verbal feedback).
4. Set CV 50 to 18 decimal (00010010, 0x12).
5. Set CV 56 to 224 decimal (11100000, 0xE0), which is the LSB for your address. Hear "CV one, seven equals five, three, four, four".
6. Set CV 29 to 34 decimal (00100010, 0x22) for Extended Address Enable and 28/128 Speed Step.

Your engine's Long ID is now 5344 and ready to operate.

5.7.6 CV 56.254[113]: About Quantum Decoder (PI = 254)

Use this CV in Service Mode to read back information about your Quantum Decoder. Use CV 50 to select among the data bytes to retrieve.

Default Value: **NA**

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Information from this CV is retrieved in Service Mode as a response to a VERIFY_BYTE or VERIFY_BIT operation.
- To select which byte of information to retrieve, write data to CV 50 as follows:

  "4" = Retrieve Product Model High Byte.
  "5" = Retrieve Product Model Low Byte.
  "8" = Retrieve Firmware Build Number.
  "10" = Retrieve Firmware Build Date.Month (1...12).
  "11" = Retrieve Firmware Build Date.Day (1...31).
  "12" = Retrieve Firmware Build Date.Year (02 = 2002).

- The Firmware Version Number can be retrieved from CV 7, Manufacturer's Version Number.

Example: Retrieve the Product Model

1. Write 254 to CV 49.
2. Write 4 to CV 50.
3. Read back CV 56. Store the returned value in H.
4. Write 5 to CV 50.
5. Read back CV 56. Store the returned value in L.
6. The Product Model = (H * 256) + L.

5.7.7 CV 56.255: Play Build Information (PI = 255)

Default Value: **NA**

CV 56.255: Play Build Information Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**0**	**0**	**0**	**D1**	**D0**

- Information from this CV is delivered as audio verbal output and is restricted to Operations Mode.
- Write data to CV 56 as follows:

113 This CV is not in BLI Hudson software ho300a02.

"0" = Play Product Identifier: you will hear the Product Identification number (e.g. "300" or "400"). This identifies the type of engine and the sounds programmed into the software.
"1" = Play Version; you will hear two sets of numbers separated by the word "point". The first number set is the version number and the second is the build number (e.g. "one point five" means Version 1, Build 5).
"2" = Play Build Date This is the date the software was released. You will hear, three sets of numbers, each separated a pause. The first number set is the month, followed by the day of the month, followed by the year (e.g. "six" pause "one five" pause "zero two" means June 15, 2002).

- Any value other than 0, 1, or 2 will be ignored and there will be no verbal output.

  Note: While the Build Information is playing, all incoming DCC packets are ignored.

Example: Play Version
7. Write 255 to CV 49. 8. Write 1 to CV 56. 9. Hear Version spoken out: for Version 1, Build 6, you would hear "one point six".

5.8 CV 62[114] QSI Control[115]

Use this CV to enable or disable Programming Verbal Acknowledgement.

Default Value: **1**

CV 62: QSI Control Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**0**	**0**	**0**	**0**	**D0**

- Write data to CV 62 as follows:

  "0" = Disable Programming Verbal Acknowledgement

  "1" = Enable Programming Verbal Acknowledgement

Example: To Disable Programming Verbal Acknowledgement
1. Set CV#62 to 0.

Note: Unlike Analog Operation, we do not have a separate and fixed Program Volume since there is no verbal reporting from the Programming Track. Verbal reporting is available during Ops Mode Programming. The overall System Volume sets the volume for these verbal responses. If you cannot hear your Ops Mode verbal responses, you will need to turn up the System Volume during programming.

Note: If you cannot hear verbal responses during Ops Mode programming, check to see if you have activated the Mute feature.

114 This CV does not exist in version ho300a02 (Hudson Steam). For that version use CV#56.0 System Configuration.
115 Write bit operation is supported for CV 62.

5.9 CV 64 CV Numeric Verbal Readout (Verbal CV Inquiry)

Use this CV to hear the value of any CV spoken as a decimal number. This works only in Operations Mode.

Default Value: **NA**

CV 64: Numeric Verbal Readout Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

5.9.1 Standard NMRA CV's

- Write the number of any standard NMRA CV to CV 64.

  Note: While the Verbal Readout is playing, all incoming DCC packets are ignored.

Example: Hear the current setting for CV 2 V-Start.
1. Write 2 to CV 64. 2. Hear the value spoken out: if the value of CV 2 were "32", you would hear "CV two equals three two".

- Writing either 17 or 18 to CV 64 will produce a verbal response indicating the full value of the Extended Address.

5.9.2 QSI CV's

- Determine the Primary Index for the value you want to know. If a Primary Index is required, write the Primary Index number to CV 49.

- Determine the Secondary Index for the value you want to know. If a Secondary Index is required, write the Secondary Index number to CV 50.

- Write the number of the QSI CV to CV 64.

  Note: While the Verbal Readout is playing, all incoming DCC packets are ignored.

Example: Hear the current setting for the bell volume.
1. Write 8 to CV 49. 2. Write 52 to CV 64 3. Hear the bell volume spoken out: if the bell volume were 13, you would hear "CV five two point eight equals one three".

Note: Unlike Analog Operation, we do not have a separate and fixed Program Volume since there is no verbal reporting from the Programming Track. Verbal reporting is available during Ops Mode Programming. The overall System Volume sets the volume for these verbal responses. If you cannot hear your Ops Mode verbal responses, you will need to turn up the System Volume during programming.

Note: If you cannot hear verbal responses during Ops Mode programming, check to see if you have activated the Mute feature.

6.1 CV 66 Forward Trim

Forward Trim specifies a scale factor by which a voltage drive level should be multiplied, when the controller is driving the unit in the Forward Direction.

Default Value: **128**

CV 66: Forward Trim Register

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Trim factor preserves the same curve shape as specified in the speed table but allows a simple multiplying factor to scale it larger or smaller for “trimming” its speed behavior in Forward. This allows making fine adjustments to match the speed of other engines, and to match the to match the engine’s Reverse speed characteristics.
- The multiplying scale factor is n/128 where “n”, the Forward Trim Factor, can be any number entered into CV 66 from 0 to 255.
- If Forward Trim Factor is “0”, then Forward Trim is not implemented.
- If Forward Trim Factor is between 1 and 128 than the voltage applied to the motor is decreased by a multiplying factor that varies from .00775 to .99225.
- If Forward Trim Factor is between 130 and 255 than the voltage applied to the motor is increased by a multiplying factor that varies from 1.0078 to 1.977.
- CV 66 only applies if the speed tables are activated in CV 29 by setting bit 4 =1.

6.2 CV 67-94 User Defined Speed Table

CV 67 – 94 allows the user to specify a speed table that is suitable for the operation his locomotive.

CV 67-94: User Defined Speed Registers

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- The speed table Consists of 28 data points for each of 28 speed steps. A value of 255 means full voltage applied to the motor while a value of 0 means no additional voltage applied to the motor over the V-Start voltage (CV 2).
- If you select 14 speed steps, every other data value is used. If you select 128 speed steps, extra points will be interpolated between each of the 28 data points to provide a smooth curve consisting of 255 points.
- The User Defined Speed Table must be enabled by setting CV 29, bit 5 is set to 1 and CV 25 bit 1 is set to 1.
- Default Values:

CV #	Speed Step	Default Value
CV 67	Speed Step 1	0
CV 68	Speed Step 2	9
CV 69	Speed Step 3	18
CV 70	Speed Step 4	28
CV 71	Speed Step 5	37
CV 72	Speed Step 6	47
CV 73	Speed Step 7	56
CV 74	Speed Step 8	66
CV 75	Speed Step 9	75
CV 76	Speed Step 10	85
CV 77	Speed Step 11	94
CV 78	Speed Step 12	103
CV 79	Speed Step 13	113
CV 80	Speed Step 14	122
CV 81	Speed Step 15	132
CV 82	Speed Step 16	141
CV 83	Speed Step 17	151
CV 84	Speed Step 18	160
CV 85	Speed Step 19	170
CV 86	Speed Step 20	179
CV 87	Speed Step 21	188
CV 88	Speed Step 22	198
CV 89	Speed Step 23	207
CV 90	Speed Step 24	217
CV 91	Speed Step 25	226
CV 92	Speed Step 26	236
CV 93	Speed Step 27	245
CV 94	Speed Step 28	255

6.3 CV 95 Reverse Trim

Reverse Trim specifies a scale factor by which a voltage drive level should be multiplied, when the controller is driving the unit in the Reverse direction.

Default Value: **128**

CV 95: Reverse Trim Registers

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Trim factor preserves the same curve shape as specified in the speed table but allows a simple multiplying factor to scale it larger or smaller for “trimming” its speed behavior in Reverse. This allows making fine adjustments to match the speed of other engines, and to match the to match the engine’s Forward speed characteristics.
- The multiplying scale factor is n/128 where “n”, the Reverse Trim Factor, can be any number entered into CV 66 from 0 to 255.
- If Reverse Trim Factor is “0”, then Reverse Trim is not implemented.
- If Reverse Trim Factor is between 1 and 128 than the voltage applied to the motor is decreased by a multiplying factor that varies from .00775 to .99225.
- If Reverse Trim Factor is between 130 and 255 than the voltage applied to the motor is increased by a multiplying factor that varies from 1.0078 to 1.977.
- CV 95 only applies if the speed tables are activated in CV 29 by setting bit 4 =1.

Appendix I

Sounds Available Under DCC Operation

Steam Sounds

1.1 Automatic Sounds

Steam Chuff: The familiar steam chuff comes from steam exhausted from the steam chest through the smoke stack, which creates a powerful draft to feed the fire. QSI Quantum chuffing produces four distinct chuff sounds per drive wheel set, a rhythm recognized by all steam fans. Our software allows the chuffs to partly overlap to create a more realistic effect; one chuff sounds does not need to terminate before the next one begins.

Articulated Chuff: The Quantum System has two sets of steam chuff sounds that will go gradually in and out of synchrony as the engine moves around the layout. Most prototype articulated locomotives had less weight over the front engine, which resulted in more slippage, causing the two engines to run at slightly different speeds.

Blower or Steam Engine Hiss: The steam from the steam chest venting through the smokestack also draws air through the firebox, keeping the fire healthy. When the engine is sitting still, blowers are often turned on to vent the steam and maintain the draft as well as keep smoke out of the engine cab. The blower sound on Quantum steam engines is a continual steam hiss heard in Neutral.

Air Pumps: Air pumps come on whenever air is used. After a long air release in Neutral, usually signifying the operation of the power reverse, you will hear the pumps start up at maximum rate to replace the air lost from the reservoir. Once the pressure is up, the pumps only turn on occasionally to maintain pressure.

Air Release: Compressed air is used on engines for the braking system and for operating various appliances like the reversing mechanisms common on large steam engines. When a large steam engine comes to a stop, you will hear air released as the power reverse as it is placed in the center Neutral Position.

Brakes: Brake squeal on prototype locomotives is usually most noticeable when the wheels are just about to stop turning. Listen for brake squeal sounds as the Quantum engine slows to a stop.

Steam Pop-off: If there is too much steam in the boiler, special pop-off valves or “safeties” on top of the engine release the excess pressure in a fury of hissing sound. This happens most often when the engine is sitting still, since the fire continues to build up steam that is not used. The Quantum pop-off sound comes on for random lengths, at random times in Neutral.

Steam Water Injector: The water used to make steam is replaced by water injectors at high pressure, to overcome the elevated pressure in the boiler. The sound of rushing water and steam hiss ends with a distinctive valve shut off. This sound comes on for random lengths of time and occurs randomly when the locomotive is in Neutral.

Steam Boiler Blow Down: As water evaporates, minerals and other residues settle to the bottom of the boiler. The fireman opens a valve to vent this material through a large pipe under the side of the cab onto the ground. Quantum’s blow down sound occurs completely at random for undetermined lengths of time when the engine is in Neutral.

1.2 Controllable Sounds

Whistle: The whistle has a distinctive start up followed by a steady whistle sound, then enters an ending sound effect immediately after you stop the whistle signal. Use the whistle Function Key to produce any combination of long or short blasts, and the whistle will react properly. Quantum Sound also includes a short hoot that is shorter and more appropriate than using the normal whistle start up followed by the end effect. You can now produce series of short hoots before starting out or for signaling.

Bell: The bell on steam engines may be either hand pulled or pneumatic depending on the size of year of the locomotive. Pull bells have a distinctive ding-dong sound as the bell moves towards and then away from the observer. With pull bells, you can sometimes hear the squeak of the bushings as the bell swings to and fro. Mechanical bells used a pneumatic clapper and produced a very regular striking pattern. The bells on steam engines are loud, because they are mounted high up on the locomotive. In addition, some bells made during World War II were manufactured from steel rather than brass. You can tell the more harsh sound of the steel bell from the more melodic sound from brass bells. Quantum uses a variety of different bell sounds from hand pulled, pneumatic, steel and brass bell types.

Doppler Run-by: Instantly recognizable, the engine sounds get louder as the train approaches, then immediately drop to a much lower pitch and lower volume as the train passes by. With a little practice you can change the pitch exactly when and where you want.

The QSI patented Doppler Run-by responds to the speed of the engine, so the sounds change more dramatically when the engine is running faster. After the Doppler shift has occurred and the whistle is no longer being blown, the locomotive's volume and sound pitch subtly return back to normal.

Flanges or Extended Brakes: When a train enters a curve, the flanges on the wheels tend to ride up on the inside of the rail and squeal. Recreate this squealing effect by pressing and releasing the Brake Sound Function Key button quickly and repeatedly as necessary. Or for slow stops, use the same function key to produce long protracted squealing brake sounds.

Coupler Sounds: There are two types of coupler sounds in Quantum depending on the type of operation. When coupling up to rolling stock, hear the sound of an engine crashing into and pushing a string of cars. When uncoupling, hear the sound of the lift bar and coupler pin after backing up over a magnet to open the couplers. Hear the knuckle opening and the air brakes parting when moving from the uncoupled cars.

Locomotive Shut Down (Protracted): The air pumps will turn off, followed by the sounds of Pop Off[116] Operating for about ten seconds and finally the Blower hiss will shut off.

Locomotive Start Up (Protracted): The Dynamo will rev up while the Headlight comes on gradually, then the Cab Lights (if available) will turn on, followed by the air pumps, the Steam Blower will turn on and then the locomotive will enter normal operation.

116 Some steam engines may not produce a Pop-Off effect during shut down.

Diesel Sounds

2.1 Automatic Sounds

Diesel Motor Rev: Quantum allows diesel motors to be operated with all eight notches corresponding to the throttle notches used on the prototype. As the throttle is turned up, the diesel motor RPM will increase in fixed increments until the maximum RPM occurs at notch 8. All eight notches are evenly distributed between 0 and the maximum speed step.

Diesel Turbo: QSI diesels have a turbo effect – a very distinctive high whine. Turbo appliances are used to improve the engines horsepower by pumping air into the intake manifold under pressure. The power to activate the turbo motor comes from the engine exhaust pressure. QSI turbo sounds are separate from the diesel motor sound, which allows the turbo effect to lag the motor when the diesel motor is revving down or revving up, just like the prototype.

Cooling Fans: The enormous diesel motors and generators enclosed in the diesel cab need ventilation to stay cool. All diesel locomotives have powerful cooling fans on the roof to draw outside air through louvers on the sides of the locomotive. When cooling fans start, you will also hear the sounds of louvers opening. When cooling fans shut down, you will hear the louvers close.

Air Pumps: When an engine is sitting still, the pumps come on in a steady beat to replace the air lost from the brake air release or any other air operated appliances. Once the pressure is up, the pumps only turn on occasionally to maintain the pressure. Diesel Air Pumps are operated directly from the motor and are quite noticeable when turned on in a non-moving locomotive. In Forward, you will hear the air pumps come on soon after the horn is operated to maintain the air pressure.

Air Release: Compressed air is used on engines for the braking system and operating various appliances.

Brakes: You can hear the brake squeal on prototype locomotives when the engine is moving slowly and can become particularly loud when the wheels are just about to stop turning. Listen at slow speeds for constant brake squeal sound and the final distinctive squealing sounds as the diesel slows to a stop.

Quick Engine Start Up. All diesel engines have a quick start up and shut down effect when an engine is selected. Protracted turn-on effects are available when engines are in Total Shut Down (see Controllable Sounds below).

2.2 Controllable Sounds

Air Horns: The Quantum system uses authentic locomotive sounds whenever possible. The Quantum horn has been recorded from a variety of diesel engines. The number of chimes and the manufacturer usually characterizes air horns. Quantum horns include single chime horns found on early F units, as well as multi-chime horns more common on modern diesels. In addition, all diesels include a special short horn blast. If you blow the horn briefly, you will produce a realistic short horn sound or “hoot”.

Bells: Diesels and Electric locomotives, as well as larger steam engines, usually have pneumatically operated mechanical bells. Diesel bells can be as distinctive as steam bells. They are characterized by their tone, clapper rep rate and their location in the locomotive. In addition, it often takes time to get the clapper up to speed on the prototype or to shut down. When the Quantum bell is turned on in Neutral, you will hear the wheezy sound of the pneumatic clapper starting up before the bell starts to ring and you will hear the bell fade out with soft rings along with the short air release sound associated with turning this appliance off.

Doppler Run-by: The engine sounds get louder as the train approaches, then immediately drop to a much lower pitch and lower volume as the train passes by. With a little practice you can change the pitch exactly when and where you want. Doppler shift is based on the speed of the engine, so the sounds change more dramatically when the engine is running faster. After the Doppler shift has occurred and the horn is no longer being blown, locomotive sounds return to normal.

Flanges or Extended Brakes: When a train enters a curve, the flanges on the wheels tend to ride up on the inside of the rail and squeal. Recreate this squealing effect by pressing and releasing the Brake Sound function key button quickly and repeatedly as necessary. Or for slow stops, use the same function key to produce long protracted squealing brake sounds.

Coupler Sounds: There are two types of coupler sounds in Quantum depending on the type of operation. When coupling up to rolling stock, hear the sound of an engine crashing into and pushing a string of cars. When uncoupling, hear the sound of the lift bar and coupler pin after backing up over a magnet to open the couplers. Hear the knuckle opening and the air brakes parting when moving from the uncoupled cars.

Low Idle: Low Idle is used on prototype engines to maintain a warm and ready locomotive with a minimum of fuel consumption. The special Low Idle sound has a lower base throb and is less harsh than the normal idle.

Locomotive Shut Down (Protracted): The air pumps will turn off, as will the Number Board Lights, followed by the sounds of the cooling fans shutting off, the louvers closing, the diesel motors shutting down and finally, the Engineer's door opening and shutting.

Locomotive Start Up (Protracted): The engineers door will open and close, then the Number Board Lights will turn on, followed by vents opening, the two diesel motors starting up one at a time (if two motor diesel), the air pumps starting up, and the locomotive entering normal operation.

Electric Locomotive Sounds

3.1 Automatic Sounds

Traction Motor Whine: Although both diesels and electric locomotives have traction motors, electric locomotives do not have loud diesel engines drowning out the sounds of the traction motors. You will hear the traction motors when Electrics starts out, especially if the cooling fan volume is turned down to a lower value. Like the prototype, the Quantum traction motor whine pitch increases and decreases with the speed of the engine. It is not affected by track voltage, only the speed.

Cooling Fans: The electric traction motors get quite hot from the enormous current supplied to their circuits. All electric locomotives have powerful cooling fans that can create so much draft the access panel doors cannot be opened when the fans are operating at full power. It is not surprising that these fans can easily be heard in idling and operating engines.

Air Pumps: When an engine is sitting still, the pumps come on in a steady beat to replace the air lost from the brake air release or any other air operated appliances. Once the pressure is up, the pumps only turn on occasionally to maintain the pressure. Air pumps are electrically operated and are quite noticeable if the fans are turned down or off.

Air Release: Compressed air is used on engines for the braking system and operating various appliances.

Brakes: You can hear the brake squeal on prototype locomotives when the engine is moving slowly and can become particularly loud when the wheels are just about to stop turning. Listen at slow speeds for constant brake squeal sound and the final distinctive squealing sounds as the Electric Locomotive slows to a stop.

3.2 Controllable Sounds

Horn: The Quantum system uses authentic locomotive sounds whenever possible. The Quantum horn has been recorded from a prototype single chime GG-1 at a passenger station. All Quantum horns and whistles are engineered by our sound experts to give you the most authentic effects. If you blow the horn briefly, you will produce a realistic short horn sound or “hoot”.

Bell: Diesels and Electric locomotives, as well as larger steam engines, usually have pneumatically operated mechanical bells. With the Quantum Electric Locomotive bell was recorded from the prototype. When the bell is shut off, you will hear the bell fade out along with the short air release sound associated with turning this appliance off.

Doppler Run-by: The engine sounds get louder as the train approaches, then immediately drop to a much lower pitch and lower volume as the train passes by. With a little practice you can change the pitch exactly when and where you want. Doppler shift is based on the speed of the engine, so the sounds change more dramatically when the engine is running faster. After the Doppler shift has occurred and the horn is no longer being blown, locomotive sounds return to normal.

Flanges or Extended Brakes: When a train enters a curve, the flanges on the wheels tend to ride up on the inside of the rail and squeal. Recreate this squealing effect by pressing and releasing the Brake Sound Function Key button quickly and repeatedly as necessary. Or for slow stops, use the same function key to produce long protracted squealing brake sounds.

Coupler: To give you the most authentic coupler sounds, QSI has identified three distinct types of coupler activity. The first is when the coupler is armed where you will hear the clanking sound of the coupler lift bar and coupler pin raising. The next is the coupler opening, with the hiss of the air-lines parting. The third is when the locomotive couples up to its load of cars, and you hear the crash as all the cars bunch together from the impact. DCC only.

Locomotive Shut Down (Protracted): The air pumps will turn off, Cab Lights will turn off, followed by the sounds of the louvers being closed and the Engineer's door being opened and shut.

Locomotive Start Up (Protracted): The engineer's door will open and close, then the Cab Lights will turn on, followed by the air pumps, directional lights, vents opening and then the locomotive will enter normal operation.

Appendix II

Recommended DCC Command Stations

Command Station	Recommended	Will Support Service Mode w/ Quantum	Comments[117]
NCE ™	Yes	Yes (See Comments)	Horn and Bell buttons are available but bell button assigned to F3 (see QSI CV 37 example). Newer NCE apparently support programming track but older command stations do not. Programming on the main is easy and straightforward. NCE currently only supports F0-F8 Function Keys.
Wangrow ™	Yes	No	Horn and Bell buttons are available but bell button assigned to F3 (see QSI CV 37 example). No Service Mode but programming on the main is easy and straightforward.
Digitrax ™	Yes	Yes	F0 = Lights, F1 = Bell, F2 = Horn. DT300 will operate in Service mode but will not read back value. Long address is automated with the DT300 and DT400 throttles, which properly writes CVs 18, 17, and 29. Click to the 4-digit mode, set address, and answer yes to the enable 4 digit address prompt. It also automatically resets CV29 if you return to 2-digit address. An exception is the obsolete DT100 throttle, which will only program Quantum in Ops Mode. Use QSI CV 56.129 to program either CV 1 or CV 17/18. Note that the DT100 only programs in hex, except for addresses, which are in decimal. This makes it easy to enter address in Ops mode. We have qualified the following Digitrax systems with Quantum (all support F0-F12): Super Chief with DT400 Zephyr with DT400 DCS100 with DT400 Chief with DT400 See Digitrax for more information on QSI compatibility at www.digitrax.com.
MRC ™	Yes	No	MRC does not provide a separate programming function. All programming is done in Ops mode with no acknowledgement feedback. A resistor is included to limit current for a Programming Track, which may limit the current below the allowable level for Quantum programming. For the Quantum system, the resistor may be left out. For other decodes, the user should follow the MRC instructions.
Lenz ™ LZ100, LV200, LZV100	Yes	Yes (See Comments)	F0 = Lights, F1 = Bell, F2 = Horn. Lenz will program in Service mode providing that a suitable resistor is added in series to the Programming Track (LV100 requires 20 ohms and LV200 requires 10 ohms). Note that CV 1, 17 and 18 cannot be programmed on the main in the standard way (see QSI CV 56.29 for alternative way to program ID

117 Many comments and opinions regarding operation with different command stations are the result of user's letters to QSI or comments on various railroad web forums. QSI is not responsible for the accuracy of these comments, which are included here only as a starting point for the customer to verify to his own satisfaction the compatibility of these products for use with the QSI Quantum System.

			numbers). Newer Lens does support F0-F12 Function Keys.
Atlas ™	Yes	Yes (See Comments)	Early models of the Atlas command station had some problems with programming. Reports from Atlas on their recent versions indicate no problems.
CVP ™	Yes	Yes	EZ DCC

Appendix III

Troubleshooting

Operations Mode

My headlight does not come on when I start my engine out but mysteriously comes on whenever I blow the horn or turn on the bell. Also, if I try to turn on the headlight, it requires two pressings for the F0 or FL key.	Pressing the horn or toggling the bell will cause your command station to send out a Function Group One command, which contains the lighting information. Not all command stations automatically send this information unless FL, F1, F2, F3 or F4 is pressed. Regarding turning on the lighting with the F0 key, the state for the light may already be on at the base station but not sent. When you press the F0 key, it toggles the lights to be off and sends that command. It takes a second press of the F0 key to send another command to turn on the light.
My brakes, bell, air release, or other sounds comes on sometimes for no apparent reason while operating my locomotive.	See above. Some functions may already be turned on but not sent. When you request any function, the entire function group that contains that function will be sent and this may trigger other features already enabled within that group. Hence, you might request the light be turned on and hear squealing brakes or the bell turn on or off. If your base station display shows the toggled condition for each of the function keys, you can determine which feature will turn or off when a Function Group One or a Function Group Two is sent.
My engine makes no sounds except an air release when power is applied and will not operate.	You have your engine in Shut Down. Double press the F6 Start-Up key to start you locomotive.
My engine runs but makes no sounds.	Your have Mute on or have turned down your System Volume or individual feature sound volumes. You may have a broken wire to the speakers or a faulty speaker.
When I turn up my throttle to higher values, the engine does not speed up but instead, the directional lighting comes on.	Your engine is set for 14 speed steps but your base station is set for 28 or 128.
When I turn on my lighting system with the F0 Key, the engine speeds up at low throttle settings.	Your engine is set for 28 or 128 speed steps but your base station is set for 14.
Sometimes my locomotive slows down when I blow the whistle or horn, particularly at high volume levels.	The Quantum Sound system takes additional power to blow the whistle or horn and this loads your power pack. This can lower the voltage on the track and your engine will slow down. Purchase a power pack with good line regulation to prevent this problem.
In Speed Control Mode, there are no speed changes above a certain throttle settings.	The top speed of your engine is dependent on the gear ratio, load on the engine and the available voltage applied to the track. Asking the engine to go faster results in no change. (See CV 56.10 for Scale Factor to change throttle range).
Under speed control, I do not get 1 scale mile per hour (smph); I get a larger number about 5 to 10 smph.	Check you speed step setting on your base station. To get 1 smph you need to be in 128 speed steps.
In Throttle Control Mode, there are no speed changes above a certain throttle settings.	Try a different speed curve or define you own to provide full range of throttle motion.

Service Mode Operation

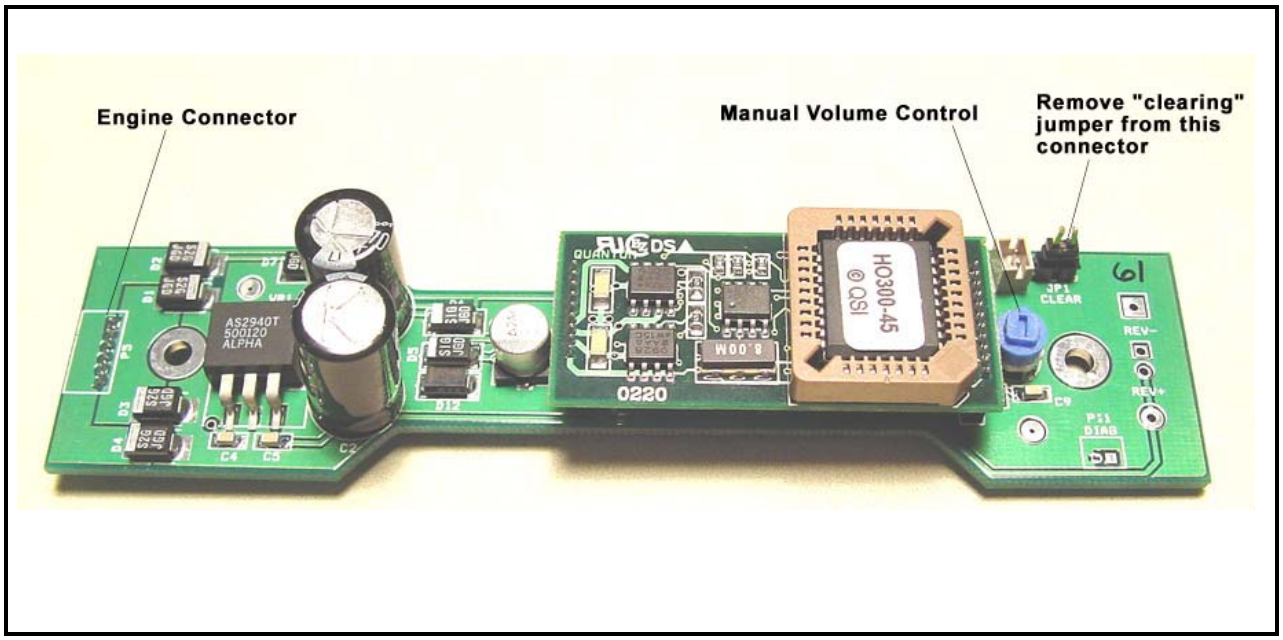
My Quantum equipped engine will not program in Service Mode with my command station.	Some command stations do not provide sufficient current to power the Quantum system. Use Ops Mode programming.
When I try to do a complete reset of all CV's using CV 56.128.255 in Program Mode, not all of the CV reset to factory values.	Resetting all CV's takes considerable time. Some command stations only allow a fixed short amount time to power the programming track after a command is sent. When you ask for a complete reset, not all of the CV's will be reset if the power shuts down part way through the procedure. We recommend doing a full reset in Ops mode. Or you can do individual reset operations such as "all NMRA CV reset", and "all QSI CV reset", etc. until you have all groups of CV's reset to factory defaults.

Appendix IIIa

Using the Quantum Reset Jumper to Return your Engine to Factory Default Values:

In case your Quantum Sound and Train Control System misbehaves and simply turning the power off from 5 to 15 seconds does not return it to normal operation, you can reset our engine to original factory settings. The jumper is located on the bottom board as shown in the diagram below.

- Turn off the main track power.
- Remove the tender body or access panel to reveal the circuit board. If it is a plastic tender, there are no screws; it is a press fit to the chassis. Die cast tenders will have retaining screws under the chassis.
- Locate the black “clearing” jumper (see below) and remove by pulling it up.
- Reapply main track power, the horn and bell will sound after a few seconds.
- Turn main track power off and reinstall jumper, and tender cab or access panel. The locomotive has now been returned to original factory settings including all Analog and DCC settings.



Note: Do not use Service Mode to perform the reset operation using the reset jumper. Always use Opts Mode.

Appendix IV

Different types of Feature Operation from Function Commands

QSI will often use the same function to control different effects depending on whether the system is in Neutral or a motive state (Forward or Reverse). This allows us to increase the number of features available to DCC functions over the NRMA specified maximum of 14 (F0(f), F0(r), F1-F12). In addition, many QSI features respond to the Function outputs in different ways. It is the purpose of this section to describe how our different features respond to functions and help you get the most out of operating your locomotives. Also, if you intend to make your own output assignments for features using CV 53, it is important to know what kinds of features are compatible for common outputs.

Classification of DCC Signal Types

There is only one kind of function signal for DCC; either a function is “on” and transmits “1’s” every time the command is sent or “off” and transmits “0’s” every time the command is sent. However, how these features respond to these function outputs can be quite different.

Classification of Feature Types

State Features: We designate features that are on when a function signal is “1’s” and off when “0’s” as a State Feature. With State Features, the operator knows the state of the feature by knowing the status of the function output signal on his handheld throttle or command station. For instance, the Directional Lighting System is on when the FL output is sending out “1’s” and turned off when the lighting output is sending “0’s”.

The Horn is also a state feature, which we assign to F2 as its factory default function key. When the F2 key is activated, then “1’s” are sent and the horn sound comes on. The Horn will continue to blow until the F2 key is pressed again to produce “0’s” whereupon the horn sound feature will turn off. When the F2 key is pressed and released a second time, “0’s” are sent and the Horn turns off and stays off.

Some command stations have a horn button that can be pressed to operate the horn effect. The Horn sounds when the horn button is pressed and then turns off when the horn button is released. However, the horn button is a custom feature on those DCC controllers and does not act like a normal F2 function key.

When the F2 key is pressed and released, “1’s” are sent resulting in a constantly blowing Horn. However, the horn button is designed to generate “1’s” whenever the horn button is pressed and held down. When the horn button is released, the horn signal returns to “0’s”. Hence, while the Horn seems like a momentary effect when using the horn button, it is actually a State Feature.

Other State Features on Quantum include, Bell, Mute and Directional Lighting. While State Features can be affected by the directional state or other states in the locomotive, the features are nevertheless “on” or enabled all the time.

One advantage of State Features is that all locomotives in a Consist receive the same known command. For instance, if the horn feature is turned on, all locomotives blow their horns or if the mute feature is activated, all engines will mute their sounds or if directional lighting is turned off, all engines shut down their lighting.

While State Feature clear on or off state that corresponds to their associated function state, there are a number of reasons a feature may not have a known or continuous “on” or “off” status.

Toggled State Features: Toggled State Features turn on when the status of a function output changes. Toggled State Features operate only when a function output changes from “1’s” to “0’s” or from “0’s” to “1’s”. Examples of Toggled State Features are Hazard Lights, Cooling Fans, and Blower Hiss.

Because changing the function output condition can toggle the feature, the operator does not know the status of the feature based on the condition of the output signal at the DCC controller. For instance, a function changing from 1's to 0's may trigger a feature on or off depending on its starting condition. However, if the status was known before the feature was triggered, a command station could keep track of the feature status by keeping track of the number of toggles. This is problematic since the receiver may not have received the signal due to some interference, which would result in the base station having the opposite condition as the locomotive.

Toggled State Features are used when the feature has two states and it is unclear which state the feature is in.

Triggered Features: Unlike toggled features that change between two states, triggered features return to their original status after they are activated, usually over a time interval. Examples of Triggered Features are Doppler, Coupler Crash, Brake Squeal, and Air Let-offs. Some triggered features, like a Short Air Let-off, operate each time they receive a trigger while other features like the coupler trigger must be armed or enabled before they can be triggered. Other triggered features depend on conditions of the engine that are not know at the controller, such as the status of the triggered feature (i.e. is it still operating or has it quit?), or the state of the engine (moving, in Neutral, armed, laboring, etc.). In addition, when a triggered feature is finished, the function output has changed to the opposite value and is ready for the next trigger. Because of these issues, the status of a triggered feature at the controller is not known.

The following is list of different kinds of Triggered Features:

Simple Triggered Feature: These are single event features that simply respond to a change in the function output. These include Air Let-offs, Brake Squeal in Forward and Reverse, Doppler shift and Neutral Events like Pop-off, Blow Down, etc. All Simple Triggered Features are a finite event. The system returns to its original state after the Trigger Feature event is finished.

Progressive Features: A Progressive Feature does two things when the function key is pressed: 1) it activates the currently enabled feature and 2) it enables the next feature. The next time the function key is pressed, it actives the newly enabled feature and enables the next feature. After no more features can be enabled, pressing the function key has no effect. An example of a Progressive Feature is engine Shut Down. There are three stages to the shut down operation. Pressing the F9 Key on an engine in Neutral will put it in Disconnect; a next pressing of the F9 Key will put it in Low Idle; a next pressing of the F9 Key will cause it to enter Total Shut Down. At this point, pressing the F9 key will have no effect.

Resettable Features: These features reset to a known state when some condition occurs. As we have specified it, Dynamic Brakes is a Resettable Toggled Feature. A locomotive can be toggled to engage Dynamic Brakes or turn them off by changing the condition of output #7. No matter what status the engine is in, when an engine enters Neutral, the dynamic brakes are reset. While dynamic brakes can be turned on in Neutral, it is always reset whenever entering or leaving Neutral. Resettable Toggled Features last indefinitely unless there is some signal or state change to reset the feature. The most common Resettable Toggled Features reset when the engine directional state is changed or when the power is turned off and back on.

Armed Features: Armed or enabled features are set to react to a second signal or condition to active the feature. An example is coupler arming which later generates a coupler opening sound effect when the Function Key is pressed a second time. Armed Features are unique in that they can supplant a specified feature's reaction to a function signal until the features is triggered. The Coupler Fire feature is an example of this since this feature will not occur until the coupler sound features is armed.

Automatic Features or State Dependent Features: Automatic Features change their state in response to on-board inputs. The most common are features that change in response to the

directional state of the locomotive. For instance, Cab Lights may come on in Neutral and go off five seconds after entering Forward or Reverse.

Set Features: These are features that respond to a change in function signal by setting the feature to some condition or value. Repeated changes in the function signal have no effect on the setting of the feature. With Set Features, there needs to be an additional method to clear the setting either through another Function Key, or during power up, or timeout condition or other encountered circumstance. An example of a Set Feature is Engine Start Up. Once Start Up has been activated with the F6 key, doing another Start Up with the F6 has no effect in starting the engine, until the engine has been shut down using the F9 Key.

Another type of feature that should be mentioned are take control features although they do not affect the classification with respect to how they can be mixed and matched in different outputs.

Take Control Features: These are automatic features that can also respond to function key signals. Once the function signal is received, the automatic operation is disabled and the "Take Control" operation is enabled. That feature is then under complete control of the Function Key output signal. For instance, Automatic Cab Lights can be toggle to its on or off state by a function key signal and there after it looses its automatic operation and now only responds to its function key signal.

With "Take Control" features, there needs to be a way to clear the "Take Control" mode to return the feature to automatic operation. Quantum returns the Take Control feature back to automatic operation when power is turned off and reapplied or if the F6 Start Up Key is pressed at any time.

QSI has specified how each feature will be operated. For most purposes, we confine our types to State, Toggle, Trigger. The table below lists all QSI features and Feature Type.

Feature ID	Feature	Feature Type	Allowed States	Feature ID	Feature	Feature Type	Allowed States
0	Null Output		All	**96**	Headlight	State	All
1	Whistle	State	All	**97**	Reverse Light	State	All
3	Bell	State	All	**101**	Cab Lights	State	All
5	Dynamic Brakes	Toggle	All	**102**	Mars Light	State	All
8	Blower Hiss/Diesel Cooling Fans	Toggle	All	**105**	Number Board Lights	State	All
9	Long Air Let-off	Trigger	All	**144**	Start Up	Trigger	NFF/NFR
10	Short Air Let-off	Trigger	All	**145**	Shut Down	Trigger	NFF/NFR
12	Pop-off	Trigger	NFF/NFR	**177**	Cruise Control	Toggle	FWD/REV
13	Blow Down	Trigger	NFF/NFR	**211**	Coupler Effect	Trigger	All
14	Injector	Trigger	NFF/NFR	**215**	Squealing Brakes	Trigger	FWD/REV
64	Mute	State	All	**217**	Pumps	Toggle	NFF/NFR
65	Doppler Shift	Trigger	FWD/REV				

Rules for Assigning Different Kinds of Features to Outputs

QSI has specified how each feature will be operated. For most purposes, we confine our types to State, Toggle, and Trigger and do not draw distinctions between the various Trigger or Toggle types.

There are a couple of rules regarding DCC function operated features.

Rule 1: Sometimes a Toggled or Triggered feature is assigned to an output to operate only in one directional state, and another feature is assigned to the other directional state. If the function is changed in one directional state, it does not affect the Toggled or Triggered Feature when the directional state is then changed. For instance, if we had the Doppler assigned to output 5 in Forward/Reverse and Bell to the same output in Neutral, and Doppler was operate for the moving

engine and then the engine was stopped in Neutral, the Bell feature would not Toggle. **To toggle or trigger a feature, or change the state of a State Feature the locomotive must be in the directional state where the feature is active.**

Rule 2: If a State Features is assigned to an output in one directional state and a Toggled, Triggered or another State Feature is assigned to the other directional state, there can be conflicts and surprises. The problem is that if a feature is changed in one directional state and then the directional state is changed where the State Feature is active, the State Feature will change to match the changed Function Output. For instance, if we assigned to output 10, Mute (State Feature) in Forward/Reverse and Bell (Toggled Feature) in Neutral, we would have a problem. If the Bell was toggle in Forward, when we returned to Neutral, the sounds would go silent. If we returned to Forward, the engine would still be Muted and you could not get it out of Mute until you returned to Neutral. **Only Toggled, Triggered or Set Features should be mixed when assigning different features to Neutral and Forward/Reverse.**

The graph below shows which Features types can be mixed for the same function output.

	State	**Toggled**	**Triggered**
State	Not Allowed	Not Allowed	Not Allowed
Toggled	Not Allowed	Allowed	Allowed
Triggered	Not Allowed	Allowed	Allowed

The following table shows our default feature assignments with feature control type indicated in blue in parenthesis.

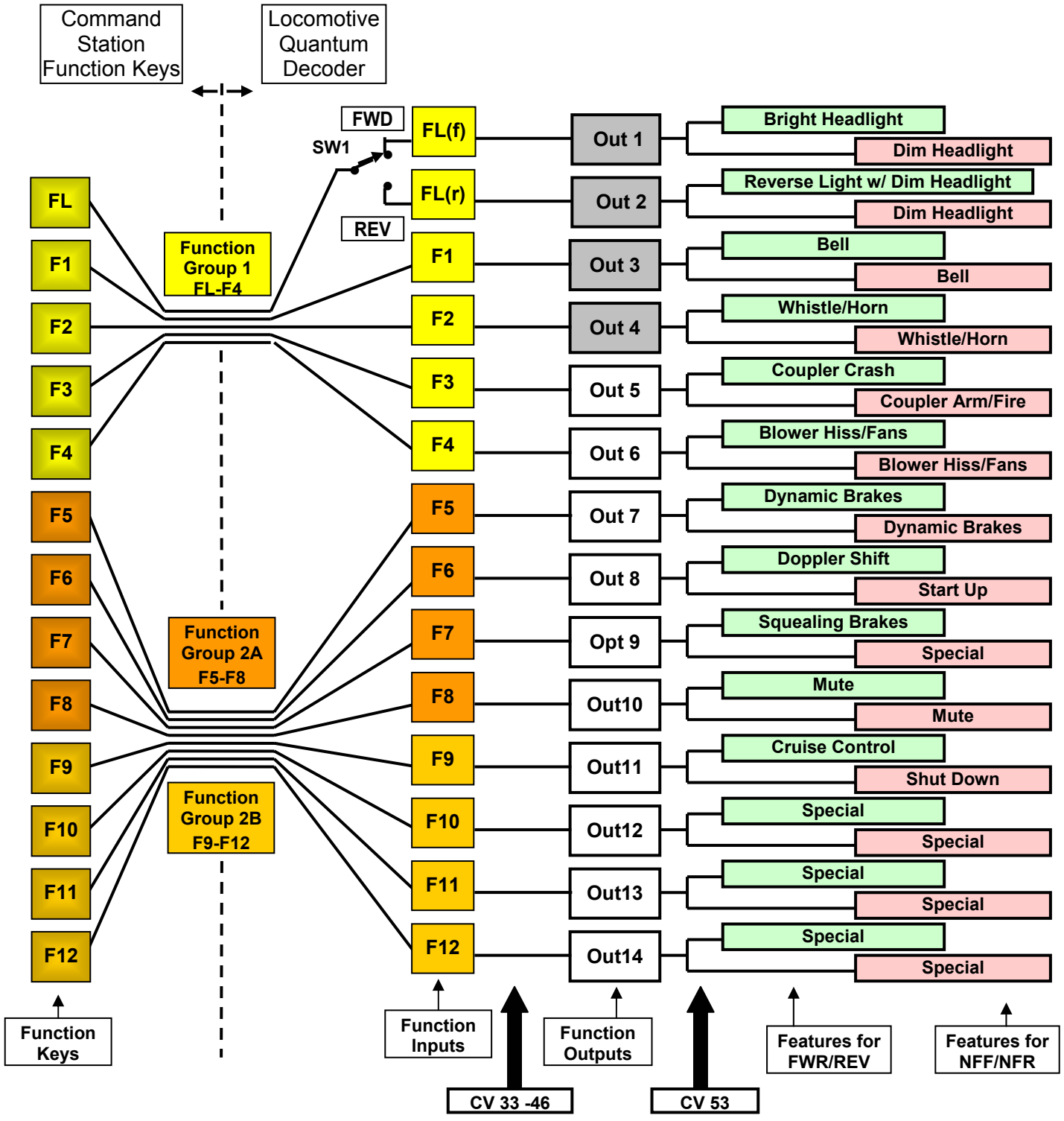
Default F-Key	**FWD/REV**	**NFF/NFR**
FL	Headlight Directional Lighting (State)	Headlight Directional Lighting (State)
FL	Reverse Light Directional Lighting (State)	Reverse Light Directional Lighting (State)
F1	Bell (State)	Bell (State)
F2	Whistle/Horn (State)	Whistle/Horn (State)
F3	Coupler Crash-Coupler Fire (Trigger)	Coupler Arm (Enable) or Coupler Fire (Trigger)
F4	Steam Blower Hiss/ (Toggle) Diesel Fans and Louvers/ Electric Cooling Fans	Steam Blower Hiss (Toggle) Diesel Fans and Louvers/ Electric Cooling Fans
F5	Dynamic Brakes (Toggle)	Dynamic Brakes (Toggle)
F6	Doppler Shift (Trigger)	Engine Start Up (Double Click Trigger)
F7	Brake Squeal-Flanges (Trigger)	Reserved
F8	Sound Mute (State)	Sound Mute (State)
F9	Cruise Control (Toggle)	Shut Down[118]: Disconnect-Low Idle set-Total Shut Down (Double Click Trigger)
F10	Reserved	Reserved
F11	Reserved	Reserved
F12	Hazard Light/Cab Light (Toggle)	Hazard Light/Cab Light (Toggle)

118 There are three stages to Shut Down. To operate Shut down, you will need to double click the F9 key for each stage.

Appendix V

Interaction of Function Keys, Function Groups, Function Inputs and Outputs and Feature Assignments

The diagram below shows graphically how the Function Keys, Function Groups, Function Inputs, and Outputs are configured and how they interact.



Function Keys and Function Groups: The thirteen colored squares shown on the left side of the dotted vertical line, designated FL, and F1 through F12 represent push buttons or Function Keys located at the Command Station or on the DCC walk-around throttle.

The Function Keys are shown color-coded depending on which Function Group they use to transmit their bit settings to the locomotive's decoder. Keys FL through F4 (Yellow) use Function Group 1 to send information to the locomotive. Keys F5 through F8 (Orange) and Keys F8 through F12 (Gold) both use Function Group 2 but not at the same time. Bit 5 in Function Group 2 specifies whether this Function Group applies to F5 – F8 or F8 - F12. Each Function Group command contains 4 or 5 bit settings for the Function Inputs.

The locomotive's decoder, shown to the right of the vertical dotted line, receives Function Group commands.

Function Inputs and Outputs: Each Function Input is shown connected to a corresponding Function Output designed by the squares Out 1 through Out 14.

The boxed labeled "CV's 33-46" with black arrow pointing up indicates that these CV's determines which Function Input controls which desired Function Output. Function Inputs cannot be connected to any Function Output. For instance, Function Inputs FL through F3 can only be connected to Outputs 1 through 8 (see CV 33-37). The diagram shows the default connections between Function Inputs and Outputs. In the description of each CV 33-42, the default Output is shown with gray background [as an example, see CV 41 on page 61, which shows the Output locations for F7. The default is Output 7 (bit 5) and is shown with gray fill, which corresponds to Output 9].

The FL Function Key is special since it connects to two different Function Inputs depending on the locomotive's direction setting. This is shown schematically in the diagram where the position of the single-pole double-throw switch, SW1, is determined by the engine's direction (FWD or REV). In Forward (or Neutral from Forward), the switch, SW1 is in the top position which connects the FL Key to the FL(f) input. When the engine is in Reverse (or Neutral from Reverse), the SW1 would be in the bottom position, which connects the FL(f) Key to the FL(r) Input.

The default Outputs for FL(f) and FL(r) are Out 1 and 2 respectively. If the locomotive is in Forward or Neutral from Forward, the FL key will affect the features connected to Out 1. If the locomotive is in Reverse or Neutral from Reverse, the FL key will affect the features connected to Opt 2. Function Outputs 1 and 2 are generally used for directional lighting effects and are usually assigned to the FL(f) and FL(r) Inputs respectively, which are the Quantum default settings.

Although each Function Input is shown connected to only one Output, there is no restriction in connecting an Input to more than one Output. This can be useful if it is desired to control two our more features at the same time. For instance, it might be desired to have the Bell turn on at the same time the Reverse Light is turned on by the FL(r) Key or to have Ditch Lights operate at the same time the Horn is activated.

Since there are only fourteen Inputs and fourteen Outputs, if more than one Output is connected to an Input, there may be unused Inputs.

Of course, the unused Inputs could be connected to other Outputs that are already assigned but this is not recommended. Because there is more than one Input controlling an Output, it is unclear which Input has control. The software is written such that the common Output would be on if any of its Inputs are on. In other words, the Output is off if and only if all connected Inputs are off[119].

Outputs that are not connected to a Function Input are always off.

[119] In other words, the Inputs to a common Output are OR'ed.

Outputs and Features: The box labeled “CV 53” with black arrow pointing up indicates that this CV determines which feature is connected to which Output. CV 53 also allows different features or accessories to be assigned to the Neutral States (locomotive stopped) or to a Motive States (Forward or Reverse). Features shown in the green boxes are assigned to the Motive States and features shown in the red boxes are assigned to the Neutral States. The diagram shows the default Quantum features assigned to the different Function Outputs for Motive and Neutral states.

Outputs 1-4 (with gray fill) indicate these Outputs that have fixed features assigned. This includes the Directional Lighting, Bell, and Whistle/Horn. You can assign these features to different Outputs other than 1-4, but these features will produce no effect when these outputs are activated.

Effects of Outputs on Different Types of Features: Features Types include State, Toggled and Triggered, which are described in Appendix IV. The following describes how these different types of features are affected by changing from a Motive State (FWD/REV) to a Neutral State (NFF/NFR) or when direction is changed between Forward and Reverse.

State Features assigned to Neutral States or Motive States can be affected by the current Output value when a Motive State is entered or when a Neutral State is entered. State features such as the Bell, will react immediately to the current condition of its Output. For instance, if the Bell where only assigned to Output 3 in Neutral but not in FWD/REV, and Output 3 was on, then the Bell would turn on when Neutral was entered and turn off when FWD/REV was entered. The Bell, of course, could also be turned on and off in Neutral by affecting Output 3 with its corresponding Function Key.

Toggle and Triggered Features, <u>will not be affected</u> when changing from a Motive State to a Neutral State or from a Neutral State to a Motive State, regardless of its current Output value. Toggled and Triggered Features only respond to changes in their Outputs. If an Output is already on or off when the engine leaves or enters Neutral, its assigned features will not toggle or trigger, even if the features are only assigned to a Neutral State (NFF/NFR) or only assigned to a Motive State (FWD/REV). For instance, if the Blower/Fans Feature were only assigned to Neutral in Output 6, it would not toggle on or off when the locomotive enters or leaves Neutral regardless of the value of Output 6. The Blower/Fans could only be affected by changing Output 6, in Neutral, using its corresponding Function Key.

Any type of Feature, State, Toggled or Triggered, assigned to Outputs that are controlled by FL(f) or FL(r), can be affected by changing direction from Forward to Reverse or from Reverse to Forward. In this case, if the Outputs are currently on, changing direction will cause the Outputs to change their values, which will affect Toggled and Triggered Features, as well as State Features; and the features will be affected regardless of whether they are assigned to a Neutral or Motive States. The FL Key, like any Function Key, will affect any Feature type assigned to their outputs.

As an example consider that Output 6 is exclusively assigned to FL(f) and that the Coupler (Triggered) feature in Neutral is exclusively assigned to Output 6. If Output 6 is on, and the engine is sitting in Neutral from Forward and the direction is changed, the Coupler will arm; if direction is changed again, the coupler will fire. This is because Output 6 is changing its value each time the direction is changed which will affect a triggered feature. The Coupler can also be armed or fired by changing FL(f) in Neutral from Forward using the FL Key. If Output 6 had been off when entering Neutral, the Coupler feature would not be affected by changing direction.

If the engine had been in Neutral from Reverse, changing direction would have no affect on the Coupler nor would the FL Key have any affect.

If a State Feature, such as Cab Lights, were exclusively assigned to Neutral instead of the Coupler effect, then if Output 6 were on, the Cab Lights would turn on in Neutral from Forward and turn off when entering Neutral from Reverse as the direction was changed.

Operating features assigned to a Neutral State and a Motive State for Outputs connected to FL(f) and FL(r) can become very confusing. We recommend that you use the default Output settings for FL(f) and FL(r) (CV33-34) which will dedicate these functions to directional lighting.

Appendix VI

Recommended Reading:

Ames, S., Friberg, R., and Loizewaux, E. *Digital Command Control*. Alt om Hobby 1998

Ireland, Zana (Editor In Chief), *The Digitrax Big Book of DCC*, Digitrax, 1999.

Appendix VII

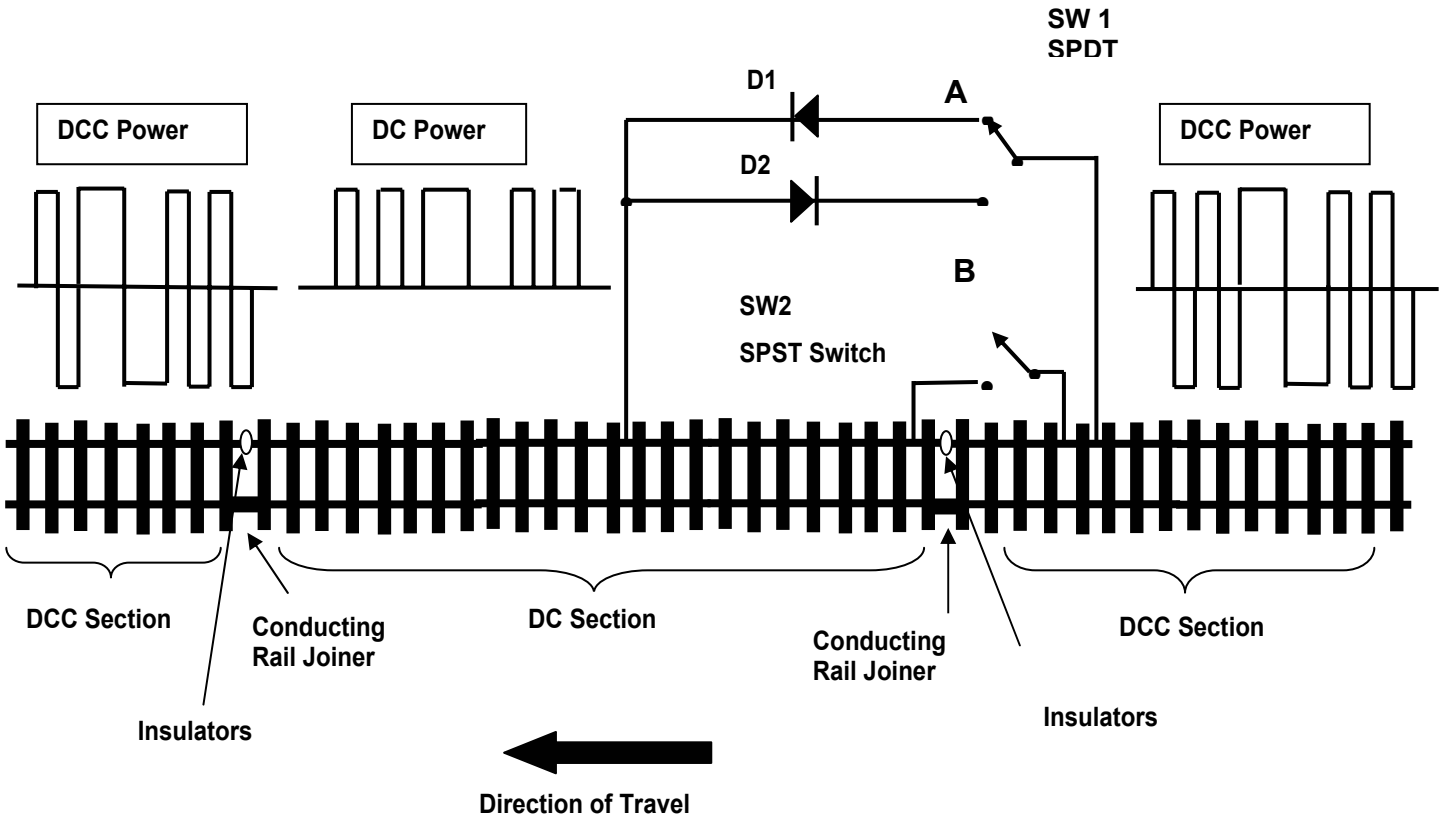
Application Notes:

1. Using DC Power Conversion for Block Signal Control

CV 29, Bit 2 =1. Applications for DC Power Conversion: Block Signal Control

DCC Power Conversion as described under CV 29, bit 2, was implement into Quantum in a way that allows for simple block signal control. Using DC power conversion allows the operator to enable a red signal light to stop a train smoothly, using its internal momentum settings, without having to use the throttle. If Bit 2=1 for CV 29, a DCC controlled engine will automatically engage DC Power Conversion when it enters a section of track what is powered with standard DC. If the polarity would normally power the analog engine in the direction it is going when it enters the DC section, the engine will continue through the DC block at the same speed. If the polarity would normally power the engine in the Reverse direction, the engine will smoothly come to a stop in the DC section.

The diagram below shows a DCC section connected to a DC section of track. The DC section is powered from the DCC power signal rather than from a separate power supply or battery. For this application, it is only necessary to insulate the one rail as shown by the two insulated rail joiners at either end of the DC section; the other rail is electrically connected to the DCC section by conductive rail joiners.



When switch 2 (SW 2) is open, the DCC signal is half-wave rectified by diodes D1 or D2 to produce a positive DC signal to the DC section when Switch 1 is at position A or a negative DC signal when Switch 1 is at position B. If Switch 2 is closed, the DCC signal is connected directly to the DC section and D1 and D2 have no effect on applying DC power to the DC section.

If DC power conversion is enabled in CV 29 (bit 2 = 1) and SW 2 is open, the polarity on the DC section can be used to stop the Quantum equipped train or let it precede, depending on the position of SW 1. If the engine is entering the DC section from the right, and SW 1 is set to A, the engine will continue at its current speed setting through the DC section. The engine, of course, will not respond to DCC signals until it leaves the DC section and reenters the DCC powered section at the far left. On the other hand, if SW 1 is set to B, the polarity on the DC section is opposite the engine's direction and the engine will slow to a stop at its DCC momentum setting. If the polarity is reversed again to be consistent with the engines direction, the engine will accelerate at its current DCC momentum setting to leave the DC section. Alternately, SW 2 could have been closed to cause DCC signals to be applied to the stopped engine, which would also have caused the engine to accelerate at its current DCC momentum value to its DCC speed setting.

Since the DC portion is powered from the DCC signal, there are no short circuit problems between the DCC powered section and the DC section as the engine wheels pass over the track insulators. In addition, since the Quantum engine is equipped with large filter capacitors, the reduced power of half-wave rectification will not affect the power available to operate the engine so there is minimal slow down effect. Also, if the train is made up of a series of Quantum engines in a Consist, and the polarity is set to stop the train, each engine in turn will couple the DCC signal through to the DC section until the last engine has passed over the boundary; only then will the entire Consist come to a stop.

The above diagram is simplified to make it easy to describe the basic concept. Switch 1 can be a relay powered by a train detector on the next block to do automatic train control. In addition, Switch 1 could have extra contracts to control red and green signals for the actual block signal. Switch 2 could also be part of relay network for all DC blocks to disable or enable block signal operation.

D1 and D2 should be rated at 2 amps minimum and have a breakdown voltage of 30 volts or more.

Appendix VIII

Binary, Hexadecimal, Decimal Conversions

Decimal	Hex	Binary	Decimal	Hex	Binary	Decimal	Hex	Binary	Decimal	Hex	Binary
0	00	00000000	64	40	01000000	128	80	10000000	192	C0	11000000
1	01	00000001	65	41	01000001	129	81	10000001	193	C1	11000001
2	02	00000010	66	42	01000010	130	82	10000010	194	C2	11000010
3	03	00000011	67	43	01000011	131	83	10000011	195	C3	11000011
4	04	00000100	68	44	01000100	132	84	10000100	196	C4	11000100
5	05	00000101	69	45	01000101	133	85	10000101	197	C5	11000101
6	06	00000110	70	46	01000110	134	86	10000110	198	C6	11000110
7	07	00000111	71	47	01000111	135	87	10000111	199	C7	11000111
8	08	00001000	72	48	01001000	136	88	10001000	200	C8	11001000
9	09	00001001	73	49	01001001	137	89	10001001	201	C9	11001001
10	0A	00001010	74	4A	01001010	138	8A	10001010	202	CA	11001010
11	0B	00001011	75	4B	01001011	139	8B	10001011	203	CB	11001011
12	0C	00001100	76	4C	01001100	140	8C	10001100	204	CC	11001100
13	0D	00001101	77	4D	01001101	141	8D	10001101	205	CD	11001101
14	0E	00001110	78	4E	01001110	142	8E	10001110	206	CE	11001110
15	0F	00001111	79	4F	01001111	143	8F	10001111	207	CF	11001111
16	10	00010000	80	50	01010000	144	90	10010000	208	D0	11010000
17	11	00010001	81	51	01010001	145	91	10010001	209	D1	11010001
18	12	00010010	82	52	01010010	146	92	10010010	210	D2	11010010
19	13	00010011	83	53	01010011	147	93	10010011	211	D3	11010011
20	14	00010100	84	54	01010100	148	94	10010100	212	D4	11010100
21	15	00010101	85	55	01010101	149	95	10010101	213	D5	11010101
22	16	00010110	86	56	01010110	150	96	10010110	214	D6	11010110
23	17	00010111	87	57	01010111	151	97	10010111	215	D7	11010111
24	18	00011000	88	58	01011000	152	98	10011000	216	D8	11011000
25	19	00011001	89	59	01011001	153	99	10011001	217	D9	11011001
26	1A	00011010	90	5A	01011010	154	9A	10011010	218	DA	11011010
27	1B	00011011	91	5B	01011011	155	9B	10011011	219	DB	11011011
28	1C	00011100	92	5C	01011100	156	9C	10011100	220	DC	11011100
29	1D	00011101	93	5D	01011101	157	9D	10011101	221	DD	11011101
30	1E	00011110	94	5E	01011110	158	9E	10011110	222	DE	11011110
31	1F	00011111	95	5F	01011111	159	9F	10011111	223	DF	11011111
32	20	00100000	96	60	01100000	160	A0	10100000	224	E0	11100000
33	21	00100001	97	61	01100001	161	A1	10100001	225	E1	11100001
34	22	00100010	98	62	01100010	162	A2	10100010	226	E2	11100010
35	23	00100011	99	63	01100011	163	A3	10100011	227	E3	11100011
36	24	00100100	100	64	01100100	164	A4	10100100	228	E4	11100100
37	25	00100101	101	65	01100101	165	A5	10100101	229	E5	11100101
38	26	00100110	102	66	01100110	166	A6	10100110	230	E6	11100110
39	27	00100111	103	67	01100111	167	A7	10100111	231	E7	11100111
40	28	00101000	104	68	01101000	168	A8	10101000	232	E8	11101000
41	29	00101001	105	69	01101001	169	A9	10101001	233	E9	11101001
42	2A	00101010	106	6A	01101010	170	AA	10101010	234	EA	11101010
43	2B	00101011	107	6B	01101011	171	AB	10101011	235	EB	11101011
44	2C	00101100	108	6C	01101100	172	AC	10101100	236	EC	11101100
45	2D	00101101	109	6D	01101101	173	AD	10101101	237	ED	11101101
46	2E	00101110	110	6E	01101110	174	AE	10101110	238	EE	11101110
47	2F	00101111	111	6F	01101111	175	AF	10101111	239	EF	11101111
48	30	00110000	112	70	01110000	176	B0	10110000	240	F0	11110000
49	31	00110001	113	71	01110001	177	B1	10110001	241	F1	11110001
50	32	00110010	114	72	01110010	178	B2	10110010	242	F2	11110010
51	33	00110011	115	73	01110011	179	B3	10110011	243	F3	11110011
52	34	00110100	116	74	01110100	180	B4	10110100	244	F4	11110100
53	35	00110101	117	75	01110101	181	B5	10110101	245	F5	11110101
54	36	00110110	118	76	01110110	182	B6	10110110	246	F6	11110110
55	37	00110111	119	77	01110111	183	B7	10110111	247	F7	11110111
56	38	00111000	120	78	01111000	184	B8	10111000	248	F8	11111000
57	39	00111001	121	79	01111001	185	B9	10111001	249	F9	11111001
58	3A	00111010	122	7A	01111010	186	BA	10111010	250	FA	11111010
59	3B	00111011	123	7B	01111011	187	BB	10111011	251	FB	11111011
60	3C	00111100	124	7C	01111100	188	BC	10111100	252	FC	11111100
61	3D	00111101	125	7D	01111101	189	BD	10111101	253	FD	11111101
62	3E	00111110	126	7E	01111110	190	BE	10111110	254	FE	11111110
63	3F	00111111	127	7F	01111111	191	BF	10111111	255	FF	11111111

Appendix IX

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