Application Engineering Bulletin

Subject: Implementing Dual Governing Dynamics on QSX15 and QSK45/60 Series Generator Drive Engines **Bulletin # 3884991**	This AEB is for the following applications: ☐ **Automotive** ☐ **Industrial** ☒ **Power Generation**

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Engine Models included: QSX15, QSK45, QSK60

Fuel Systems Included: HPI-TP (QSX15), HPI-PT (QSK45/60)

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Scope:

This document applies to QSX15, QSK45 and QSK60 Generator Drive Engines governed by the Generator-Drive Control System controllers. This compliments information contained in Cummins Bulletin No. 3884960 "QSX15, QSK45, QSK60 Generator-Drive Control System Application Manual".

Introduction:

Some generator drive applications require different gain or droop settings for the same installation. A typical example is a Standby Generator Set which is also used for Peak shaving, which may have the following needs:

Stand Alone	Parallel
High Governor Gain – for fast transient response	Low Governor Gain – for smooth loading changes
Minimal or no Governor Speed Droop – for constant frequency at all load levels	High Governor Speed Droop – for droop method load control

This Bulletin provides details on two methods of meeting these needs.

Definitions:

Governor Speed Droop The amount that the governed speed is reduced as engine load increases. It is usually defined as a percentage difference between no-load and full-load speed. For example, 3% droop means that the governed speed at full-load will be 3% less than the governed speed at no load. If the no-load speed is 1854 RPM for a system with 3% droop, then the governed speed will be 1827 RPM at half-load and 1800 RPM at full-load.

Governor Gain A combination of the rate and amount of corrective action taken in response to a deviation from the governed speed. A system with higher relative gain will generally take more corrective action sooner than a system with low gain.

Governor Gain and Governor Speed Droop Input Basics

The Generator-Drive Control System Electronic Control Module (GCS ECM) has analog inputs allocated for remote gain and remote droop control signals. The GCS ECM must be configured to use remote gain or droop. Refer to the "Performance, Frequency and Droop Controls" section of the QSX15, QSK45, QSK60 Generator-Drive Control System Application Manual for details.

The input range for each of these signals is zero to 3.177 volts. A 2.87 k Ohm resistor is installed within the control and is connected between each input and an internal 5 volt power supply. This allows the use of a potentiometer (variable resistor) to be used to provide the voltage input. The QSX15, QSK45, QSK60 Generator-Drive Control System Application manual suggests using a 5 k Ohm potentiometer. Figure 1 shows a simplified equivalent circuit for Speed Droop. Figure 2 shows a simplified equivalent circuit for Governor Gain.

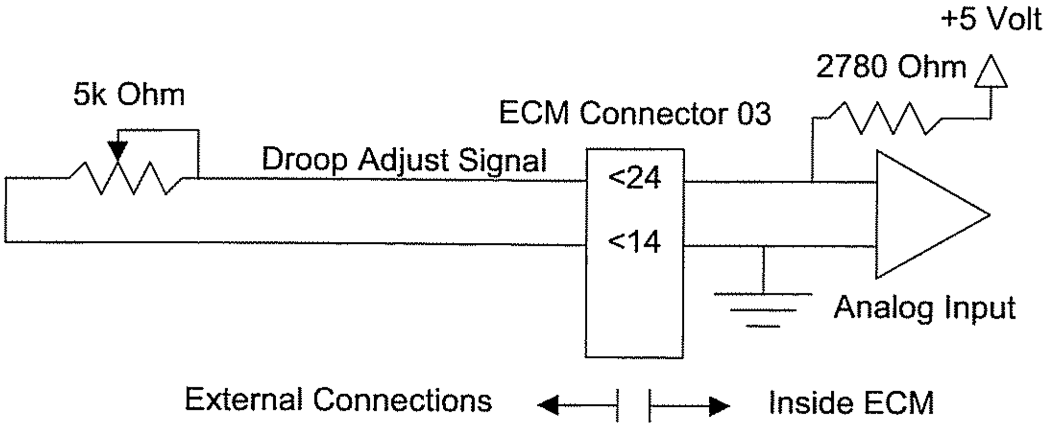

Figure 1: Simplified Equivalent Circuit for Remote Droop Adjustment

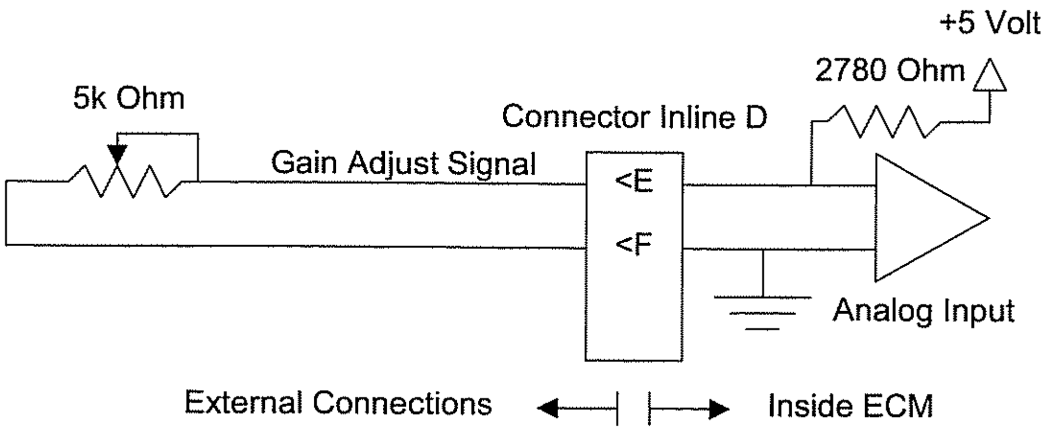

Figure 2: Simplified Equivalent Circuit for Remote Gain Adjustment

As the resistance on the potentiometer is reduced, the voltage provided to the corresponding input is reduced. The control interprets the lower voltage input as a command to use a corresponding lower gain or droop in its control algorithms.

Maximum Range Governor Gain and Governor Droop Implementation

Figure 3 shows a very simple method of implementing a dual Governor Droop. Figure 4 shows a very simple method of implementing a dual Governor Gain. This technique utilizes a set of "form C" relay or switch contacts (one normally open and one normally closed contact sharing a common connection) to select between two potentiometers. An advantage of this scheme is that both potentiometers can be independently set anywhere within the adjustment range.

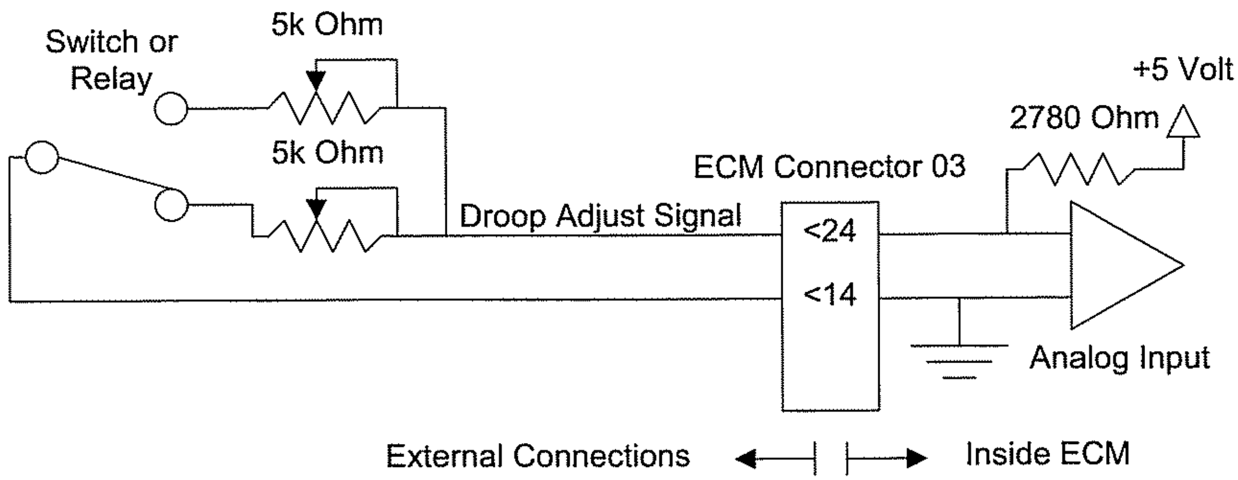

Figure 3: Maximum Range Dual Droop Implementation

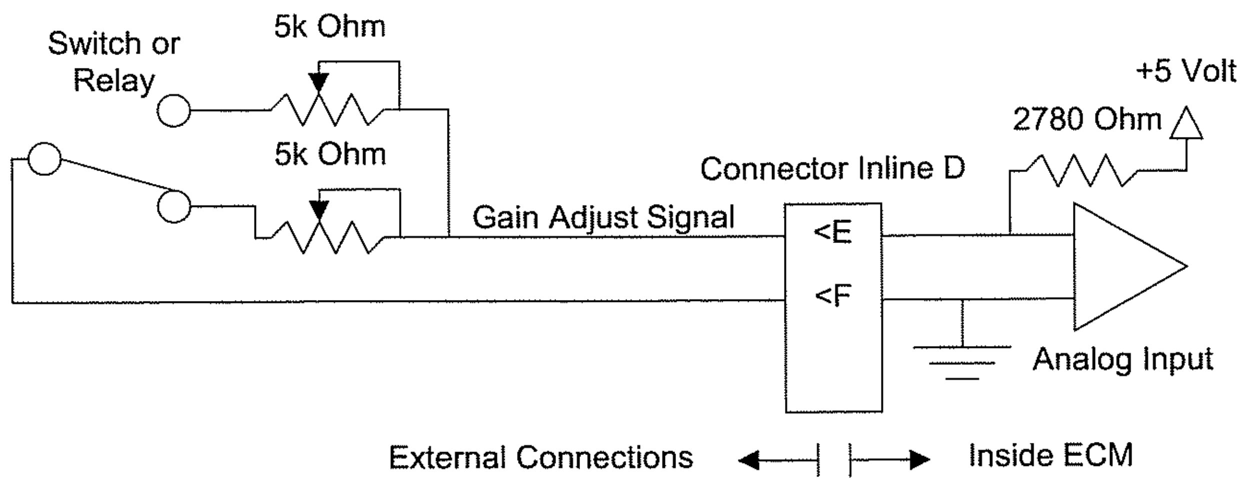

Figure 4: Maximum Range Dual Gain Implementation

A disadvantage of this scheme becomes apparent if there is a failure of either one of the contacts. For any time period when there is no resistance or abnormally high resistance on the enabled droop input, the control uses a default droop value of 0%. For any time period when there is no resistance or abnormally high resistance on the enabled gain input, the control uses a default gain value of 1. If the abnormal condition is present for more than 1 second, an Out-Of-Range Fault is detected. For example, suppose the normally closed contacts fail to close. When the relay or switch is in the normal mode, there is no potentiometer connected to the input. The control recognizes this as an abnormal condition and applies the default value in its control algorithms. After one second of this Out-Of-Range condition, the control records an Out-Of-Range Fault. If this Out-Of-Range failure mode behavior can cause a problem, the In-Range Failure Mode Governor Gain and Governor Droop Implementation scheme described below should be utilized.

A second disadvantage is that there will be a momentarily high or low signal provided to the input when the switch or relay changes state. Switches and relays are typically produced to perform in one of two manners: Make-before-Break and Break-before-Make.

If a Make-before-break relay is used, the two potentiometers will be momentarily paralleled. The equivalent resistance is much less than either value, so the input is momentarily provided with a signal which is much less than either desired setting. If this very low signal can disrupt the engine-driven system, then the In-Range Failure Mode Governor Gain and Governor Droop Implementation scheme described below should be utilized.

If a Break-before-make relay is used, then for a moment neither potentiometer is connected to the input. In this case, the control will use the corresponding droop default value (0%) or gain default value (1.0) while both sets of contacts are open. If this performance can disrupt the engine-driven system, then the In-Range Failure Mode Governor Gain and Governor Droop Implementation scheme described below should be utilized.

Optimal Failure Mode Governor Gain and Governor Droop Implementation

Figure 5 provides an implementation scheme for droop governing that avoids the undesirable Failure Mode and switch transition performance described for the previous scheme. Figure 6 is same technique applied to the Gain input.

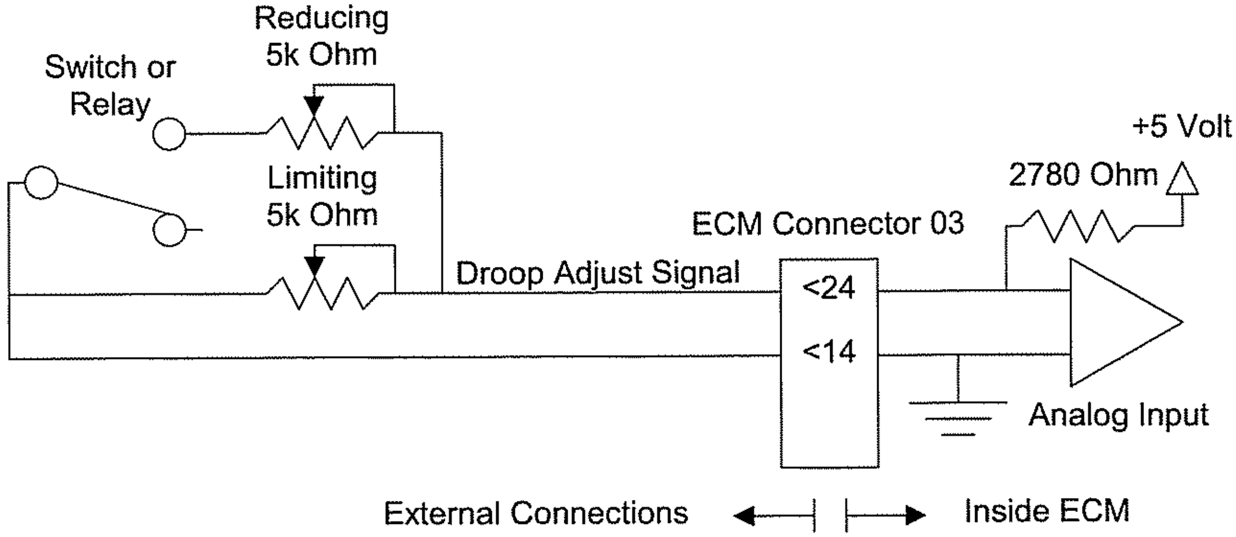

Figure 5: Sample In-Range Failure Mode Dual Droop Implementation

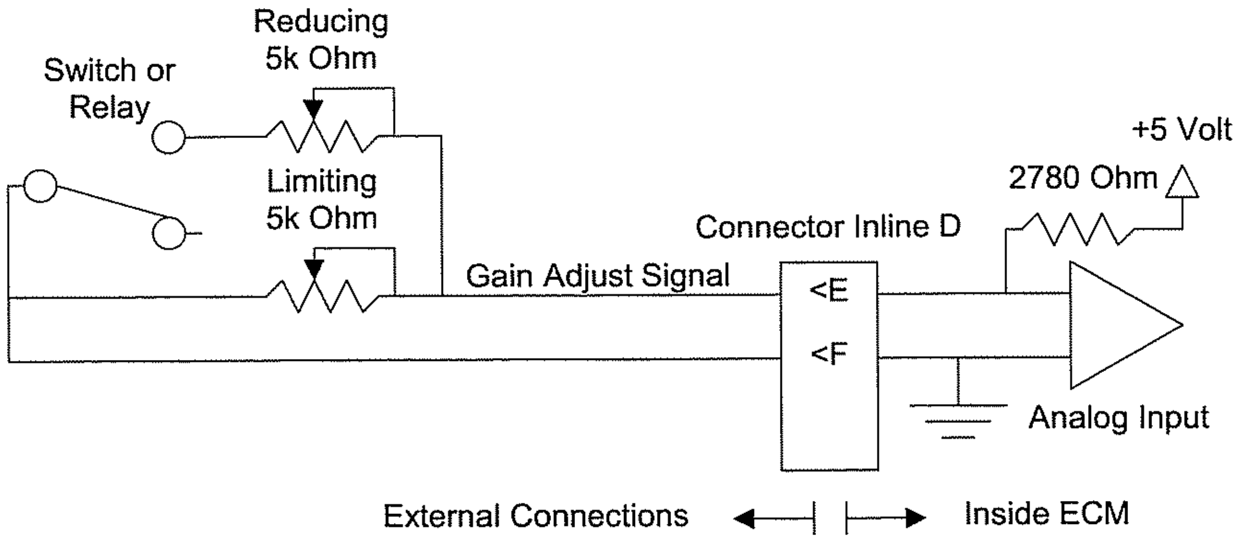

Figure 6: Sample In-Range Failure Mode Dual Gain Implementation

A single set of switch contacts is used to determine whether the signal presented to an input is determined by only one or by both of the potentiometers. The potentiometer that is always connected is termed the Limiting Potentiometer and the switch potentiometer is referred to as the Reducing Potentiometer.

The Limiting Potentiometer is always connected, so the maximum resistance (without a wire break) that is ever provided to the input is the setting of the Limiting Potentiometer. The Reducing Potentiometer is connected when the switch or relay contacts are closed. Since it is only connected in parallel with the Limiting Potentiometer, it serves to reduce the equivalent resistance when the switch or relay contact is closed. The equivalent resistance (R_{equiv}) is equal to the product of the two potentiometers' setting divided by the sum of the two potentiometers' settings:

$R_{equiv} = (R_1 * R_2)/(R_1 + R_2)$, where R_1 is the Reducing Potentiometer resistance in ohms, and R_2 is the Limiting Potentiometer resistance in ohms.

The formula given in the QSX15, QSK45, QSK60 Generator Drive Control System Application manual can be used to determine the actual gain or droop setting for various potentiometer settings. Table 1 is derived using the Application manual formula and provides the droop adjustment range for several Potentiometer values. Table 2 is similarly derived gain ranges. As the tables show, the adjustment range for the mode where the potentiometers are connected in parallel is not as wide when only the Limiting Potentiometer is connected. Note that the Second Adjustment Range is calculated assuming the Limiting Potentiometer is set to its highest value. If it is set to a lower value, the Second Adjustment Range is similarly reduced.

R_1 (Ohms)	R_2 (Ohms)	Primary (Limiting) Droop Adjustment Range	Maximum Second (Reduced) Droop Adjustment Range
500	500	0 – 1%	0 – 0.5%
500	1000	0 – 1%	0 – 0.7%
500	2000	0 – 1%	0 – 0.8%
500	5000	0 – 1%	0 – 0.9%
1000	1000	0 – 2%	0 – 1.0%
1000	2000	0 – 2%	0 – 1.3%
1000	5000	0 – 2%	0 – 1.7%
1000	10,000	0 – 2%	0 – 1.8%
2000	2000	0 – 4%	0 – 2.0%
2000	5000	0 – 4%	0 – 2.9%
2000	10,000	0 – 4%	0 – 3.3%
2000	20,000	0 – 4%	0 – 3.6%
5000	5000	0 – 10%	0 – 5.0%
5000	10,000	0 – 10%	0 – 6.7%
5000	20,000	0 – 10%	0 – 8.0%
5000	50,000	0 – 10%	0 – 9.1%

Table 1: Maximum Adjustment Ranges for Optimal Failure Mode Dual Droop Circuit

R_1 (Ohms)	R_2 (Ohms)	Primary (Limiting) Gain Adjustment Range	Maximum Second (Reduced) Gain Adjustment Range
500	500	0.05 – 2.37	0.05 – 1.30
500	1000	0.05 – 2.37	0.05 – 1.68
500	2000	0.05 – 2.37	0.05 – 1.97
500	5000	0.05 – 2.37	0.05 – 2.19
1000	1000	0.05 – 4.10	0.05 – 2.37
1000	2000	0.05 – 4.10	0.05 – 3.00
1000	5000	0.05 – 4.10	0.05 – 3.57
1000	10,000	0.05 – 4.10	0.05 – 3.82
2000	2000	0.05 – 6.48	0.05 – 4.10
2000	5000	0.05 – 6.48	0.05 – 5.25
2000	10,000	0.05 – 6.48	0.05 – 5.80
2000	20,000	0.05 – 6.48	0.05 – 6.12
5000	5000	0.05 – 10.0	0.05 – 7.34
5000	10,000	0.05 – 10.0	0.05 – 8.47
5000	20,000	0.05 – 10.0	0.05 – 9.17
5000	50,000	0.05 – 10.0	0.05 – 9.65

Table 2: Maximum Adjustment Ranges for Optimal Failure Mode Dual Gain Circuit

Special Case: Droop/Isochronous Switch Selection

Some Applications may require the engine's operating mode to be Droop/Isochronous, based on a switch or relay contact state. Figure 7 provides a method of implementing this.

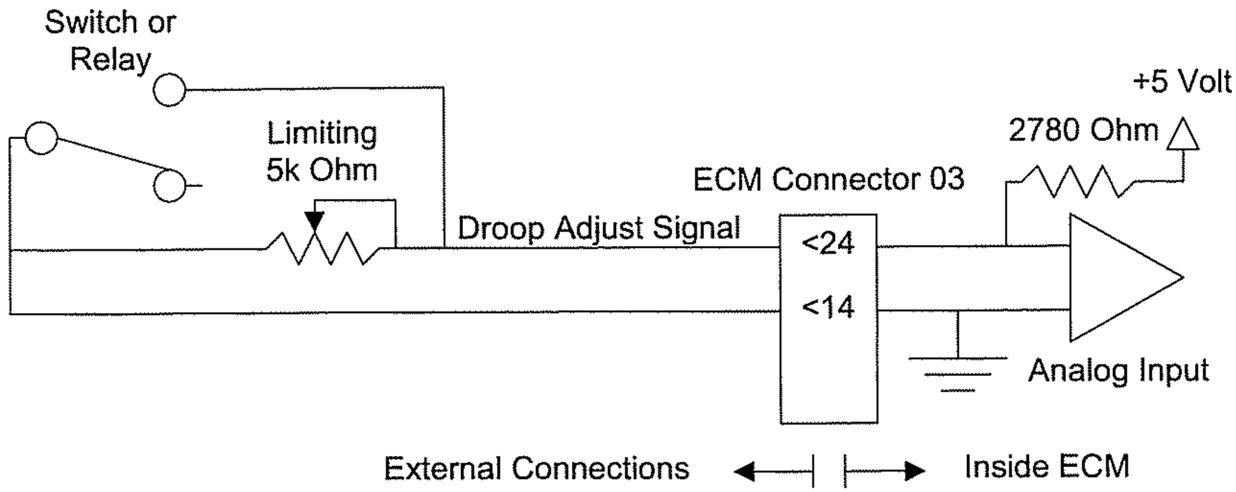

Figure 7: Sample Droop/Isochronous Switch Selection

This circuit is merely a specialized case of the circuit in Figure 5 with the value of the Reducing Potentiometer set to zero Ohms. When the switch or relay contact is closed, shorting the Droop Adjust Signal at pin 24 to the signal return at pin 14, the controller's input is supplied a zero volt signal, which is interpreted as a command to control the engine with a droop value of 0%.

A Sample Application: Droop/Isochronous and Dual Gains

An example application of where the dual gain and droop/isochronous selection is needed is a generator set which is used both as an emergency standby generator and in parallel with a utility grid for peak shaving. Figure 8 is a one-line diagram of the electrical distribution.

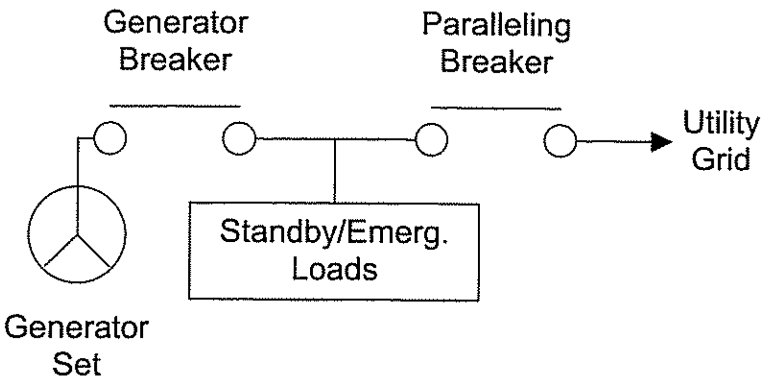

Figure 8: Sample Application One-Line Distribution Diagram

In this sample application, two sets of auxiliary contacts provided by the paralleling breaker are used to determine the engine's operating mode. Figure 9 shows how the remote Gain and Remote Droop inputs are wired.

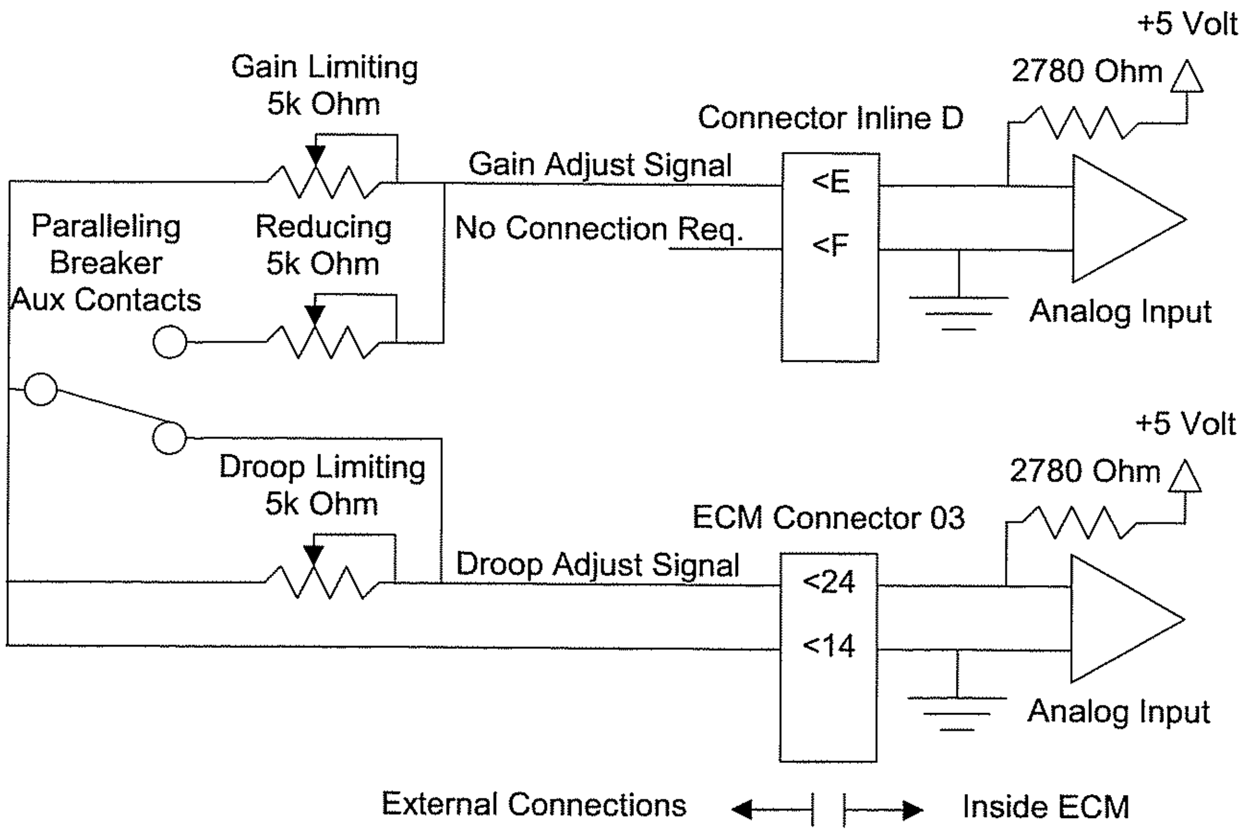

Figure 9: Sample Application Wiring

When the set is operating as a standby generator set, the paralleling breaker is open. One set of auxiliary contacts commands the engine to operate in isochronous mode (droop commanded to zero) and gain set by the Limiting Potentiometer setting. This allows a responsive gain setting with no droop for the stand-alone operation.

When the set is paralleled with the utility grid, the paralleling breaker is closed. In this state the engine is commanded to operate with speed droop and a lower gain setting (defined by the equivalent resistance of the two gain potentiometers connected in parallel). The speed droop allows for manual load control and the lower gain setting provides for smooth load operation while the generator set is paralleled to the utility grid.

Conclusion:

Design of the optimal system for controlling Governor Gain and/or Governor Speed Droop must include considering the conditions associated with the installation, normal operating modes and failure modes. Specific installations may require additional controls to provide the desired results. Contact Application Engineering if your application include features or needs beyond the scope of this bulletin.