Caterpillar
Grade Control Information for Motor Graders and Track-Type Tractors

Version: 1.3

Date: 07/25/2014

CATERPILLAR®

CATERPILLAR®

CATERPILLAR GRADE CONTROL INFORMATION FOR CATERPILLAR EQUIPMENT MANUAL END USER LICENSE AGREEMENT

The enclosed Caterpillar Grade Control Information for Caterpillar Equipment Manual (together with all related documentation, data, protocols, pin-out arrangements and content delivered, the "Manual"), is licensed, not sold, to you for use only under the terms of this End User License Agreement (the "License"). Title to the Manual belongs to, and at all times shall remain the property of, Caterpillar Inc. and/or its affiliated companies and licensors ("Caterpillar"). The Manual is protected by copyright law and may be protected by patents and/or trademarks. By agreeing to this License Agreement, you do not become the owner of the Manual or acquire any rights therein or in any intellectual property other than those rights specifically granted below. Caterpillar reserves all rights not expressly granted to you. Use of the Manual by anyone other than you is strictly prohibited. USING THE MANUAL IN ANY MANNER INDICATES YOUR ACCEPTANCE OF THIS LICENSE. IF YOU DO NOT AGREE TO ALL OF THE TERMS AND CONDITIONS OF THIS LICENSE, YOU MUST NOT USE THE MANUAL AND MUST PROMPTLY RETURN THE MANUAL TO CATERPILLAR.

LICENSE

You may use the Manual only to facilitate the integration of your grade control systems with the applicable Caterpillar machines in a reasonable and appropriate manner. You may not:

1. Transfer, assign, resell or otherwise convey any interest in this License or otherwise provide, duplicate, or disclose the Manual or any copy thereof to any third party;
2. Grant a sublicense, a lease, or any other right in the Manual to any third parties;
3. Export or re-export the Manual without the appropriate United States and/or foreign government license(s);
4. Circumvent the Caterpillar protocols, systems and processes described in or related to the Manual; or
5. Utilize the Manual to reverse engineer, decompile or deconstruct any Caterpillar products.

NO WARRANTIES

Caterpillar, in its sole discretion, shall determine the content of the Manual. Caterpillar does not warrant that the Manual will meet your requirements or that operation of the Manual will be uninterrupted or error-free. THE MANUAL IS PROVIDED "AS IS" WITHOUT OTHER WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. YOU ASSUME RESPONSIBILITY FOR THE SELECTION OF THIS MANUAL TO ACHIEVE YOUR INTENDED RESULTS, AND FOR THE INSTALLATION, USE, AND RESULTS OBTAINED FROM THIS MANUAL.

IMPROVEMENTS

If you improve, modify, or make derivative of the Manual or any portion thereof, then you shall promptly notify Caterpillar and such improvements and shall assign, and do hereby assign, all intellectual property rights arising from such modifications and derivatives to Caterpillar. Caterpillar may use such improvements, modifications and derivatives without restriction.

LIMITATION ON LIABILITY

In no event will Caterpillar be liable to you, in law or equity, for any direct, special, indirect or consequential damages arising out of your use of the Manual. You agree that regardless of the form of any claim you may have, Caterpillar's liability will not exceed the license fee you paid for your rights to use the Manual.

TERM

This Agreement is effective until terminated as hereinafter provided. The license granted herein will automatically terminate without further action of Caterpillar if you fail to comply with the restrictions as recited herein. These restrictions are for the benefit of Caterpillar and/or applicable licensors of the copies thereof. Caterpillar may also terminate this License at any time. You may terminate this Agreement at any time by either returning the Manual together with all copies thereof to Caterpillar or by destroying the same. Upon termination all of your rights to use Manual shall cease and any further use by you is strictly prohibited.

INDEMNIFICATION

You will indemnify, defend and hold harmless Caterpillar, its directors, officers, employees and agents from and against any and all suits, claims, demands, losses, damages, costs and expenses of any nature whatsoever, including without limitation, litigation expenses, attorney's fees and liabilities incurred in connection therewith, for any third party claim arising out of this agreement or your use of the Manual.

PUBLICITY

This Agreement is binding upon and inures solely to the benefit of the parties hereto and their respective successors and permitted assigns, and no third party shall have any rights, privileges, or remedies hereunder or pursuant hereto. This Agreement will not be construed to establish a fiduciary, partnership, agency, joint venture, or other similar relationship. You agree not to use, or allow the use of, any trademark, name or trade name, service mark, trade dress or other designation of, or owned by, Caterpillar or its affiliates in connection with: (a) your business, (b) the marketing, sale or distribution of your grade control systems, or (c) your use of the Manual.

GENERAL

This Agreement will be governed by the laws of the State of Illinois, United States of America. This Agreement may be modified only in a writing signed by the duly authorized representatives of Caterpillar. No action may be brought for any breach of warranty more than one year following the initial of the grant of the License hereunder.

YOU ACKNOWLEDGE THAT YOU HAVE READ THIS AGREEMENT, UNDERSTAND IT AND AGREE TO BE BOUND BY ITS TERMS AND CONDITIONS. YOU FURTHER AGREE THAT IT IS THE COMPLETE AND EXCLUSIVE STATEMENT OF THE AGREEMENT BETWEEN US, WHICH SUPERSEDES ANY PROPOSAL OR PRIOR AGREEMENT, ORAL OR WRITTEN, AND ANY OTHER COMMUNICATIONS BETWEEN US RELATING TO THE SUBJECT MATTER OF THIS AGREEMENT.

1 Introduction

1.1 Opening Statement

Caterpillar manufacturers and sells construction equipment that is ready for or includes integrated machine guidance systems. These machine guidance systems are engineered, developed and tested in cooperation with Caterpillar Trimble Control Technologies, a machine guidance systems joint venture company between Caterpillar and Trimble Navigation Ltd. While Caterpillar machines will support interface to other machine guidance systems, Caterpillar's preferred aftermarket machine guidance system is Cat AccuGrade – which is specifically engineered and tested for use on Caterpillar machines. Caterpillar's preferred technology partner is Trimble Navigation Ltd. Caterpillar does not have partnerships with other 3rd party machine guidance system providers, and has not validated these systems on Cat equipment.

1.2 Document Purpose

The purpose of this document is to share, information related to Caterpillar machine and machine guidance systems to allow better machine integration with other providers of machine guidance.

1.3 Document Scope

The scope of this document is to specify some technical information regarding the aftermarket machine control and guidance systems on Caterpillar machines that will facilitate better integration of other providers of aftermarket machine control and guidance on Caterpillar machines. This information will include descriptions of some machine control and guidance features, pin information, harnesses, layout, and software protocol utilized.

2 General System Operation

2.1 Product Perspective

2.1.1 Machine Guidance Control for Track Type Tractor Operation

The purpose of this function is to provide automatic blade control for Track Type Tractor machines. The feature automatically controls the lift and tilt solenoids on the machine to maintain a given grade.

The system is either:
2D System – Referenced to Laser, sonic or slope sensor that defines the desired grade
3D System – Referenced to an internal electronic file in the display that defines the desired grade (GPS or total station)

2.1.2 Machine Guidance Control for Motor Grader Operation

The purpose of this function is to provide automatic blade control for Motor Grader machines. The feature automatically controls the lift solenoids on the machine to maintain a given grade.

The system is either:
2D System – Referenced to Laser, sonic or slope sensor that defines the desired grade
3D System – Referenced to an internal electronic file in the display that defines the desired grade (GPS or total station)

3 General Interface Details

3.1 Introduction

Many Caterpillar machines models have an electronic control module (ECM) that controls the blade on the machine. Grade control systems can communicate with this ECM to provide automatic control of the blade.

3.2 General Machine Interactions

3.2.1 Software Enabled Attachment

To operate a grade control system on a Caterpillar machine the AccuGrade software enabled attachment (SEA) must be installed into the machine or implement ECM. This SEA enables grade control systems (AccuGrade as well as other 3rd party systems) to work with the machine or implement ECM to control the blade.

Most machines built after January 2013, have this SEA installed from the factory.

This SEA is available free of charge from any Caterpillar dealer. The dealer uses the Caterpillar Feature Protection System (FPS) to generate the SEA and the Caterpillar Electronic Technician (ET) service tool to install the SEA onto the ECM.

3.2.2 Grade Control Logic

Arbitration logic in the ECM is used to decide which signal is used to drive the implement valves that move the blade.

A summary of the logic is:

Automatic Mode

Implement handle (of the automatically controlled function) **in neutral position**

- Grade control system commands drive the valves

Implement handle (of the automatically controlled function) **out of the neutral position**

- Operator implement handle commands drive the valves

Manual Mode

- Operator implement handle commands drive the valves

3.2.3 Machine Interlocks

There are machine interlocks that prevent the ECM from allowing automatic control in certain conditions.

To allow grade control, the following interlocks must be met:

- Parking brake must be off
- Implements must be unlocked
- No active diagnostics on grade control switches or implement solenoids
- Operator must put the grade control system into Automatic mode (The system defaults to the Manual mode on each power up of the machine)
- There may be other machine specific interlocks

To allow grade control calibrations (Land Leveling(LOI) Service Mode)

- Parking brake can be on

3.3 CAN Interface

3.3.1 CAN Physical Layer

Caterpillar typically uses unshielded twisted pair for the CAN bus. See J1939/15 for more information on the physical CAN bus characteristics.

Caterpillar dedicates a CAN bus specifically for grade control. The grade control CAN bus is separate from the machine CAN bus. It is physically accessible through the Grade Control Ready (GCR) connector which is described in this grade control electrical interface document. A grade control system must not splice into a non-grade control machine CAN bus.

3.3.2 CAN Data Rate

The Caterpillar ECM CAN bus runs at 250k bits/second.

3.3.3 CAN Bus Termination

A properly terminated CAN bus has a 120 ohm terminator at each end of the harness. So the CAN bus must have a 60 ohm impedance between the CAN Hi and CAN Lo wires.

3.3.4 CAN Bus Load

In general the steady state bus load of the grade control system should be less than 35%. Note that excessive CAN bus loads can degrade the machine ECM performance.

3.3.5 J1939 Address Claim

All components on the CAN bus should use J1939 source address arbitration to prevent address conflicts on the CAN bus. Address claim information is also used in the auto-detection function (see below).
PGN 60928
See J1939/81 for definitions of PGN

3.3.6 J1939 Land Leveling System Operational Information (LOI)

This CAN message is used to communicate operational information from the Caterpillar ECM to the grade control system. This includes machine status and switch information.

PGN 61453

For Track Type Tractors:

SPN 3156 – Blade Control Mode Switch
SPN 3157 – Desired Grade Offset Switch

SPN 3158 – Blade Auto Mode Command

For Motor Graders:
SPN 3158 – Blade Auto Mode Command
SPN 3334 – Left Blade Control Mode Operator Control
SPN 3336 – Left Desired Blade Offset Operator Control
SPN 3335 – Right Blade Control Mode Operator Control
SPN 3337 – Right Desired Blade Offset Operator Control
SPN 3338 – Side-shift Blade Control Mode Operator Control

Note: Error Indicator and Not Installed states will be sent if the system is not installed or if there is an error with the switch.

See J1939/71 for definitions of PGN and SPN

3.3.7 **ISO 11783 Auxiliary Valve Command**

This CAN message is used to communicate valve commands from the grade control system to the Caterpillar ECM.
PGN 65073, 65074 and 65075

For track type tractors:
PGN 65073 controls blade lift
PGN 65074 controls blade tilt

For motor graders:
PGN 65073 controls blade left lift cylinder
PGN 65074 controls blade right lift cylinder
PGN 65075 controls blade side shift

See ISO 11783-07 for full definition of PGN

Note: that Caterpillar ECM's use loop based (not interrupt driven) tasks to process the valve commands. The period of the processing task can vary by machine model.

Note: The machine ECM will timeout the Auxiliary Valve Commands if they are not seen for 250ms. The machine ECM will turn off current to the solenoid valves until a valid auto command or manual input is seen

3.3.8 Grade Control Auto-Detection

Some machine implement handle switches have multiple uses. For example on some Track Type Tractors, the grade control Auto/Manual switch is used for blade shake when a grade control system is not connected. The Caterpillar ECM uses auto-detection to sense if a grade control system is connected to change the function of these switches.

The Auto-detection feature has three modes, Automatic, Enabled and Disabled. The Enabled and Disabled modes should only be used for trouble shooting purposes.

Automatic – This is the default mode.

Grade control is enabled, if a J1939 Address claim is made for specific grade control system components listed in the table below. (See J1939 Table B12 for more details on Name Functions.)

Industry Group	Vehicle System	Name Function	Description
03	00	129	Laser Receiver
03	00	131	Electric Mast
03	00	133	Land Leveling System Display
03	00	144	Survey Total Station Target
03	00	160	GPS Receiver (not assigned in J1939)

If no corresponding address claims are seen, the grade control feature is disabled and alternate implement handle switch features (like blade shake) are available for use.

Enabled – Auto-Detection is disabled and the grade control feature is set to be always enabled. Machine switches are dedicated to grade control and any secondary feature (like blade shake) is disabled.

Disabled - Auto-Detection is disabled and the grade control feature is set to be always disabled. Machine switches are dedicated to non-grade control features (like blade shake) and the grade control feature is disabled.

These modes can be programmed using the Caterpillar ET service tool or using button presses at power up. Access to Caterpillar ET service tool is available upon request through your local Caterpillar dealer.

- Automatic - Press and hold Auto/Manual for at least 5 seconds. but no more than 15 seconds at machine power up
- Enabled - Press and hold Increment for at least 5 seconds. but no more than 15 seconds at machine power up
- Disabled - Press and hold Decrement for at least 5 seconds. but no more than 15 seconds at machine power up

Note: If needed, see Operation and Maintenance Manual for button locations

3.3.9 Other Machine Information

Additional machine specific information (direction, gear, parking brake) is also available on the grade control CAN bus. Information is available in J1939 format.

4 Electrical Connector Details

The following list of connectors and connections used in the system. Provisions must be made to electrically connect these components and adjoining harnesses

- Quick connectors for coil cords
- Front harness / main fall connections
- Dash connector
- Lightbar connector
- Data Radio connector
- Expansion connector
- J1939 diagnostic connector
- Power module pass thru connectors
- Power module connectors
- GCR CAN connector
- GCR Power connector

Note – *the power module is a device specific for use with the Cat AccuGrade machine guidance system.*

The following sections outline the detailed mechanical requirements, starting from the front of the machine and moving back.

4.1 Quick Connectors

AccuGrade Ready Option (ARO) Track Type Tractors (TTT) have three Quick Connectors on the front of the machine. AccuGrade Ready Option (ARO) Motor Graders (MG) have four Quick Connectors on each side of the gooseneck on the machine. These connectors are used to connect to blade mounted position sensors via coil cables.

4.1.1 Connector Information

Quick connector p/n - 230-2566

4.1.2 Connector Locations

- For ARO TTT machines, mounting positions for left, right and slope connectors are placed in accessible locations for connecting the coil cables near the front of the machine. Left and slope are often located on the same side.
- For ARO MG machines, mounting positions are located with two connectors on the right side of the gooseneck and two connectors on the left side of the gooseneck

4.1.3 **Connector Pinouts**

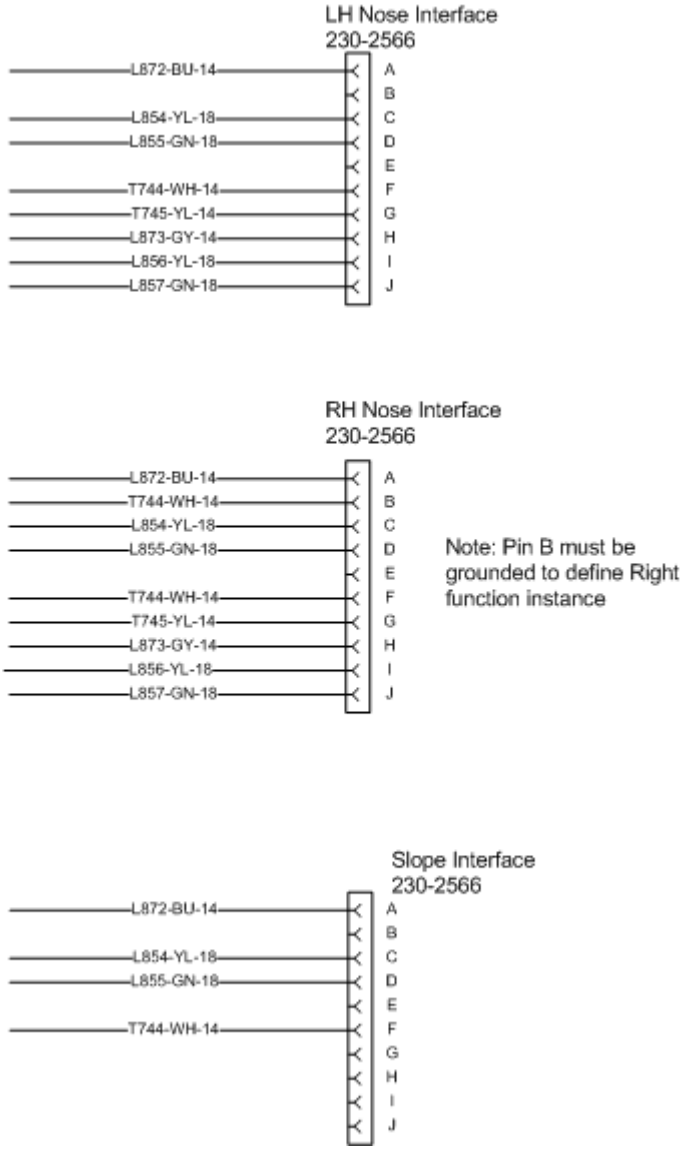

Figure 1: Left/Right and Slope Connector Pinouts for TTT machines

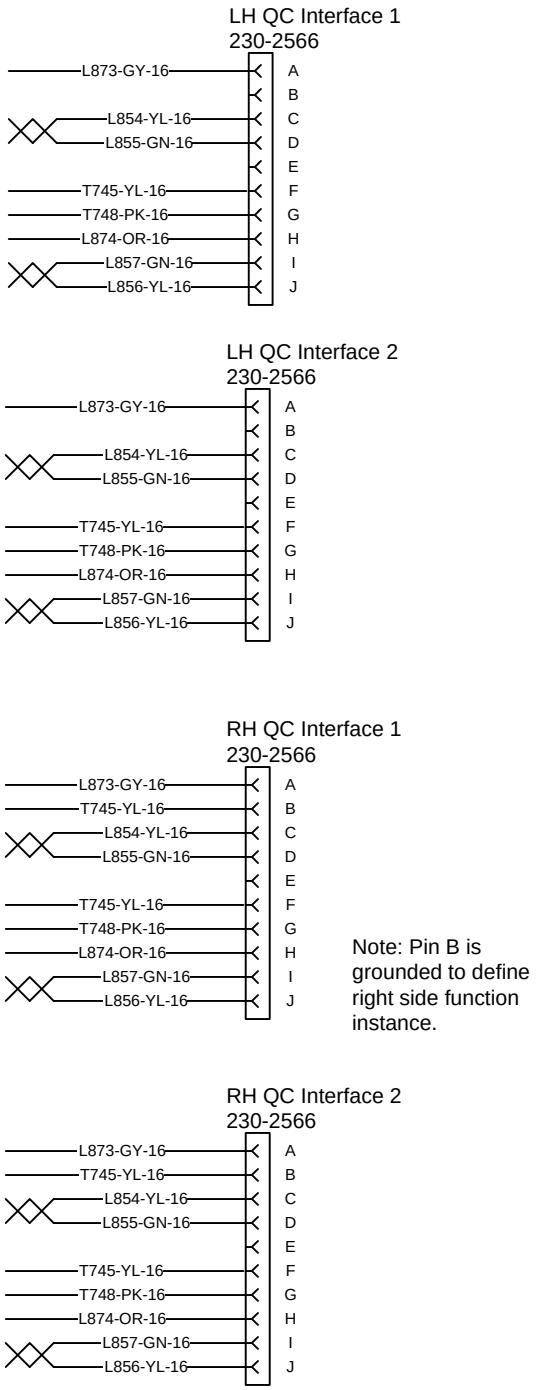

Figure 2: Left/Right Quick Connector Pinouts for MG machines

4.1.4 Model Variations

- Smaller TTT machines may mount the connectors on the front of the radiator housing.
- Larger TTT machines may mount the connectors on the sides of the lift cylinders.

4.2 Front Harness Connector

TTT ARO machines have a 12-pin front harness connector. MG ARO machines have a 14-pin front harness connector. Common front harness connectors are used to provide signals to the front of the machine. This connector contains CAN signals and switched power and can also be used to connect a main fall (machine pitch) sensor.

4.2.1 Connector Information

155-2252 – Machine / chassis side (TTT)
3E-5179 – Quick connect side (TTT)
359-5180 – Machine / chassis side (MG)
359-5179 – Quick connect side (MG)

4.2.2 Connector Location

For ARO TTT machines, the 12-socket connector is mounted outside the cab engine compartment. This allows a mainfall sensor to be mounted on the frame in the engine compartment and allows for access to the front nose connectors.
For ARO MG machines, the 14 pin bulkhead connector is located at the front of the cab, typically on the right side.

4.2.3 Connector Pinout

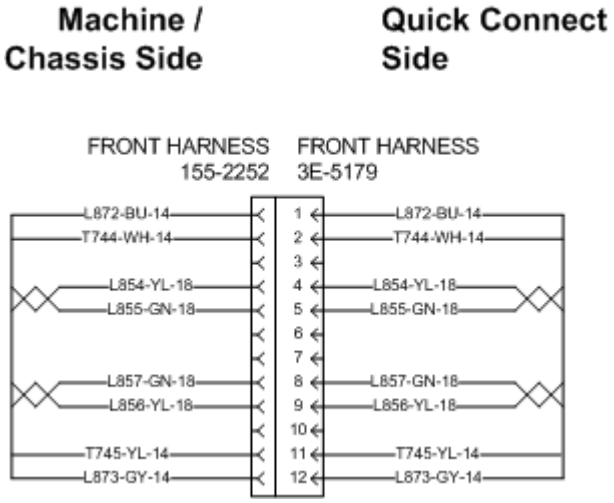

Figure 3: ARO TTT Machine Front Harness Connector Pinout

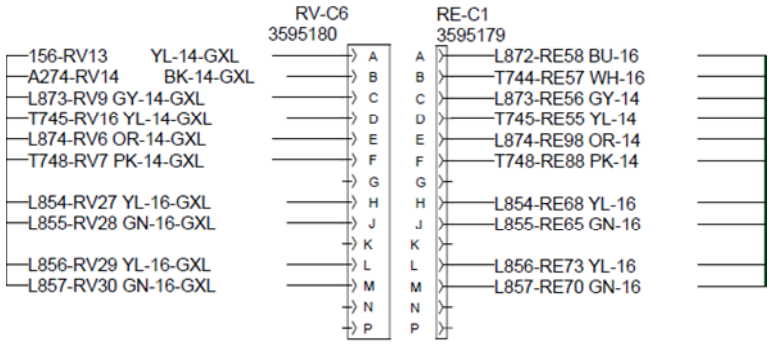

Figure 4: ARO MG Machine Front Harness Connector Pinout

4.2.4 Model Variations

Usual locations for the connectors on ARO TTT machines are near the radiator (on the engine side).
Usual location for the connectors on ARO MG machines are near the lower right of the front of the cab

4.3 Dash Connector

TTT and MG ARO machines have a 31-pin Dash connector.
A common dash connectors is used provide signals to the display.

4.3.1 Connector Information

Connector p/n's (pick connector appropriate for type of wire used)

- 225-3861
- 331-3595

4.3.2 Connector Location

This 31-pin connector is a bulk-head mounted connector that allows a single hole through which all the signals can enter the cab. In most instances the connector will be located in the dash to allow for a dash mounted display.

4.3.3 Connector Pinout

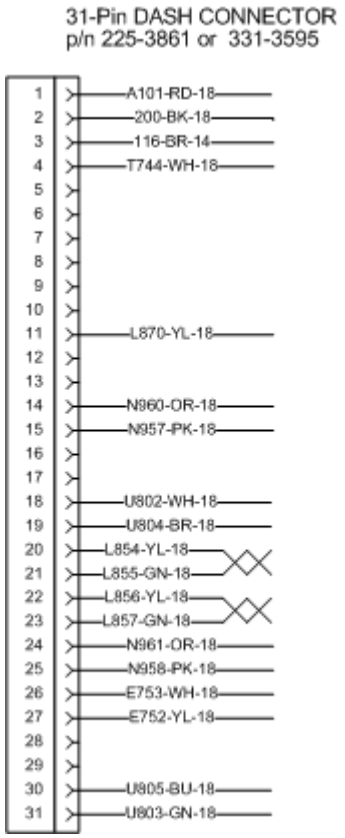

Figure 5: Dash Connector Pinout

4.4 Data Radio Connector

TTT and MG ARO machines have a 12-pin Data Radio connector to provide signals to various radios. This connector contains serial, CAN and Ethernet signals as well as power.

4.4.1 Connector Information

Connector p/n – 237-0164

4.4.2 Connector Locations

This 12-socket connector is usually mounted outside the cab so that the radio can be installed on the roof.

4.4.3 Connector Pinout

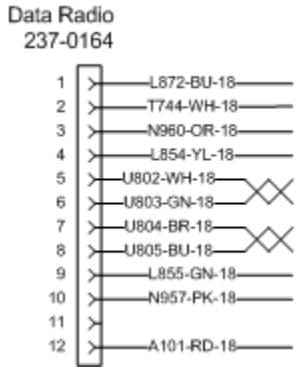

Figure 6: Data Radio Connector Pinout

4.4.4 Model Variations

Note: The Data Radio and Expansion connector are typically grouped in the same location.
Note: This connector is usually near the end of the CAN bus meaning the terminating resistor is often installed nearby

4.5 Expansion Connector

TTT and MG ARO machines have a 12-pin expansion connector.
This common "expansion" connector provides signals to third party radios, cab mounted GPS and other components. This connector contains serial and CAN signals as well as power. It also can provide signals relevant for cab mounted GPS applications.

4.5.1 Connector Information

Connector p/n – 155-2253

4.5.2 Connector Location

This 12-socket connector is mounted outside the cab next to the Data Radio connector. This allows connecting third party radio to be placed on the roof, or provides connectivity to a cab/roof mounted GPS receiver.

4.5.3 Connector Pinout

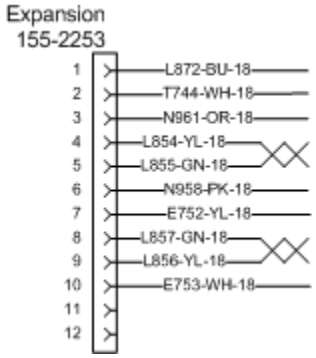

Figure 7: Expansion Connector Pinout

4.5.4 Model Variation

Note: The Data Radio and Expansion connector are typically grouped in the same location.
Note: This connector is usually near the end of the CAN bus meaning the terminating resistor is often installed nearby

4.6 J1939 Diagnostic Connector

TTT ARO machines have a 9-pin J1939 connector to be used for diagnostics.

4.6.1 Connector Information

P/N 210-8950

4.6.2 Connector Location

If included, this 9-socket connector is typically located inside the cab.

4.6.3 Connector Pinout

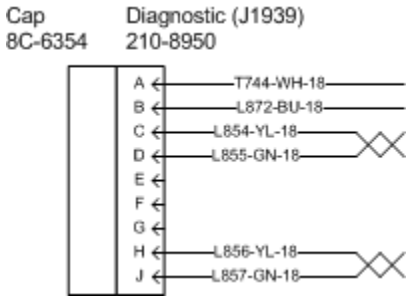

Figure 8: J1939 Diagnostic Connector Pinout

4.6.4 Model Variations

On some machines, this service connector may be wired as a CAN drop-on-a-drop without negative impact.

4.7 Power Module Pass Thru Connectors

TTT ARO machines use a 12-pin power module pass thru connectors.
Common power module connector are used to provide signals to the power module. This connector contains Power signals as well as an awake signal to turn on the power module. The design allows the connectors to be plugged in and by-pass the power module for standard machines (providing only sensor power).

4.7.1 Connector Information

230-4009 IN from GCR power
230-4010 OUT from power module

4.7.2 Connector Location

The 12-pin power module pass thru connector is located near the power module. Typically this is under the cab in TTT ARO machines and in the headliner on MG ARO machines.

4.7.3 Connector Pinout

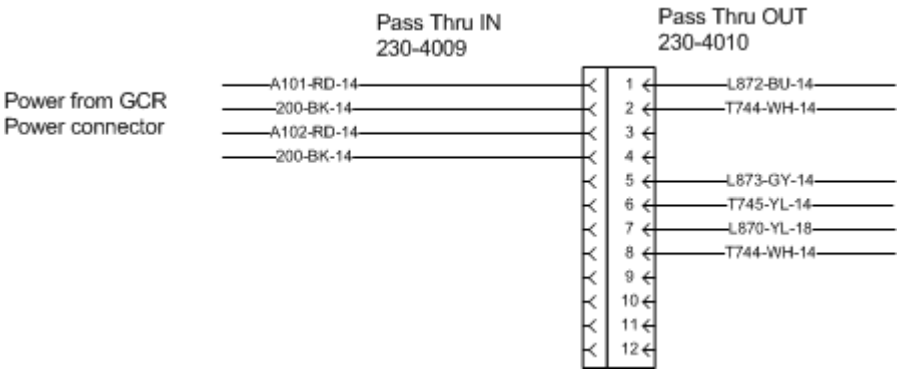

Figure 9: POWER MODULE Pass Thru Connector Pinout

4.7.4 Model Variation

Note: The power module is currently offered as part of the ARO (factory and dealer installed)

4.8 POWER MODULE Connectors

The power module supplies conditioned switched power for grade control system components.

4.8.1 Connector Information

155-2252 – Machine / chassis side
3E-5179 – Quick connect side

4.8.2 Connector Location

The 12-pin power module pass thru connector is located near the power module. Typically this is under the cab in TTT ARO machines and in the headliner on MG ARO machines.

4.8.3 Connector Pinout

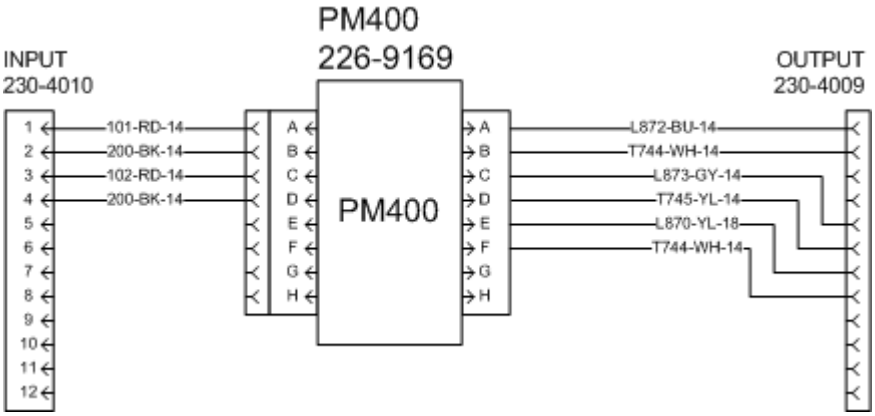

Figure 10: POWER MODULE Connector Pinout on TTT ARO machines

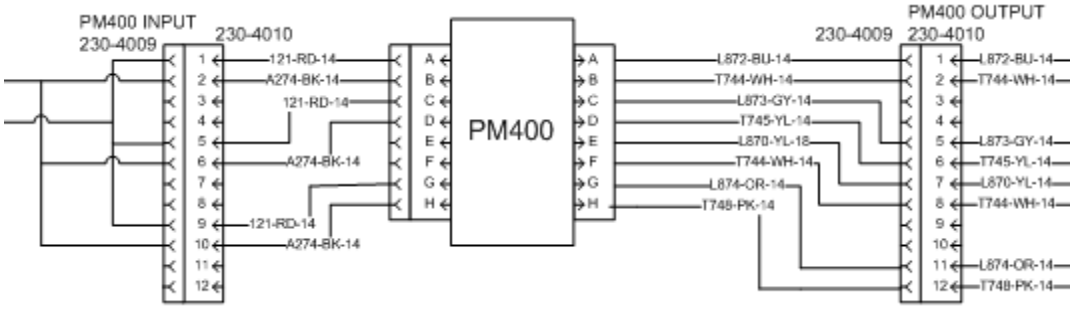

Figure 11: POWER MODULE Connector Pinout on MG ARO machines

4.9 GCR CAN Connector on TTT ARO machines

TTT ARO machines have the Standard 6-pin GCR CAN connector. This connects the machine guidance system to the implement ECM.

Note: If a Stable Blade sensor is included on the machine, it will have connectivity to the machine guidance system. This system needs to have a fully terminated CAN bus without Machine guidance installed.

4.9.1 Connector Information

174-0502 – Machine / chassis side
133-0973– ARO connection side

4.9.2 Connector Location

This 3-pin connector is located in an accessible area on the machine outside the cab so that a dealer installed system can be easily installed. The GCR CAN and GCR Power connectors should be mounted close to each other.

4.9.3 Connector Pinout

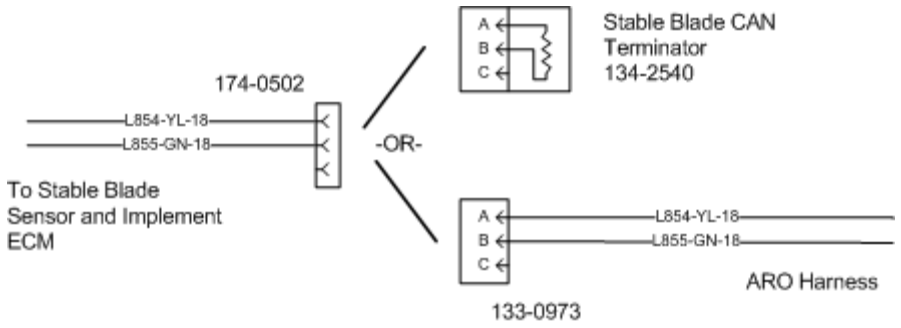

Figure 12: Standard GCR CAN Connector Pinout

4.10 GCR Power Connector on TTT ARO machines

TTT ARO machines have the Standard 6-pin GCR Power connector.

4.10.1 Connector Information

155-2273 – Machine / chassis side
3E-3382 – ARO / POWER MODULE… connected side

4.10.2 Connector Location

This 6-pin connector is located in an accessible area on the machine outside the cab so that a dealer installed system can be easily installed. The GCR CAN and GCR Power connectors should be mounted close to each other.

4.10.3 Connector Pinout

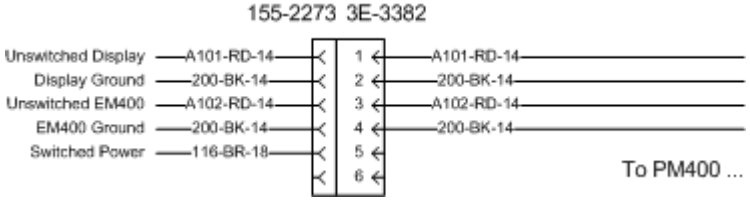

Figure 13: Standard GCR Power Connector

4.11 GCR Connector on MG ARO machines

MG ARO have the Standard 8-pin GCR connector. This connects the machine guidance system to the implement ECM through CAN B as well as supplying machine switched power, unswitched power, and ground.

4.11.1 Connector Information

3E-3388– ARO connection side

4.11.2 Connector Location

This 8-pin connector should be located in an accessible area on the machine so that a dealer installed system can be easily installed.

4.11.3 **Connector Pinout**

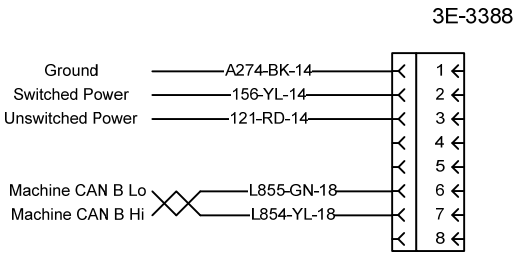

Figure 14: Standard GCR Connector Pinout

5 Electrical Information

5.1 Complete Signal List

The following figure summarizes the signals utilized by the Machine guidance system.

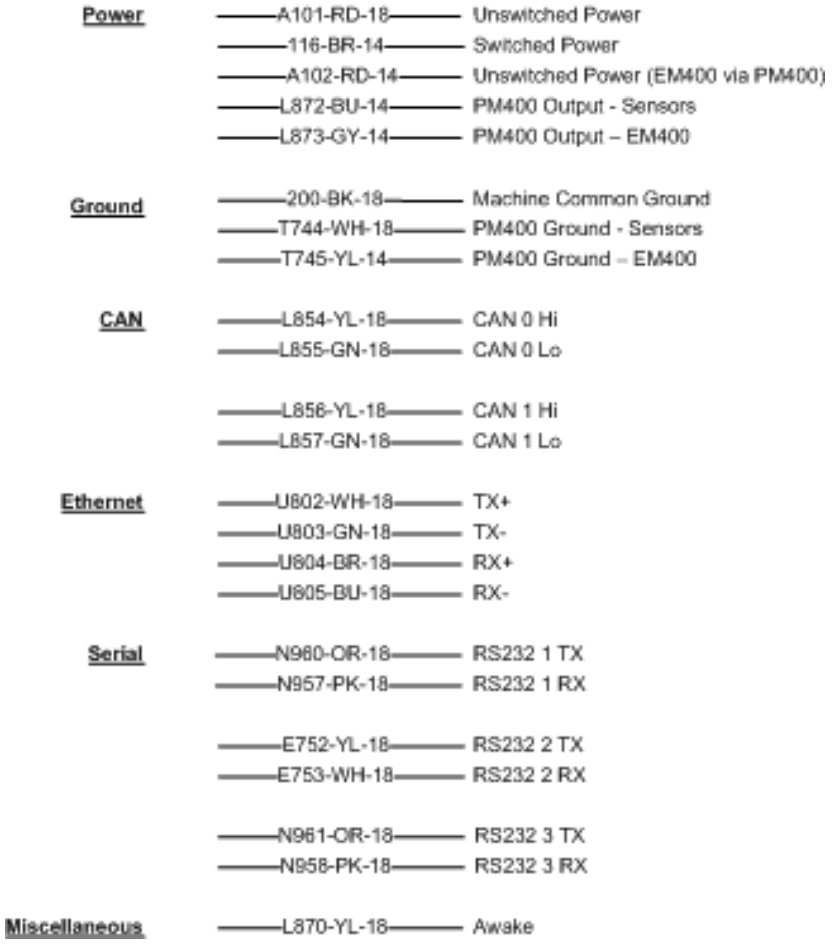

Figure 15: Complete Signal List

6 Reference Material

For model specific information on machine operation consult the machine Operations and Maintenance Manual, or contact your local Caterpillar Dealer.

7 History

Table of document changes for tracking content

Date	Version	Author	Description
11/27/2013	1.0	B. Hobbs	Addition of button timeout info on the Auto Detection Modes
4/1/2014	1.1	B. Hobbs	Addition of document change history table
6/4/2014	1.2	B. Hobbs	Removal of inaccurate interlock condition and addition of interlock exceptions in service mode
7/25/2014	1.3	J. Thomas	Final review and Opening Statement addition