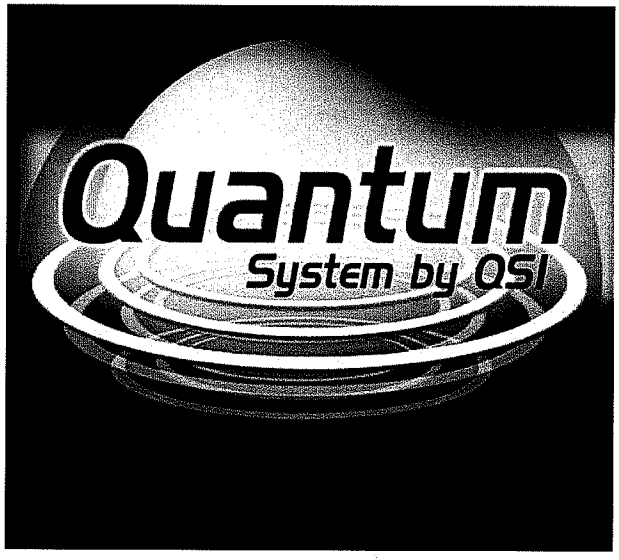
Exhibit E - Part 1



NMRA DCC Reference Manual *for* QSI Quantum® HO Equipped Locomotives

Version 3.0
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Digital Command Control 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 usually not currently available under conventional Analog Control[2], 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 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.
[2] Some Quantum systems use an advanced Analog control system called QARC™ (Quantum Analog Remote Control) Technology that does provide many of the same features available in DCC. See the Quantum Analog Reference Manual for details.

Important Notes About Quantum DCC Operation

This is a complete reference manual for DCC features included in the 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 Appendix VII 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 Operation 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[3]
- 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[4] 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 (or operating Mars Light) will dim when it stops and enters Neutral, which was common practice for prototype locomotives under Rule 17[5]. You will also hear a Short Air Let-off whenever the engine enters Neutral.

Locomotive Directional States under DCC Operation

Each Quantum locomotive has four distinct Directional 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 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

3 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.

4 Earlier Quantum Systems would stop in Neutral for up to three seconds before changing direction. This period has been shorted to an almost zero to make it easier and more efficient to do uncoupling over magnetic uncoupling tracks.

5 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.

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 or Standard Throttle Control in CV 56.4.

Important Legal Notice

Regulated Throttle Control, Speed Control and Cruise 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 Mike's 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 Mike's Train House claims to have invented them. QSI does not believe that Quantum Sound System infringes any MTH patent.

Check you individual Operating Manual that came with your locomotive to determine if these features are included in your particular model.

1.4 Sound of Power™

Quantum locomotives will produce labored sounds under acceleration and lighter non-labored sounds under deceleration[6] and 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.

1.5 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 Operation 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 0-12 Function Key standard as now accepted by the NMRA; the old 0-8 standard is not supported in new Quantum equipped locomotives[7].

1.5.1 Common Feature Function Key Assignments

Default F-Key	FWD/REV	NFF/NFR
FL(f)[8]	Headlight, Reverse Light, and Hazard Light Directional Lighting	Headlight, Reverse Light, and Hazard Light Directional Lighting
FL(r)	Headlight, Reverse Light, and Hazard Light Directional Lighting	Headlight, Reverse Light, and Hazard 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 and Air Brakes	Long Air Let-off or Gas Turbine Start Up/Shut Down toggle.
F8	Audio Mute	Audio Mute
F9	Short Air Let-off or Cruise Control[9]	Shut Down10: Disconnect-Standby set-Total Shut Down
F10	Status Report (SMPH)	Status Report (ID's, etc.)
F11	Number Board Lights	Number Board Lights
F12	Automatic Cab Lights	Automatic Cab Lights

- The FL Key is sometimes labeled F0, Headlights, Lights or Directional Lighting on different DCC controllers.

1.5.2 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 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

6 Steam Locomotives produce louder chuffs under acceleration and lighter low volume chuffs under deceleration. Diesel locomotives produce louder Diesel Motor sounds under acceleration and lower volume sounds under deceleration.
7 The only Quantum equipped engine using the F0-F8 specification is the 2002 J1e Hudson by BLI, version ho300a02.
8 FL(f) and FL(r) control the on/off of Headlight, Reverse Light, and Hazard Directional Lighting regardless of which direction the train is moving.
9 Cruise Control was only available on engines equipped with Speed Control.
10 There are three stages to Shut Down. To operate Shut down, you will need to double click the F9 key for each stage.

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 – F8 or F9 – F12.

Some decoders do not send out function groups until there is a change to one 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 non-prototypical.

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 were selected for the previous locomotive, that may not be what the operator wants for the newly selected engine.

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

The F0 key turns the Directional Lighting System on or off. 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 capability.

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

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

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

Some locomotives are equipped with a special strobing hazard light called a Mars Light, or with a pair of Ditch Lights which strobe when the Horn blows, mounted on the front of the locomotive. The table below is a summary of Mars Light and Ditch Lights operation in the different directional states.

	Forward	Neutral from Forward	Reverse	Neutral from Reverse
Mars Light*	Strobing	Dim non-strobing	Dim non-Pulsing	Dim non-Pulsing
Ditch Lights	On; Strobes when Horn blows	Off	Off	Off

*If your locomotive has a Mars Light, the Headlight may not be dimmable. In those directional states where the Headlight would normally be dim, the Headlight is off.

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 predictably affect the headlight or Reverse Light, see the troubleshooting 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.

1.7 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.

1.8 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 an 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 an uncoupler magnet. 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 turn 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 turn on or off 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/Reverse 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[11].

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[12] 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[13] with other engines that do have Dynamic Brake sounds in multiple unit Consists.

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11 Under Disconnect, the Diesel Motor can be revved up and down in Neutral with Dynamic Brakes on (see page 17 – Disconnect).
12 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.

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.

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 within four seconds, 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: 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: 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: 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.

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

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

Squealing brakes will occur automatically when the speed is reduced to 20 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 F7 key when the engine is moving at any speed. The F7 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.

Note: If you slow the engine too quickly, the brake sounds will terminate abruptly when the locomotive stops and enters Neutral.

Note: If you lower your throttle to speed step 0 on a moving locomotive, the F7 key will apply Air Brakes as long as the locomotive continues moving and will affect how rapidly it comes to a stop (see below).

1.13 Air Brakes (F7)

If you have selected any non-zero deceleration inertia or momentum value in CV 4 and/or CV 24, the F7 key can be used to apply Air Brakes to stop the engine more quickly than it would normally stop from the inertia settings[14]. To use Air Brakes:

- Turn the throttle down to speed step 0 on a moving engine; this enables the F7 key to act as a brake.
- Press the F7 key. Hear a brief brake squeal sound and air being released from the brake lines continually. The longer the air is released the greater the braking action.
- Press the F7 key again to stop the air release. The train will continue to slow at the last braking value.
- If you want to apply more braking, press the F7 key again to release more air. When you reach the desired amount of braking, press F7 again to stop the air release.

Note: If you continue to release air, all the pressure will eventually be released and brakes are on full; you will hear no further air release sounds.

- Turn up the throttle to any value above 0 to release the brakes; this returns the engine's deceleration to a value determined by the sum of CV 4 and CV 24.
- If the engine is in Neutral when the F7 key is pressed, a Long Air Let-off sound simulates setting the brakes. However, no braking effect is activated[15].

If the throttle is set to any speed step except 0, Air Brakes are not enabled; instead the F7 key will now manually activate Squealing Brake/Flange sounds but will not affect the engine's deceleration.

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

[14] C4 and C24 determine the deceleration rate. Applying the brakes increases this deceleration rate.
[15] If the brakes are set in Neutral, turning up the throttle automatically releases the brakes.

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 Status Report (F10)

Quantum provides verbal information about the engine's current operating state when the locomotive is in Neutral or the engine's current speed in scale miles per hour when the locomotive is moving.

- Press the F10 key in Neutral; the locomotive will verbally report first its currently enabled long or short loco ID followed by its consist ID if it has one, followed by its Shut Down state (Disconnect, Standby or Shut Down).
- Press the F10 key in Forward or Reverse; the locomotive will verbally report the locomotive's speed in scale miles per hour (SMPH).

Note: When Neutral Status Report or Verbal Speedometer Readout is activated, the locomotive's sounds will reduce to one half their current volume settings during the verbal report and then return to normal volume when the report has ended.

Note: In a consist, all engines will simultaneously report their status when the F10 key is pressed unless the function is disabled in CV 22.

1.17 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[16].

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.

16 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.

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 Let-off after entering Disconnect, which represents the pneumatic reverse lever on a steam engine 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 in disconnect.

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 Let-off followed by Directional Lighting and optional Mars Light. The motor will remain disconnected, while the Air Pumps, automatic Steam Blower/Cooling Fan operation, Number Board Lights and Cab Lights will continue to operate. In Standby, the engine will not respond to throttle or most function keys[17]. The three exceptions are the F6 Start Up Function Key (described below), the F8 Mute Key (described above) and the F10 Status Key (described above).

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 cab and number board lights and occasional Air Pump or Blowers and Fan sounds.

Stage Three: Total Shut Down

- Double-press the F9 in Standby to enter Total Shut Down.
- 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 two exceptions are the F6 Start Up Function Key (described below) and the F10 Status Key (described above).

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, the Cab Lights shutting off, and finally the Blower hiss will trail off and finally shut off completely.

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 Motor(s) shutting down, Cab Lights shutting off, 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 command, and will power up in that Shut Down stage[18].

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[17] Function keys will only produce a short air let-off.

18 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.

If Start Up is initiated during any of the above Shut Down procedures, Shut Down is aborted and the engine returns to normal operation.

1.18 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[19] the F6 Key. Start Up will be different for each stage of Shut Down, but all will start up with a Long Air Let-off and will enter normal operation[20].

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, Quantum will not respond to any of function keys.

Start Up procedures from Total Shut Down are different for different locomotives.

Steam Locomotives: The Quantum System will produce a Long Air Let-off, the Dynamo will rev up and the Directional Lighting will turn on (if previously turned "on" and a Normal Engine or Lead Helper), then Cab Lights will turn on (if available), followed by the Air Pumps and the steam Blower turning on and finally the locomotive entering normal operation.

Diesel Locomotives: The Quantum System will produce a Long Air Let-off, followed by the sound of the engineer's door opening and closing, Cab Lights turning on (if available and Normal or Lead Helper), Number Boards coming on (if available and a Normal Engine or Lead-Helper), Directional Lighting turning on (if previously on), followed by the vents opening and fans starting up, the Diesel Motor or Motors starting up one at a time, the Air Pumps turning up, and finally the locomotive entering normal operation.

Electric Locomotives: The Quantum System will produce a Long Air Let-off, followed by the sound of the engineer's door opening and closing, Cab Lights coming (if available and Normal or Lead Helper), Number Boards and colored Marker Lights turning on (if available and a Normal Engine or Lead-Helper), Directional Lighting turning on (if previously on), followed by the vents opening and fans starting up, the Air Pumps turning on, and finally the locomotive entering 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.

1.19 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

19 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.

20 Locomotive enters Neutral with Long Air Let-off if speed step is zero. If speed step is non-zero, locomotive will enter either forward or reverse.

and instead will be controlled by its associated function key commands. Automatic and Take Control operations are described in the table below for our current 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	Turns Steam Blower On/Off

- 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 to off (0) 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**
Vents & Cooling Fans	Non-operating	Non-operating	On and off at random times	F4	Turns Vents/Fans operation On/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 Cooling Fans in addition to taking control of the feature. For instance, if the automatic Fans are on, pressing the F4 key to off (0) will toggle the Fans to off and they will stay off.

Electric Locomotive "Take Control" Operation

	Automatic Operation		Take Control	
	Forward/Reverse	**Neutral**	**Function Key**	**Operation**
Cab Lights	Lights off after 15 sec	Lights on after 10 sec	F12	Turns Cab Lights On/Off
Cooling Fans	On after 20 sec	Off after 10 sec	F4	Turns Cooling Fans On/Off

- Take control of the Cab Lights with the F12 key to stop automatic Cab Lights operation.
- 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 to off (0) will toggle the Cab Lights to off and they 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).

1.20 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 or Air Brakes for a moving Steam Engine but activates the Boiler Water Injector if the locomotive is in Neutral.
- F6 results in Doppler shift for a moving engine but activates Start Up when in Neutral.
- F9 toggles Cruise Control[21] 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.

21 If Cruise Control is not available on your model, you will hear a Long Air Let-off when F9 is pressed for a moving engine.

2 Programming

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

1. **Operations Mode**[22] (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 operating preferences.
2. **Service Mode**[23] 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[24] 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. 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

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.

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

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). You can also purchase from Tony's Train Exchange®[25], a simple, inexpensive power booster (PowerPak™ by DCC Specialties) that will allow you to program on the program track with any DCC command station.

[25] Tony's Train Exchange; 1-800-978-3427; info@ttx-dcc.com .

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, which will set the engine's ID to short address 3. (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) One 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 Period26	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	0	
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	6	28 speed step mode. Power Source Conversion enabled.
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	

26 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	QSI Feature Configuration	O	Y		
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	-	.
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 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-Total Shut Down)	Mute	Squealing Brakes – Air Brakes (Brake Set)	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:

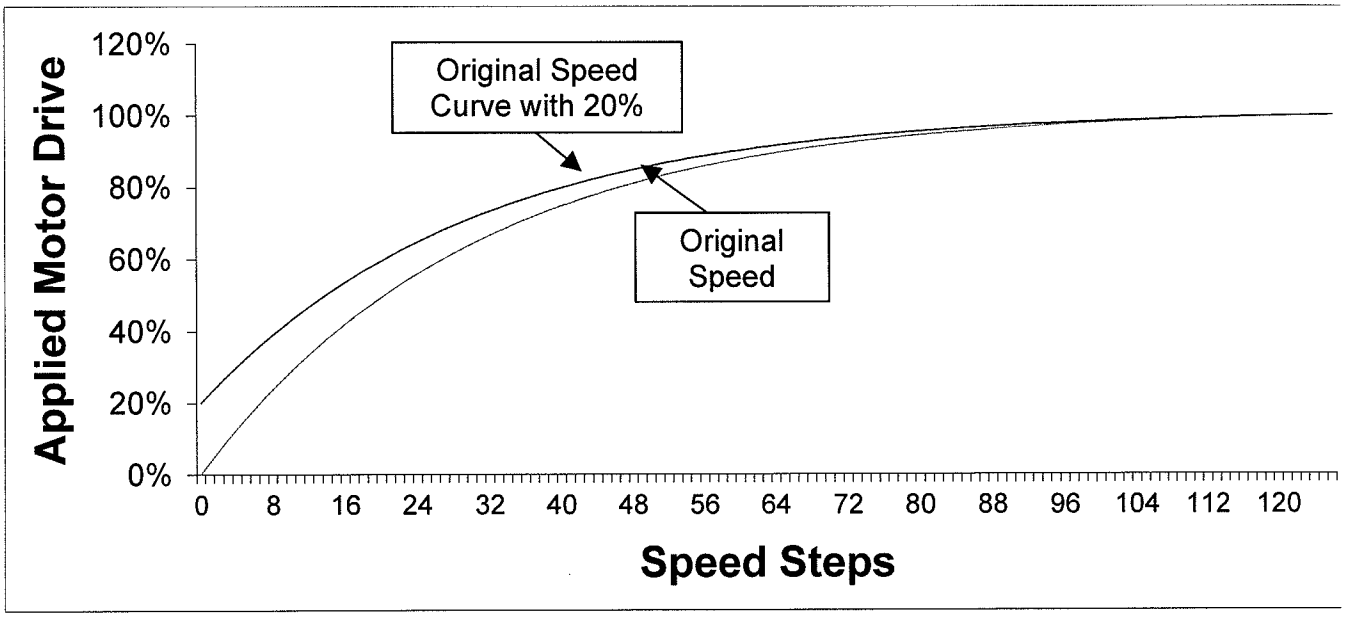
  Start Voltage = (Track Voltage) x (CV2/255)

  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:

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

  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[27]

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.

27 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[28]

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.

28 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)

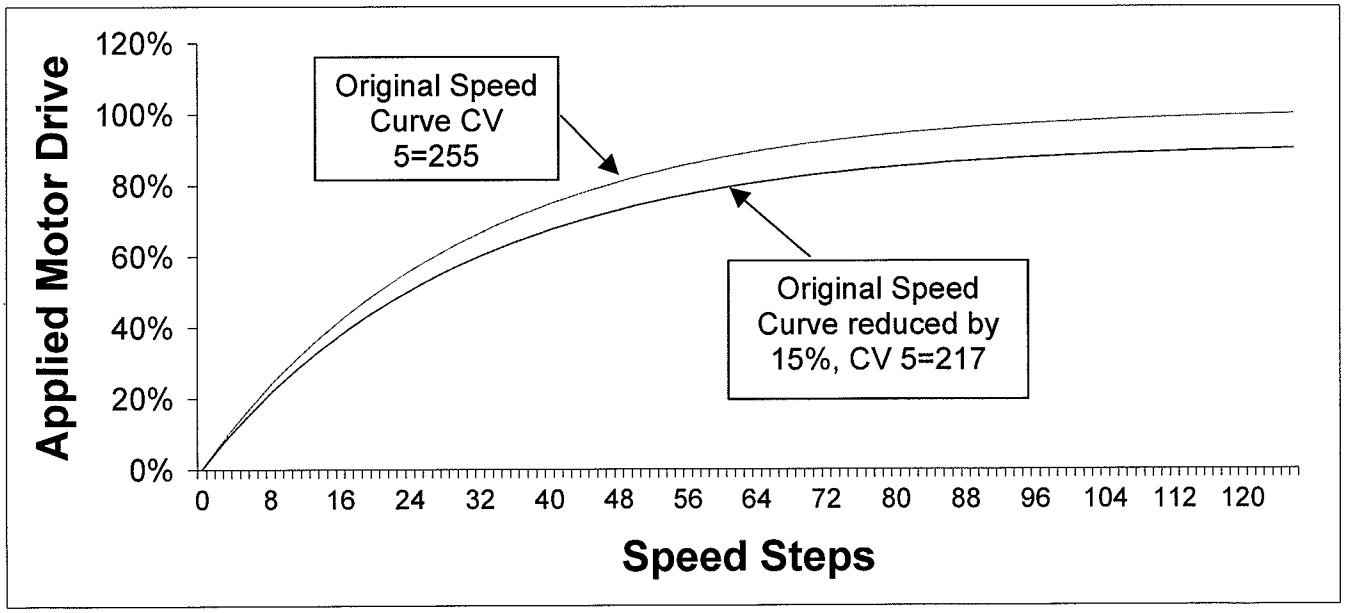
  For instance, a value of "200" for CV 5 means that the maximum voltage will be 217/255 or 85% of the applied track voltage.

  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.

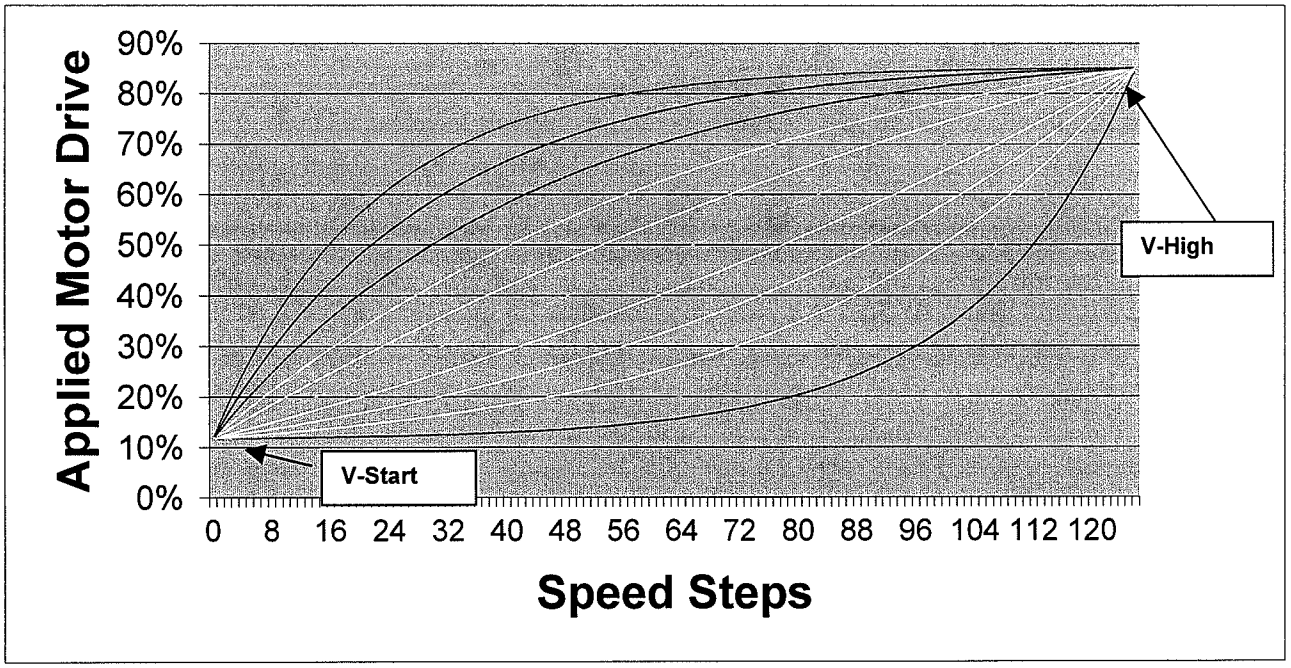


V-High is not related to V Max for Analog Operation.
V-High is not used when Throttle Mode = Speed Control.

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[29] (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.



29 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.

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 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[30]. 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.

30 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[31]
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.

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.

31 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.

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 steam engine cab numbers. See if your calculations match the values in the table. After you have calculated your ID numbers, just follow the procedure below to enter you extended ID number.

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.
5) Read your ID number back from your program track or verbally in Opts Mode to see if you entered the correct number.

Common Steam 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
611	194	99	C2	63	11000010	01100011
8444	224	252	E0	FC	11100000	11111100
4449	209	97	D1	61	11010001	01100001
3751	206	167	CE	A7	11001110	10100111
261	193	5	C1	5	11000001	00000101
1218	196	194	C4	C2	11000100	11000010
1361	197	81	C5	51	11000101	01010001
700	194	188	C2	BC	11000010	10111100

Note: If your 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[32] 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.

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

3.11 CV 21 Consist Address Active for F1-F8[33]

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

Default Value: **0**

CV 21: Consist Address Active for F1-F8 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 and Air Brakes	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**

33 Write bit operation is supported for CV 21.

Recommended value of CV 21 for a Mid[34] 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 and Air Brakes	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	**1**	**1**	**1**	**1**	**0**	**0**	**0**

Recommended value of CV 21 for an End[35] 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 and Air Brakes	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	**1**	**1**	**1**	**1**	**1**	**0**	**0**

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

3.12 CV 22 Consist Address Active for FL and F9-F12[36]

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 Helper locomotives within the Consist. For instance, only the Lead Engine should have operational Directional Lighting. Helpers should have their directional lighting disabled.

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.

F10, Status Report should be disabled for all Helper types in a Consist since it would be difficult to hear the verbal announcement if more than one engine announced its status at the same time.

Features for F keys 11 and 12 are usually designed for Number Board Lights and Cab Lights. It is recommended that Cab Lights be disabled and Number Board Lights be enabled. At times F11 and F12 are reserved for custom appliance sounds or operations for the different engine types (Steam, Diesel or Electric) such as steam Blow Down, etc. It is recommended that these functions be disabled for all Helper types except the Lead engine to avoid confusion. Check your individual models to determine which features are assigned to F11 and F12.

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).

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

N/A	N/A	Cab Lights	Number Board Lights	SMPH Report (Status Report)	Cruise Control (Disconnect-Standby-Total Shut Down)	Directional Lighting	Directional Lighting
N/A	N/A	F12	F11	F10	F9	FL(r)	FL(f)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**1**	**1**	**1**	**1**	**1**

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

36 Write bit operation is supported for CV 22.

N/A	N/A	Cab Lights	Number Board Lights	SMPH Report (Status Report)	Cruise Control (Disconnect-Standby-Total Shut Down)	Directional Lighting	Directional Lighting
N/A	N/A	F12	F11	F10	F9	FL(r)	FL(f)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**1**	**0**	**1**	**0**	**0**

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

N/A	N/A	Cab Lights	Number Board Lights	SMPH Report (Status Report)	Cruise Control (Disconnect-Standby-Total Shut Down)	Directional Lighting	Directional Lighting
N/A	N/A	F12	F11	F10	F9	FL(r)	FL(f)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**1**	**0**	**1**	**0**	**0**

When making up your consist, remember to have the directional lighting turned off before you assign zeros for bits 0 and 1. Otherwise the directional lighting will be on with no way to turn them off with the FL(r) or F(f) keys[37].

The above selections for directional lighting for engines in a consist is not ideal for the following reasons:

1. You may not want the Lead locomotive to have an operating Directional Reverse Light since it would only illuminate the engine behind it and not the track. To eliminate the Reverse Directional Lighting feature, assign Outputs 1 and 2 to Directional Headlight (Feature ID 96) in CV 53. With bits 0 and 1 in CV 22, the Front Directional Light will be controlled from either F(f) or FL® and the Reverse Light will not operate at all.
2. You may want the End Helper to have an operational reverse facing light (which may be either the End Helper's Reverse Light or Headlight depending on the locomotive's direction within the consist). If the End Help is facing Forward, Assign Outputs 1 and 2 to the Directional Reverse Light (Feature ID 97) in CV 53 and set bit 0 and bit 1 in CV22 to 1. If the End Help is facing Backwards, Assign Outputs 1 and 2 to the Directional Headlight (Feature ID 96) in CV 53 and set bit 0 and bit 1 in CV22 to 1. The End Helper will now have a non-operating Headlight and an operating Directional Reverse Light that can be enabled with either the FL(f) or FL(r) key.

With the above changes, the directional lighting in your consist will operate like a single locomotive. That is, the FL key is on, the Lead Engine Directional Headlight will be on, all other Helper Headlights will be off, and all Reverse Lights will be off. If the consist is moving in Reverse, only the End Helper Reverse Light will be on and the Lead Engine Headlight will either be off or Dim (if the Dim feature is part of the Directional Headlight for your model).

Alternately, for your End Helper, you could also set bits 0 and 1 to 0 in CV 23, along with the newly assigned lighting for outputs 1 and 2 (as described in item 1 above) and turn on the Directional Lighting by selecting the End Helper by its Engine ID. This would allow you to leave the End Helper Directional lighting disabled when the consist was coupled to its train.

[37] Since the default for directional lighting is off, any helpers that did have their directional lighting on will be set to off if the power is turned off and back on, or if the engine is shut down and started using the F9 and F6 keys.

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:

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

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

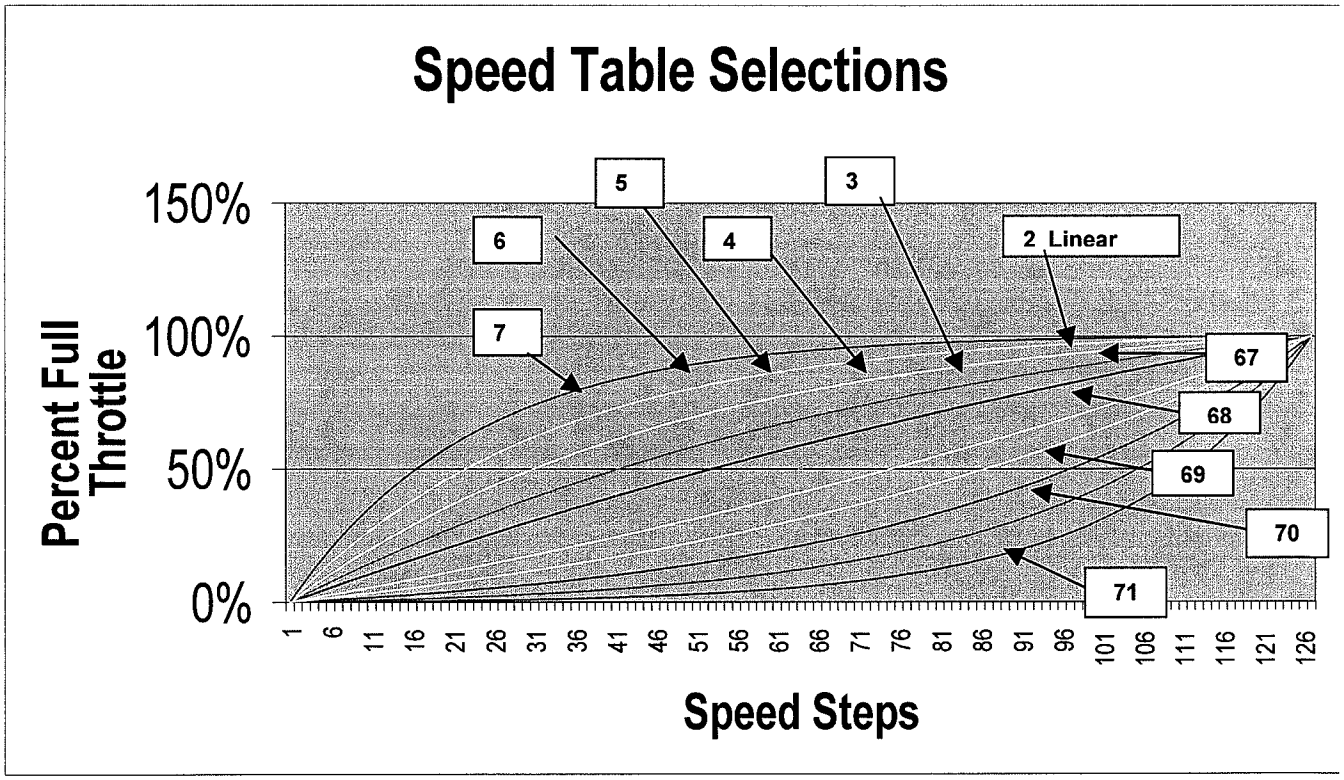
User selection of one of 11 speed curves.

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[38]

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

Default Value: **00000110 = 6**

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[39] elapses in which no DCC packet is detected, then the engine will convert to Analog power.

  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.

38 Write bit operation is supported for CV 29.
39 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 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).

NOTE: This bit must be set to 1 in order for engine to operate on an Analog track. See trouble shooting section.

- 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[40] 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[41] 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													
	Common Default Quantum Features Assignments	Automatic Cab Lights	Number Board Lights	SMPH Report (Status Report)	Cruise Control (Shut Down)	Mute	Squealing Brakes Air Brakes (Brake Set)	Doppler Shift (Engine Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler	Whistle/Horn	Bell	Directional Lighting	Directional Lighting
	Outputs	14	13	12	11	10	9	8	7	6	5	4	3	2	1
33	FL(f)							0	0	0	0	0	0	1	1
34	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 light gray background shows the Output default settings for Quantum. For example, CV 36 has a "1" in the column for Output 4, indicating that Function 2 controls Output 4 which will operate the Whistle or Horn.

Each Input Function can control up to 8 Outputs. The white squares in the table show allowed possible assignments of Outputs for each Function. The dark gray areas indicate where Outputs cannot be assigned. 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.

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

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 without rewiring the features.

For Sound Decoders like the first Quantum System, only some of the Outputs were "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. Features that were hardwired to fixed outputs on early decoders included headlamps, reverse lamp, cab lamps, couplers, smoke generators, etc.

On modern decoders, even those features that do require external wires, such as lights and smoke generators, are not necessarily "hardwired" to any particular Output. Outputs are now virtual and can be connected internally by firmware in the Quantum microprocessor to any physical driver, such as a power output for a lamp or a controller for a smoke generator. The connection between a virtual output and a physical feature is called a control port or simply "port". For consistency with NMRA definitions, virtual outputs are called simply "outputs".

Quantum software allows us to direct "any virtual" output to any port. This has allowed us to combine some features that require two or more ports to a single virtual output. For example, our Directional Lighting, which operates a reverse lamp, forward light and sometimes a pulsing Mars Light.

Since the user on longer needs to concern himself about restrictions of which features can be assigned to which output, he has much more latitude and economy in configuring how his function keys operates different feature. For instance, if it is a light or other control port, Quantum will automatically make sure that the virtual Output is connected to the correct port to control that feature. This extra freedom means you could connect some feature to operate in Forward with the FL(f) key and some other feature to operate only in Reverse with the FL(r) key and not loose the Directional Lighting feature which would be assigned to some other Output. As an example, you could assign FL(f) to Cruise Control (since Cruise Control is less needed as a desirable control in Reverse) and FL(r) to Coupler Operation since this is where the Quantum Coupler crash sound is likely more appropriate. And then assign the Directional Lighting System to the Output 5, which was previously assigned to Coupler Sounds. You have now freed up Output 11, which was formally used for Cruise Control, to do operate another feature.

Quantum also allows outputs to be redirected to different features depending on the directional 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. For QSI Quantum Sound Decoders, features are assigned to outputs in CV 53.

The above table shows Common Default Quantum Features Assignments in the second row. Features assignments that operate only in Neutral are shown in parenthesis under the feature that operates in Forward and Reverse. If no Neutral feature is shown, the assigned feature shown will operate in all directional states.

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[42], we recommend you follow the two 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 and Output 2, where we have both FL(f) and FL(r) operating the Directional Lighting System. This is an exception, which does work for Directional Lighting using FL(f) and FL(r). In general, it is not a good idea.
- In CV 53, do not assign the same feature to two or more Outputs.

Note: The following CV's for output assignments also show default features and the affect of sending a "1" or "0" function command for Level Activated (LA) features or sending a change in the function such as "1-0" or "0-1" for Transition Activated (TA) features, or sending a double command such as "1-0-1" or "0-1-0" for Pulse Activated (PA) features. See Appendix V and Appendix V1 for a complete description of LA, TA and PA features.

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[42] See Appendix VI *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)[43]

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: **00000011 = 3**

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	Directional Lighting	Directional Lighting
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. In CV 53, the default setting for Outputs 1 and 2 is the Directional Lighting System. Therefore, by default FL(f) controls the Directional Lighting System 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 Outputs 1 and 2.
- Assuming the default CV 53 settings (shown in the top row)[44], you can specify that FL(f) controls the following features.

Bit 0 Output 1: Directional Lighting

"0" The Directional Lighting System will turn off by FL(f).
"1" The Directional Lighting System will turn on by FL(f).

Bit 1 Output 2: Directional Reverse Light

"0" The Directional Lighting System will turn off by FL(f).
"1" The Directional Lighting System will turn on by FL(f).

Bit 2 Output 3; Bell

"0" The Bell will turn off by FL(f).
"1" The Bell will turn on by FL(f).

Bit 3 Output 4; Whistle/Horn

"0" The Whistle/Horn will turn off by FL(f)
"1" Whistle/Horn will turn on by FL(f).

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

"0-1" or "1-0" If FL(f) is changed when engine is moving, coupler crash sounds are produced. If FL(f) is changed when engine is in Neutral, Coupler Arm or coupler Fire occurs.

43 Write bit operation is supported for CV 33.
44 Features that are different in the Neutral state are shown in parentheses

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

"0" Blower-Hiss/Fans will turn off by FL(f), and you will "take control" of Blower-Hiss/Fans.
"1" Blower-Hiss/Fans will turn on by FL(f), and you will "take control" of Blower-Hiss/Fans.

Bit 6 Output 7: Dynamic Brakes

"0" Dynamic Brakes will turn off by FL(f).
"1" Dynamic Brakes will turn on by FL(f).

Bit 7 Output 8: Doppler, Start Up

"0-1" or "1-0" If FL(f) is changed, Doppler shift will occur in a moving engine. In Neutral, if
"0-1-0" or "1-0-1" FL(f) is double pressed[45], Quantum will clear all "Take Control" operations and produce engine Start Up sounds (if in Shut Down).

45 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.

4.3 CV 34 Output Location for FL(r)[46]

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	Directional Lighting	Directional Lighting
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. In CV 53, the default setting for Outputs 1 and 2 is the Directional Lighting System. Therefore, by default FL(r) controls the Directional Lighting System 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)[47], you can specify that FL(r) control the following features.

Bit 0 Output 1: Directional Lighting
"0" The Directional Lighting System will turn off by FL(r).
"1" The Directional Lighting System will turn on by FL(r).

Bit 1 Output 2: Directional Lighting

"0" The Directional Lighting System will turn off by FL(r).
"1" The Directional Lighting System will turn on by FL(r).

Bit 2 Output 3; Bell

"0" The Bell will turn off by FL(r).
"1" The Bell will turn on by FL(r).

Bit 3 Output 4; Whistle/Horn

"0" The Whistle/Horn will turn off by FL(r).
"1" Whistle/Horn will turn on by FL(r).

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

"0-1" or "1-0" If FL(r) is changed when engine is moving, coupler crash sounds are produced. If FL(r) is changed when engine is in Neutral, Coupler Arm or coupler Fire occurs.

46 Write bit operation is supported for CV 34.
47 Features that are different in the Neutral state are shown in parentheses