

## CHAPTER 3. ELECTRICAL SYSTEM

## SECTION 2. SYSTEMS AND SUB-SYSTEM DIAGRAMS AND DIAGNOSTICS

## STARTING AND CHARGING CIRCUIT AND THEORY OF OPERATION

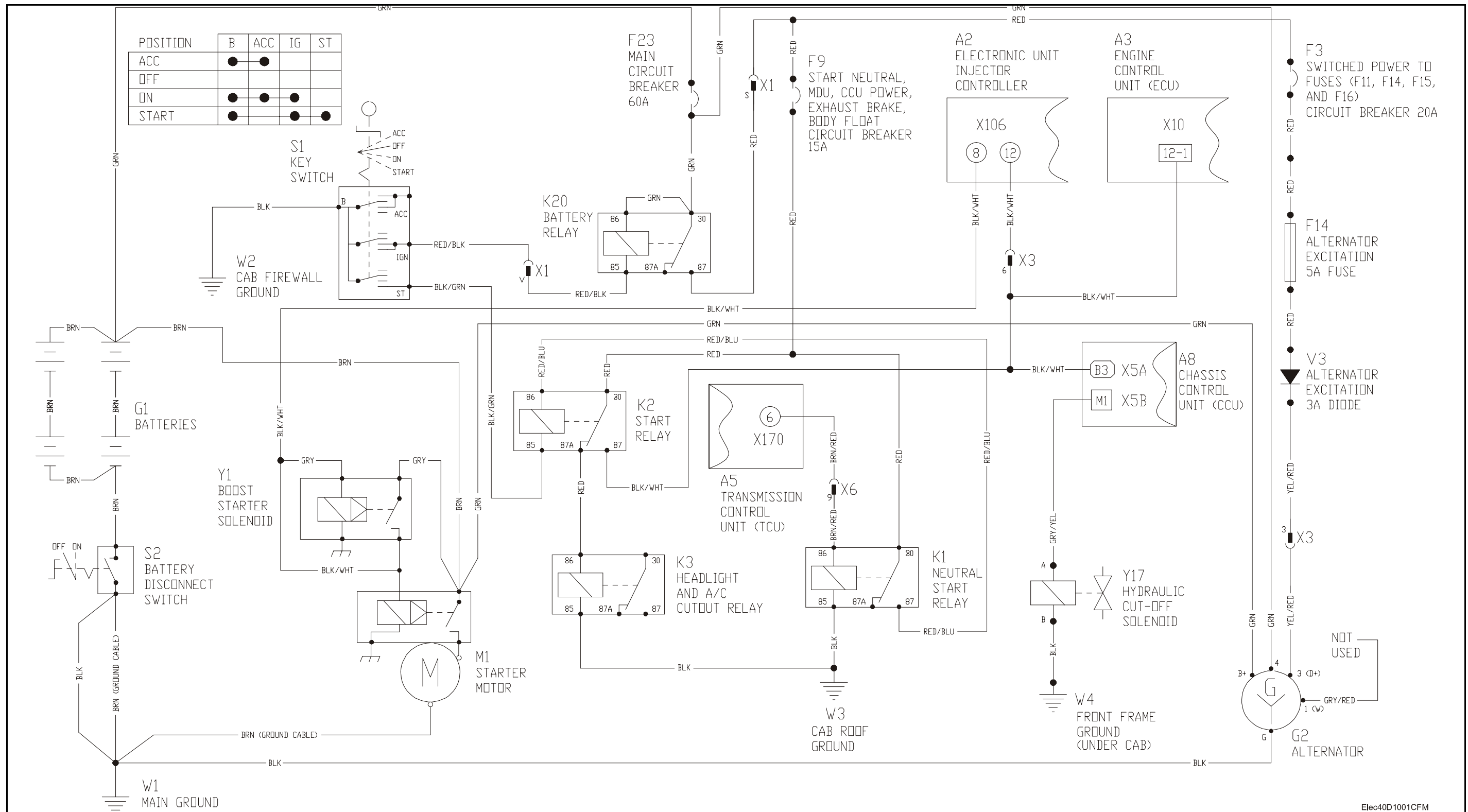


Figure 3-1

The tachometer on the Menu Display Unit is accurate enough for test work. (See **Operators Manual CHAPTER 2 for more information and CHAPTER 8 for detail operating the Menu Display Unit**).

Starting Circuit

When key switch (S1) is turned to the “ON” position, power becomes available at terminal 30 of neutral start relay (K1). At the same time, current flows across the normally closed contact of start relay (K3), energizing the relay. With relay (K3) energized, current is allowed to flow to the headlight and air conditioning circuits, allowing these circuits to function as needed.

With the key switch in the “ON” or “START” position, the transmission control unit (TCU) (A5) will confirm if transmission is in neutral. When it is confirmed that the transmission is in neutral, the TCU will allow current to flow out terminal 6 of TCU connector X170 to the coil of neutral start relay (K1), energizing the relay. With relay (K1) energized, power is now available at the coil of start relay (K2). The TCU also sends a signal to the transmission shift control (not shown in circuit schematic), to an “N” on the range indicator.

Turning key switch (S1) to the “START” position provides a ground to the coil of start relay (K2), energizing the relay. With relay (K2) energized, current flows to the electronic unit injector (EUI) controller (A2), engine control unit (CCU) (A8), signalling the “START” process.

When the CCU receives current at terminal B2 of connector X5A, the CCU sends current out terminal M1 of CCU connector X5B to hydraulic cut-off solenoid (Y17), energizing the solenoid. With hydraulic cut-off solenoid (Y17) energized, the hydraulic pump is destroyed, which allows the engine to crank easier.

The start signal at terminal B3 of connector X5A also causes the CCU to apply the park brake.

**NOTE:1. For information on operation of the hydraulic pump and load sensing circuit, (See “Main Hydraulic Pump Operation” on page 336).**  
**2. For more information on the park brake, See “PARK BRAKE AND EXHAUST BRAKE CIRCUIT THEORY OF OPERATION” on page 76.**

When the ECU receives current at terminal 12-1 of connector X10, it will confirm the start signal then send a signal through the CAN data line to the EUI controller. When the EUI controller receives current at terminal 12 of connector X106, it checks to see if any engine service codes exist.

**NOTE:1. For more information on the ECU, See “ENGINE CONTROL UNIT CIRCUIT THEORY OF OPERATION” on page 64.**  
**2. For more information on the EUI controller, See “ELECTRONIC UNIT INJECTOR CONTROLLER CIRCUIT THEORY OF OPERATION” on page 62.**

If no engine service codes exists, the EUI controller will send current out terminal 8 of EUI controller connector X106. This current flows to the starter solenoid of starter motor (M1), and at the same time flows to the coil of boost starter solenoid (Y1), energizing the boost starter solenoid. The current from the output of the EUI controller is not sufficient to energize the starter solenoid by itself, but is sufficient to energize solenoid (Y1).

When solenoid (Y1) is energized, current from the battery flows directly to the starter solenoid, energizing the starter solenoid. With the starter solenoid energized, high current from the batteries is allowed to flow through the starter motor windings, causing the starter motor to crank the engine.

During engine cranking, current flow to headlight and A/C cutout relay (K3) is interrupted, thus de-energizing the relay. With relay (K3) de-energized, current to the headlight and air-conditioning circuits is interrupted, deactivating these systems (if activated). Deactivating the headlights and air-conditioning reduces the cranking load on the engine during start-up.

To assist engine starts in cold weather, a cold start system is provided. For information on the cold start system See “COLD START CIRCUIT THEORY OF OPERATION” on page 60.

Charging Circuit

Alternator (G2) provides power to all machine circuits and charges the batteries when the engine is running. Terminal B+ of the alternator is connected to battery positive (+) at all times.

When key switch (S1) is in the “ON” position, current from circuit breaker (F3) is sent to terminal D+ on the alternator to excite the alternator field windings. Alternator excitation diode (V3) prevents current feedback from the alternator if the alternator circuitry is improperly connected or has a major failure.

The battery charge light on the MDU will come ON if any of the following occur:

- Key Switch (S1) is in the “ON” position with engine speed less than 400 r.p.m.
- Alternator (G2) has malfunctioned.
- Alternator output less than 25.5 volts or more than 29.5 volts.
- Difference between single battery voltage and 1/2 system voltage is more than 1.5 volts. See “**Battery Balancer And 12-Volt Accessory Circuit Theory of Operation” on page 90**

During normal machine operation, system voltage is shown on the monitor display.

The battery charge status is digitally displayed in the menu structure of the MDU, when accessed. For more information on the menu structure, See **CHAPTER 8 in Operator’s Manual**.

## COLD START CIRCUIT THEORY OF OPERATION

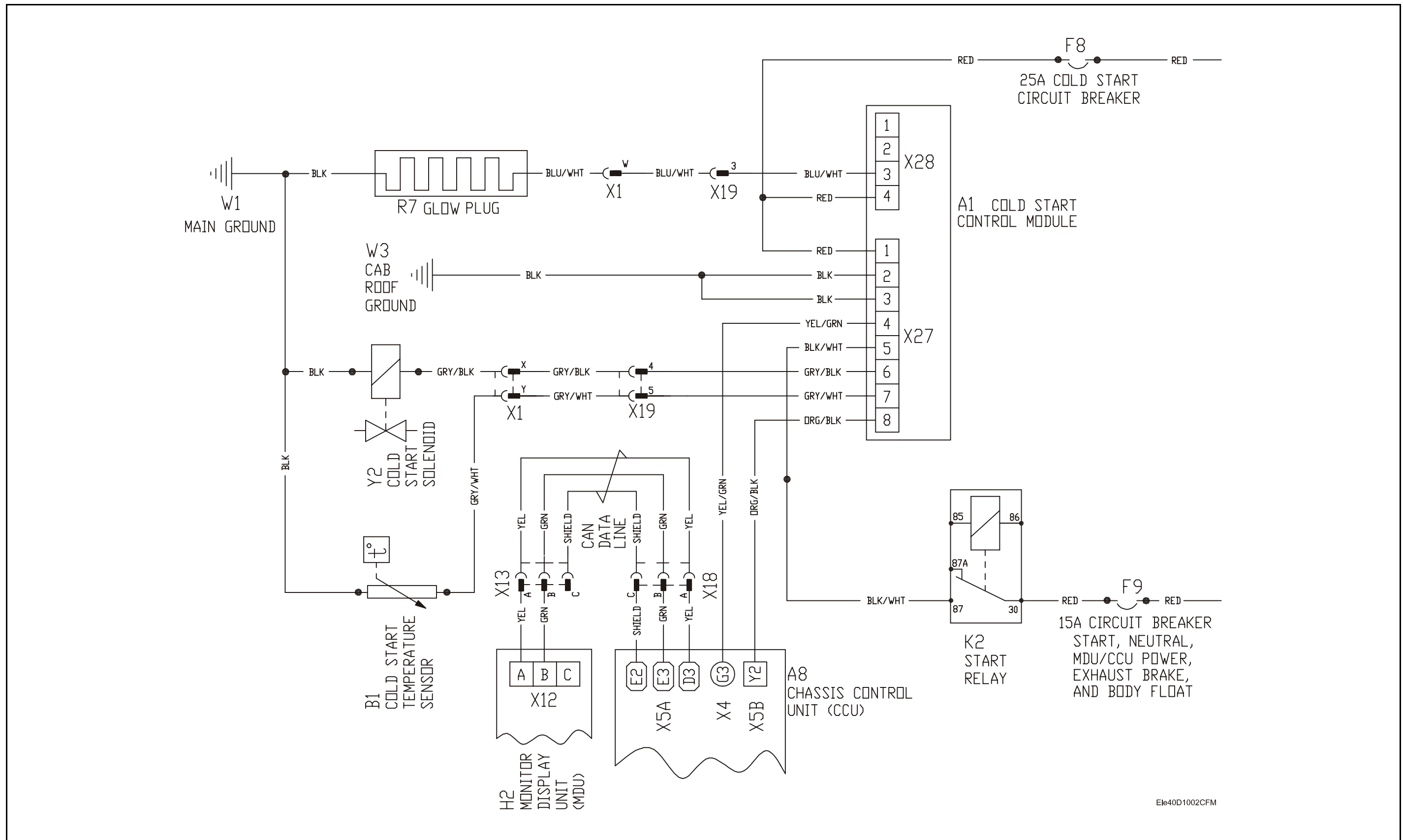


Figure 3-2

When the key switch is turned to the “**ON**” position, power from cold start circuit breaker (F8) is provided at terminal 1 of connector X27 and terminal 4 of connector X28 on cold start module (A1). The cold start control module (A1) will send a signal out terminal 8 of connector X27 to terminal Y2 of connector X5B on chassis control unit (CCU) (A8).

The CCU will then send the signal through the CAN data line to monitor display unit (MDU) (H2), which will cause the COLD START light to come **ON**.

If the ambient air temperature is below 15°C (59°F) the cold start system will remain **ON** for approximately 20 seconds.

If the ambient air temperature is above 15° C (59°F), the cold start light will go **OFF** after 2 seconds.

**NOTE:**The cold start status is displayed in the menu structure of the MDU, when accessed. For more information, See CHAPTER 8 in the OMM.

During a cold start, glow plug (R7) will become hot and the cold start light will lit for approximately 20 seconds then go **OFF**, signalling the engine is ready to be cranked.

During cranking, current from start relay (K2) flows to terminal 5 of connector X27 to let cold start control module (A1) know that the engine is being cranked. During this time, cold start control module (A1) sends current to cold start solenoid (Y2) to allow a small amount of fuel to be sprayed over the hot glow plug, this producing a flame in the combustion chamber located in the intake manifold.

The flame pre-heats the air evenly for all cylinders, which helps reduce fuel consumption during warm-up. This process of glow plug heating and fuel spray will continue until the engine reaches a temperature of 23° C (73° F), then the cold start system will deactivate automatically.

The cold start system will also deactivate if the engine cranking begins before the **COLD START** light goes **OFF**, or if the engine is not started within 30 seconds after the cold start light goes **OFF**. To let the cold start module know the engine is running, the CCU sends a signal out G3 of connector X4 to terminal 4 of cold start module connector X27.

## ELECTRONIC UNIT INJECTOR CONTROLLER THEORY OF OPERATION

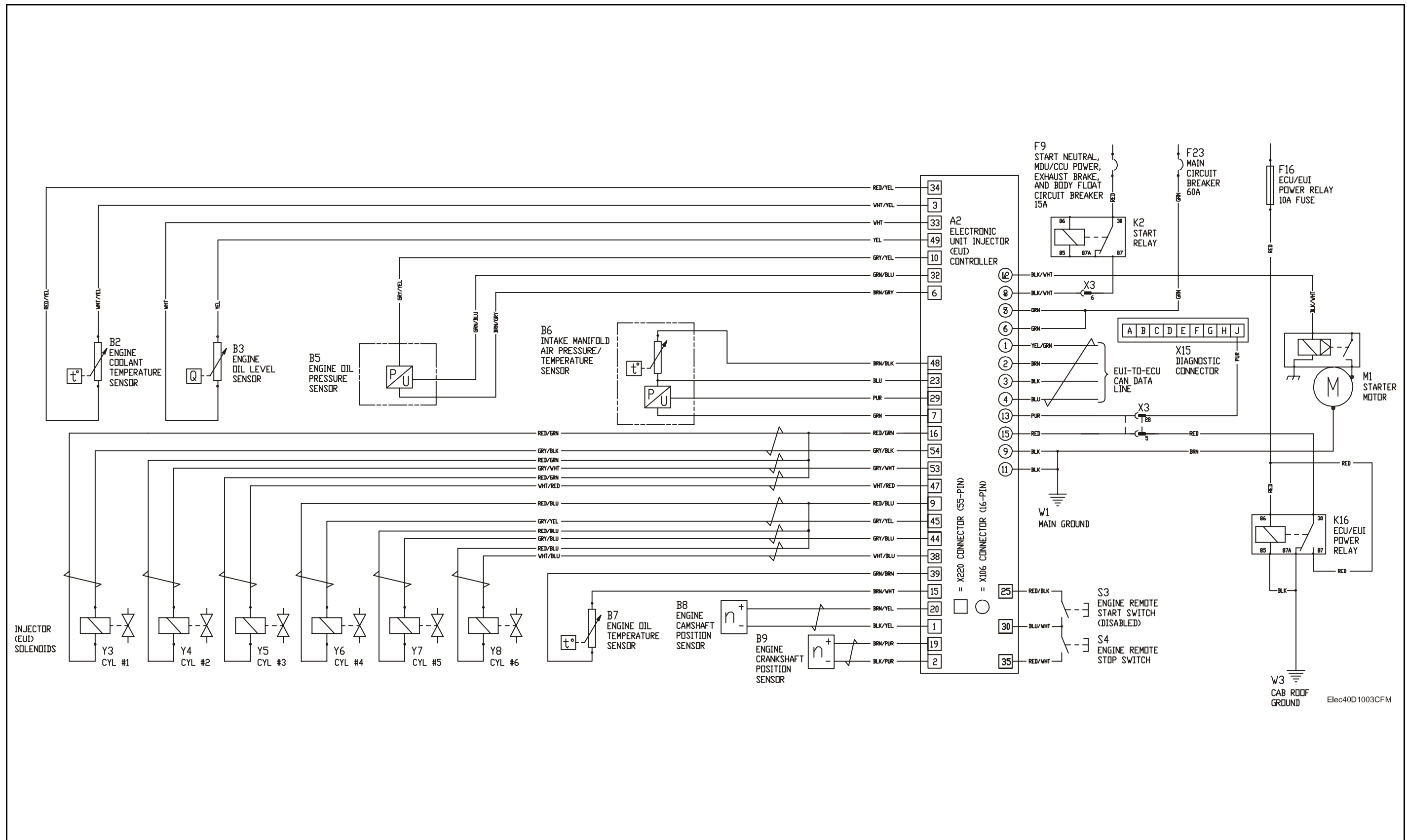


Figure 3-3

The electronic unit injector (EUI) controller (A2) receives unswitched battery power at terminals 5 and 6 of connector X106.

Switched power from the ECU/EUI power relay fuse (F16) is provided at terminal 15 of connector X106.

The EUI controller constantly analyses all relevant engine data (start of injection, load on engine, ambient conditions, etc.) from the engine sensors and data from the engine control unit (ECU), (e.g., accelerator pedal position). For information on the ECU, **See “ENGINE CONTROL UNIT CIRCUIT THEORY OF OPERATION” on page 64.**

The data is stored in the EUI controller and compared with the controller’s pre-programmed software. The controller then computes the quantity of fuel needed (delivery angle) and the optimal injection time (start of delivery), then actuates each injector solenoid of the individual cylinders accordingly. For more information on how the Electronic Unit Injectors Function, **See “Electronic Unit Injector Fuel System” on page 42.**

The EUI controller limits the torque request if the governed speed or a specific engine limit is reached.

The EUI controller has to detect the following variables in order to calculate proper start of delivery:

- Engine Speed.
- Specified Torque.
- Engine coolant temperature.
- Intake manifold air temperature (MAT).
- Intake manifold air pressure (MAP).
- Atmospheric pressure.
- Top dead centre (TDC) of cylinder #1.
- Start signal to starter solenoid.

Engine Speed and TDC

Engine crankshaft position sensor (B9) is the primary sensor for detecting engine speed. It is also used as a backup for detecting top dead centre (TDC) of cylinder #1 should engine camshaft position sensor (B8) malfunction.

To detect engine speed, 36 holes have been machined into the outer edge of the flywheel at 10 degree intervals. A 37th hole, located 65 degrees before top dead centre, is used for the detection of TDC.

Engine camshaft position sensor (B8) is the primary sensor for TDC of cylinder #1. It is also used as backup for detecting engine speed should the engine crankshaft position sensor (B9) Malfuction.

To detect the engine speed, 12 holes has been machined into the outer edge of the camshaft gear at 30-degree intervals. A 13th hole, located 55 degrees before TDC, is for detecting the TDC.

The camshaft and crankshaft position sensors allow the EUI controller to precisely determine piston position in relation to TDC so that the EUI controller can command the correct EUI solenoid at the correct time. The EUI controller then controls the fuel delivery by energizing and de-energizing the individual solenoids that open and close the EUI spill valves.

Temperature Sensors

All engine related temperature sensors used on the B35D and B40D ADT's have a negative temperature coefficient (i.e., sensor resistance decreases as temperature increases).

The EUI controller sends a low reference voltage to the sensor, monitors the voltage drop across the sensor, then compares the voltage drop to pre-programmed values in the EUI controller memory to determine the temperature.

▲ WARNING

Do not apply battery voltage to any of the engine temperature sensors. Damage to the sensor will occur.

Engine Coolant Temperature Sensor

The EUI controller monitors the signal from engine coolant temperature sensor (B2) for:

- Engine protection purposes.
- Starting fuel quantity determination (The EUI controller will adjust the amount of fuel delivered during start-up based on initial engine coolant temperature).
- Start of fuel delivery determination (The EUI controller will adjust the timing of fuel delivered during start-up based on initial engine coolant temperature).
- Specified torque calculation (Limits engine output).

The EUI controller also sends the engine coolant temperature information to the engine control unit (ECU).

The ECU transmits the information through the CAN data line to the MDU where the information is displayed on the COOLANT TEMP. gauge.

**NOTE:1. For more information on the COOLANT TEMP. gauge and the MDU, See “MENU DISPLAY UNIT CIRCUIT THEORY OF OPERATION” on page 78.**  
**2. The engine coolant temperature status is digitally displayed in the menu structure of the MDU, when accessed. For more information on the Menu Display Unit Menu Function, See CHAPTER 8 in Operator’s & Maintenance Manual.**

Engine Oil Temperature Sensor:

The EUI controller monitors the signal from engine oil temperature sensor (B7). The sensor varies voltage with respect to temperature change as follows:

- Oil Temperature @ 130° C (266° F)0,41 volts
- Oil Temperature @ 115° C (239° F)0,56 volts
- Oil Temperature @ 90° C (194° F)0,97 volts
- Oil Temperature @ 70° C (158° F)1,50 volts
- Oil Temperature @ 10° C (50° F)3,96 volts
- Oil Temperature @ -5° C (23° F)4.41 volts
- Oil Temperature @ -20° C (4° F)4,71 volts
- Oil Temperature @ -40° C (-40° F)4.90 volts

Manifold Air Temperature (Mat) Sensor

The MAT sensor is an integral part of the intake manifold air pressure/temperature sensor (B6). The EUI controller monitors the intake manifold air temperature in conjunction with the manifold air pressure to determine air density, then adjust the fuel delivery accordingly.

Pressure Sensors

Manifold Air Temperature (MAP) Sensor

The MAP sensor is an integral part of the intake manifold air pressure/temperature sensor (B6).

The EUI controller monitors the intake manifold air pressure in conjunction with the manifold air temperature to determine air density, then adjust the fuel delivery accordingly.

The EUI controller compares the MAP sensor data with data from an atmospheric pressure sensor located inside the EUI controller.

The comparing of manifold pressure with atmospheric pressure is used for diagnostics purposes and to protect the engine when operating at full throttle above certain altitudes.

Engine Oil Pressure Sensor

The EUI controller monitors the signal from engine oil pressure sensor (B5) and passes the information to the engine control unit (ECU).

The ECU sends the information through the CAN data line to the Menu Display Unit where the information is displayed on the Engine Oil Pressure Gauge.

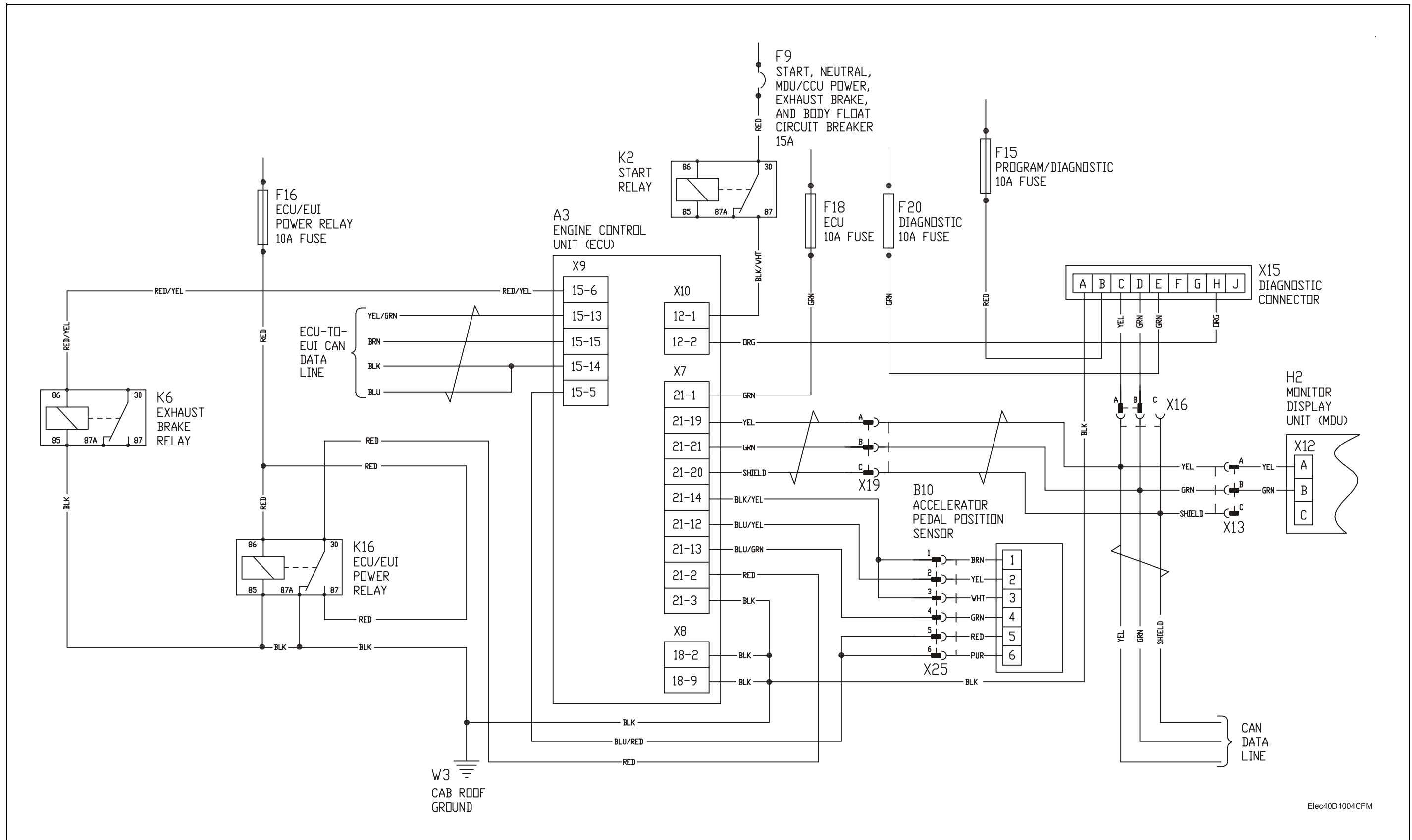
When engine oil pressure becomes less than a predetermined low pressure setting, the red Service light will flash and an audible alarm will sound.

**NOTE:For more information on the Engine Oil Pressure gauge and low oil pressure alarm, See MDU Circuit Theory of Operation in this Section. The engine oil pressure status is digitally displayed in the menu structure of the MDU, when accessed. For more information on the menu structure, See CHAPTER 8 of the Operator’s & Maintenance Manual.**

Switches

Engine remote stop switch (S4), located at the right side of the engine, has a direct connection to the EUI controller for remote engine shut-down. Engine remote start switch (S3), located next to the stop switch, is disabled and has no function.

## ENGINE CONTROL UNIT CIRCUIT THEORY OF OPERATION



Elec40D1004CFM

Figure 3-4

When the key switch is in the **ON** position, power for ECU (A3) comes from ECU/EUI power relay fuse (F16). The ECU stores vehicle specific data for operation of the engine and any engine related service codes.

It constantly monitors data from the EUI controller, the accelerator pedal position sensor and the start circuit. For information on the start circuit, **See** "STARTING AND CHARGING CIRCUIT AND THEORY OF OPERATION" on page 58.

The ECU transmits any engine service codes that may occur through the CAN data line to the MDU, causing the engine service light to come **ON** and the service code to be displayed.

**NOTE:**1. To diagnose service codes, see **Service Code Diagnostics - Engine Control Unit** in "Service Code Diagnostics - Engine Control Unit" on page 99.  
2. The ECU status is digitally displayed in the menu structure of the MDU, when accessed. For More information on the MDU menu functions - See **CHAPTER 8 of the Operator's & Maintenance Manual**.

The engine speed is controlled automatically. There is no mechanical link between the engine and the accelerator pedal. Accelerator pedal position sensor (B10) communicates accelerator position to the ECU using pulse width modulation (PWM).

The ECU receives the PWM signal and compares it to pre-programmed limit values. It then passes a torque request through the CAN data line to the EUI controller. The EUI controller processes the information along with data from the other engine inputs to control the EUI solenoid accordingly. (For information on the EUI controller, **See** "ELECTRONIC UNIT INJECTOR CONTROLLER CIRCUIT THEORY OF OPERATION" on page 62).

Engine slow idle and fast idle speeds are pre-programmed into the ECU. When at the maximum speed, the ECU requests only the torque which is necessary for maintaining the speed even if the accelerator is at the full throttle position.

Whenever the ECU or the accelerator pedal position sensor is replaced, it may be necessary to calibrate the accelerator pedal position.

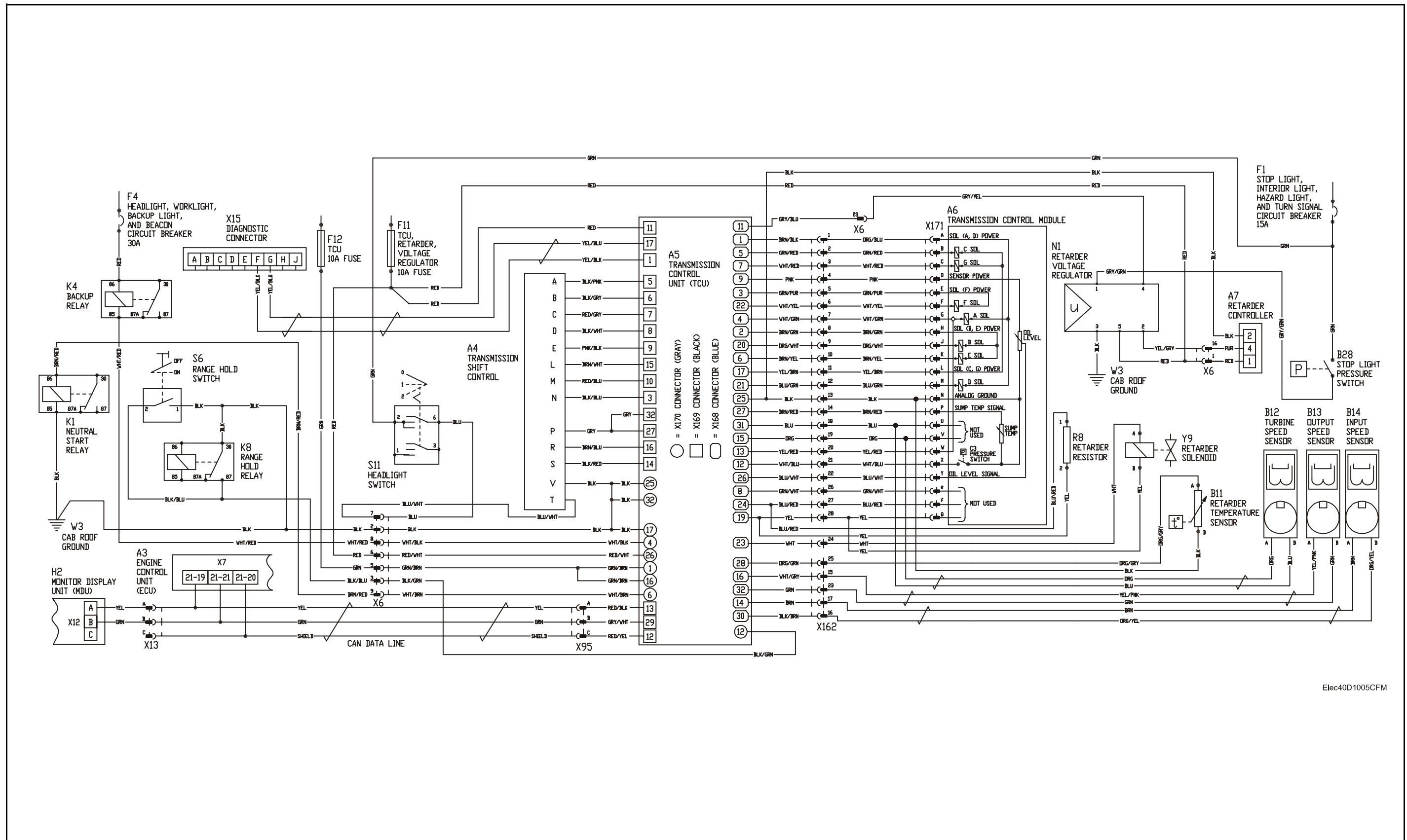
An acceptable margin of error between pedal movement relative to percentage read-out on the MDU will differ from operator to operator. Because of this, the need for re-calibration will be determined by operator preference.

To program the ECU, a special diagnostic tool (The Mini Diag II Version B) is required. The Mini Diag II is capable of reading and deleting engine related service codes and calibrating accelerator pedal position.

The Mini Diag II can be acquired from **BELL EQUIPMENT** Part No. 280479. Follow the instructions that come with the diagnostic tool.

In the event of an overspeed condition or when engine speed is above 800r.p.m., the torque convertor is locked up and the accelerator pedal position is less than 10%, the ECU will send current to the coil of exhaust brake relay (K6), energizing the relay and activating the engine exhaust brake. (For more information on the engine exhaust brake, **See P**"PARK BRAKE AND EXHAUST BRAKE CIRCUIT THEORY OF OPERATION" on page 76).

## TRANSMISSION CONTROL UNIT AND RETARDER CIRCUIT THEORY OF OPERATION



Elec40D1005CFM

Figure 3-5

Transmission Control Unit

Transmission control unit (TCU) (A5) receives unswitched battery power at terminals 1 and 16 of connector X170.

When the key switch is in the ON position, power from TCU, retarder, voltage regulator fuse (F11) is provided to terminal 26 of TCU connector X170, terminal 11 of TCU connector X169, terminal 1 of retarder controller (A7) and terminal 5 retarder voltage regulator (N1).

The TCU receives and processes information defining:

- Shift Selector position.
- Accelerator Pedal position.
- Input (Engine) speed.
- Turbine speed.
- Transmission output speed.
- Transmission Sump temperature.
- Engine Coolant temperature.
- Retarder temperature.
- Percentage of retardation.
- C3 Pressure Switch status.
- Transmission Oil level.

**NOTE:**The ECU sends the accelerator pedal position and engine coolant temperature data through the CAN data line to the TCU.

The TCU uses this information to control the transmission solenoids and valves, supply system status and provide diagnostic information such as service codes.

To activate the transmission solenoids, the TCU uses pulse width modulation (PWM) which varies the duty cycle (ON Time) of each corresponding transmission solenoid for optimum shift quality.

▲ CAUTION

**When diagnosing transmission solenoids, never apply system voltage (24 volts) to activate the solenoid (Damage will occur). Use only 5 volt DC. It is recommended that 3 AA batteries connected in series be used to obtain the required 5 volts).**

After a shift is completed, the TCU compares the shift to an ideal shift profile in the TCU program and makes adjustments before the next shift of the same kind is made. This is called “adaptive logic” which establishes the initial conditions for shifts.

There is “fast adaptive” logic and “slow adaptive” logic.

When in fast adaptive mode, the TCU makes large changes in the initial shift conditions to adjust for major system tolerances. Major system tolerances are solenoid - to -solenoid, main pressure and clutch - to - clutch variations.

When in slow adaptive mode, the TCU makes small changes in the initial shift conditions in response to minor system changes. Minor system changes occur slowly and are items such as wear and solenoid degradation or drift.

The TCU changes from fast adaptive to slow adaptive when the profile of an actual shift has nearly reached the ideal profile desired. When a new or newly rebuilt transmission has been installed, the adaptive logic information should be removed from the TCU memory. This is done using the Service ADVISOR™ application or the PRO-LINK® Diagnostic Data Reader.

**NOTE:**1. The Pro-Link diagnostic tool requires a special adapter harness, Part No. 207663, to connect to the diagnostic connector (X15).  
2. The transmission status is digitally displayed in the menu structure of the MDU, when accessed. For more information on the menu structure, see CHAPTER 8 of the OMM.

The TCU is an integral part of the neutral start system. During engine start, the TCU verifies if the transmission is in neutral. Once neutral is confirmed, the TCU provides an output to the coil of neutral start relay (K1), energizing the relay. For more information of the start circuit, See “STARTING AND CHARGING CIRCUIT AND THEORY OF OPERATION” on page 58

When the range hold circuit is enabled, range hold switch (S6) or range hold relay (K8) provide a ground at terminal 12 of TCU connector X170, thus putting the TCU in range hold mode.

When in this mode, the TCU will prevent the transmission from up-shifting to a higher gear than the gear selected at the time of activation. For more information on the range hold system, See “BIN CONTROL, FAN DRIVE AND RANGE HOLD CIRCUIT THEORY OF OPERATION” on page 74.

Retarder Control

The retarder system is activated whenever transmission output is over 300r.p.m. and the accelerator pedal is fully released to slow idle position or service brakes applied.

Activating the retarder will cause the stop lights to come ON. For more information, See “Stop Light Circuit Theory of Operation” on page 84.

When the service brakes are not applied, the amount of retardation is controlled by retarder controller (A7). The retarder control lever has seven positions with position 0 being the lowest percentage of retardation (12%) and position 6 being the highest percentage of retardation (100%).

Although there are seven lever positions, there are only six levels of retardation. Lever position “0” and “1” send the same amount of voltage to terminal 2 of retarder voltage regulator (N1), while each successive lever position sends a higher voltage to the retarder voltage regulator.

The retarder voltage regulator, in turn, sends a successively higher voltage to terminal 11 of TCU connector X168. Each successive voltage level received at terminal 11 causes the TCU to vary the duty cycle to retarder solenoid (Y9) accordingly.

**NOTE:**1. A low voltage at terminal 11 of TCU connector X168 causes the TCU to produce a short duty cycle (modulated) output to retarder solenoid (Y9), which results in less charge oil flow to the retarder.  
2. A higher voltage at terminal 11 causes the TCU to produce a longer duty cycle output to the retarder solenoid which results in more charge oil flow to the retarder.

If the TCU receives an abnormal speed signal from output speed sensor (B13) or an over-temperature signal from retarder temperature sensor (B11), the TCU will send the appropriate retarder response signal to retarder solenoid (Y9), regardless of the position of the retarder control lever.

When a retarder over-temperature situation exists, sensor (B11) sends a signal to the TCU which activates the retarder light on the MDU, shortens the duty cycle signal to solenoid (Y9) as necessary to reduce oil flow to the retarder, log service codes and down shift the transmission as prescribed by the software program.

Applying the service brakes causes stop light pressure switch (B28) to send current to terminal 1 of retarder voltage regulator (N1).

When this happens, the retarder voltage regulator sends the maximum voltage signal representing 100% retardation to the TCU. The TCU then puts the retarder at 100% retardation regardless of the position of the retarder control lever.

Having the service brake circuit enable, the retarder allows the retarder to function even if the accelerator pedal position sensor malfunction. For more information on how the service brakes interact with the retarder, **See** Table on page 84

**NOTE:**The retarder status is digitally displayed in the menu structure of the MDU, when accessed. (For more information on the menu structure, **See** CHAPTER 8 of the OMM.)

**Service Codes**

The TCU stores both active and historical (non-active) service codes. An active code is any code that is current in the TCU decision making process.

Historical codes are codes that are retained in the TCU's memory and will not necessarily affect the TCU decision making process. Historical codes are useful in determining if a problem is isolated, intermittent or results from a previous malfunction.

Service codes can be accessed and cleared using transmission shift control (A4), the service ADVISOR™ application, or the PRO-LINK® Diagnostic Data Reader.

Active codes are cleared when power to the TCU is removed. Some codes are self-clearing when the condition which causes the code is no longer detected by the TCU. Other codes must be manually removed.

**NOTE:**1. The Pro-Link diagnostic tool requires a special adapter harness, Part No. 207663, to connect to the diagnostic connector (X15).  
2. The transmission status is digitally displayed in the menu structure of the MDU, when accessed. For more information on the menu structure, see CHAPTER 8 of the OMM.

Should an electrical failure to the TCU occur and as long as key switch is not turned to the **OFF** position, the machine may be operated for a limited amount of time in what is called the “Limp Home” mode.

The “Limp Home” mode is a hydraulic latched system designed into the transmission in the event the TCU losses power or has a major malfunction.

When in “Limp Home” mode the transmission shifts to a predetermined gear depending on what gear was operating at the time of the electrical failure. The transmission will not upshift, down shift, shift into reverse or lock up the convertor.

If the engine is stopped (key switch turned to **OFF** position), the next time the machine is started will cause the transmission to remain in neutral until the malfunction is repaired.

In the event of a loss of electrical power, the transmission defaults to the following ranges:

| Attained Range | Default Range |
|----------------|---------------|
| Reverse        | Neutral       |
| Neutral        | Neutral       |
| Low            | 3rd           |
| 1st            | 3rd           |
| 2nd, 3rd, 4th  | 4th           |
| 5th            | 4th           |
| 6th            | 5th           |

For most transmission related service codes, the TCU will send a signal through the CAN data line to the MDU, causing the Transmission Service light to come **ON**.

To diagnose service codes, **See** “Service Code Diagnostics -Transmission Control Unit (TCU)” on page 105.

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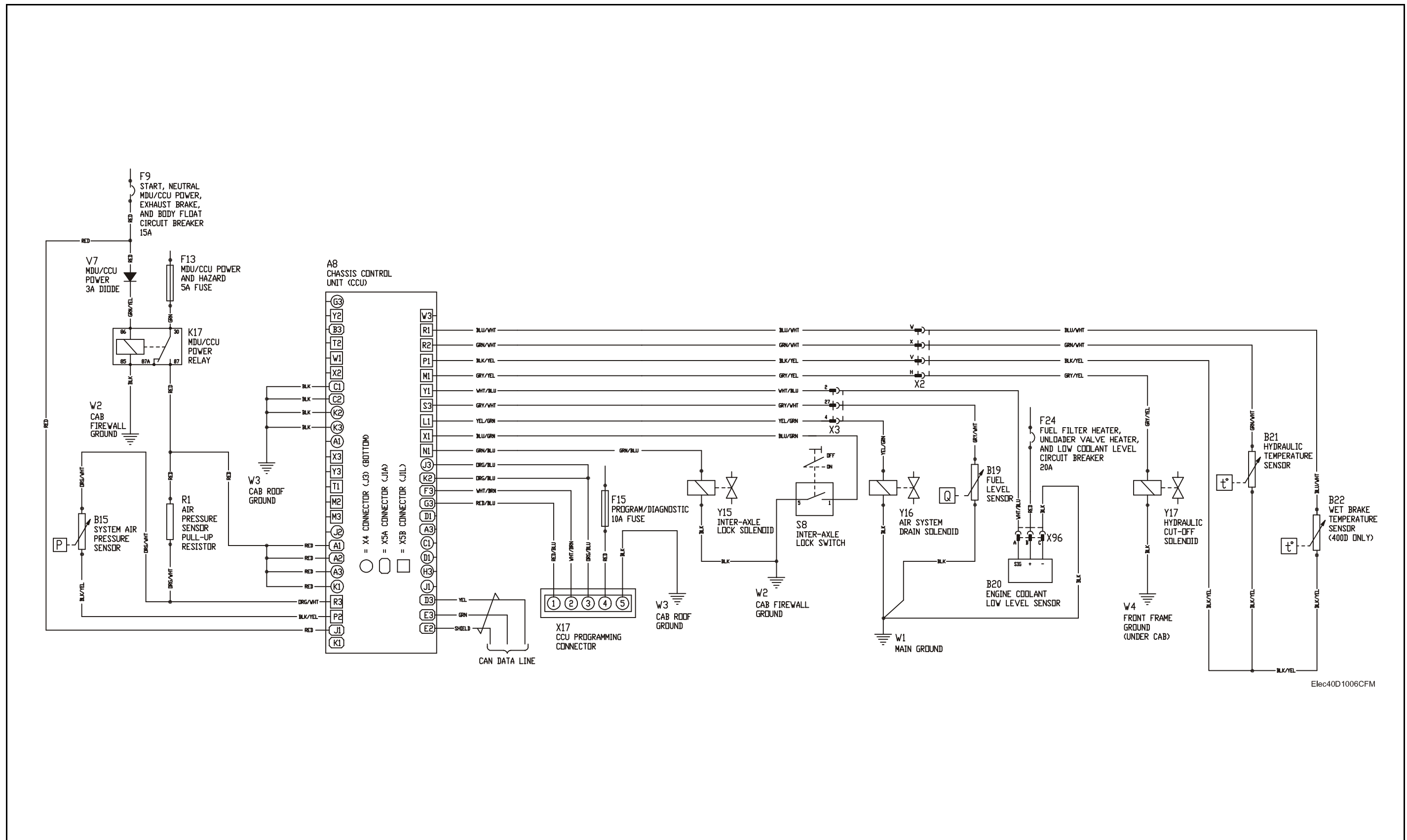


Figure 3-6

Unswitched power is available at terminal 30 of MDU/CCU power relay (K17). turning the key switch to the **ON** position, sends current from circuit breaker (F9) to the coil of MDU/CCU power relay (K17), energizing the relay. The current also flows to chassis control unit (CCU) (A8) at terminal J1 of connector X5A.

With MDU/CCU power relay (K17) energized, current from MDU/CCU power and hazard fuse (F13) is sent to the CCU at the following terminals:

- Terminals A3 and K1 of connector X4
- Terminals A1 and A2 of connector X5A

CCU programming connector (X17) is provided so software can be down loaded to the CCU using a RS232 interface and laptop computer. The connector receives switched power from program/diagnostic fuse (F15) at terminal 4.

The following functions are controlled or monitored by the CCU:

- Park Brake and Exhaust Brake - See "PARK BRAKE AND EXHAUST BRAKE CIRCUIT THEORY OF OPERATION" on page 76.
- Bin Control and Range Hold - See "BIN CONTROL, FAN DRIVE AND RANGE HOLD CIRCUIT THEORY OF OPERATION" on page 74.
- Turn Signal and Four-Way Flashers - See "Turn Signal And 4-Way Flasher Circuit Theory of Operation" on page 82.
- Intermittent Wipers - See "Wiper/Washer Circuit Theory of Operation" on page 88.
- Hydraulic Cut-Off - See "STARTING AND CHARGING CIRCUIT AND THEORY OF OPERATION" on page 58.
- Battery Charge and Battery Balance - See "Battery Balancer And 12-Volt Accessory Circuit Theory of Operation" on page 90.
- Inter-Axle Lock
- System Air.
- Engine Coolant Level.
- Fuel Level.
- Hydraulic Temperature.
- Wet Disc Brake Temperature (B40D only).

**Inter-Axle Lock Circuit**

**NOTE:**1. For information on the mechanical operation of the inter-axle lock, See "Inter-Axle Lock Operation" on page 279.  
2. For information on the pneumatic operation of the inter-axle lock, See "Inter-Axle Lock circuit" on page 322.

Putting the inter-axle lock switch (8) in the **ON** position connects terminal X1 of CCU connector X5B to ground. When this happens and if the engine speed is 900 r.p.m. or less, the CCU sends current out terminal N1 of connector X5B to inter-axle lock solenoid (Y15), energizing the solenoid.

With solenoid (Y15) energized, the planetary gear set (inside the transfer case) locks up, causing the front and rear drive shafts to turn in unison.

When the inter-axle lock is engaged, the inter-axle lock pressure switch (B25) (Not shown in the circuit schematic) sends a signal to the MDU, causing the Inter-Axle Lock Light to come **ON**.

Once engaged, the inter-axle lock will stay engaged as long as the inter-axle lock switch (S8) is in the **ON** position, even if the engine speed increases above 900 r.p.m.

**NOTE:**1. For more information on the inter-axle lock pressure switch (B25), Inter-Axle Lock Light and the MDU, See "MENU DISPLAY UNIT CIRCUIT THEORY OF OPERATION" on page 78.  
2. The inter-axle lock status is digitally displayed in the menu structure of the MDU, when accessed. For more information on the menu structure, See **CHAPTER 8 of the OMM.**

**Sensors**

**System Air Pressure Sensor**

The system air pressure sensor (B15) detects system air pressure and sends an analog signal representing the amount of air pressure back to the CCU. The sensor is connected in series with air pressure sensor pull-up resister (R1) so when the key switch is in the **ON** position, current flows through the 830 ohm resister (R1) and sensor (B15), then to terminal P2 (ground reference) of CC connector X5B.

The pull-up resistor is required because the CCU does not send out a reference voltage of its own to the sensor. Instead, an external voltage (system voltage) is used as the reference voltage.

The pull-up resister absorbs most of the system voltage so the voltage drop across the pressure sensor will be with-in the 0-5 volts required by the CCU.

The signal representing the air pressure is measured across sensor (B15), then sent to terminal R3 of CCU connector X5B. The CCU sends the information through the CAN data line to the MDU where a gauge displays the amount of air pressure to the operator.

**NOTE:**1. For more information on the air pressure gauge and MDU. See "MENU DISPLAY UNIT CIRCUIT THEORY OF OPERATION" on page 78.  
2. The system air pressure status is digitally displayed in the menu structure of the MDU, when accessed. For more information on the MDU - menu function, See **CHAPTER 8 in OMM.**

The air pressure sensor varies resistance with respect to air pressure as follows:

- 0 kPa {0 bar (0 psi)} = 10 Ohms
- 200 kPa {2 bar (29 psi)} = 51 Ohms
- 400 kPa {4 bar (58 psi)} = 86 Ohms
- 600 kPa {6 bar (87 psi)} = 122 Ohms
- 800 kPa {8 bar (116 psi)} = 152 Ohms
- 1000 kPa {10 bar (145 psi)} = 180 Ohms

Fuel Level Sensor

The fuel level sensor (B19) is a variable resistor that sends an analog signal to the CCU at terminal S3 of connector X5B.

The CCU sends the signal through the CAN data line to the MDU where a gauge displays the amount of fuel to the operator.

When the fuel reaches a pre-determined low level, the MDU will activate the audible alarm.

**NOTE:1. For more information on the fuel gauge and MDU. See “MENU DISPLAY UNIT CIRCUIT THEORY OF OPERATION” on page 78.**  
**2. The fuel level status is digitally displayed in the menu structure of the MDU, when accessed. For more information on the MDU - menu function, See CHAPTER 8 in OMM.**

When the fuel tank is empty, the fuel level sensor measures 75 ohms of resistance. When the fuel tank is full, the sensor measures 7.5 ohms of resistance.

Engine Coolant Level Sensor

The engine coolant level low sensor (B20) consists of two components: a capacitance probe and an interface module.

The probe detects water level using the “princi[ple of capacitance”. When two electrically conductive materials are separated by an electrical insulator, a capacitance will exist between the two conductors. The amount of capacitance is directly proportional to the area of the two plates.

The probe consists of a brass rod (1st plate) covered with polytetrafluoroethylene (PTFE) (the insulator). When the probe is covered in water, the water acts as the 2nd plate.

Maximum capacitance is obtained when the probe is fully submersed in water. Minimum capacitance exists when the probe is completely out of the water.

When little or no coolant contacts the probe, the interface module will send a signal (2.5 volts) to terminal Y1 of CCU connector X5B.

With an input at terminal Y1, the CCU will send a signal through the CAN data line to the MDU, causing the Coolant Level light to come **ON**.

**NOTE:The engine coolant low level status is digitally displayed in the menu structure of the MDU, when accessed. For more information on the MDU - menu function, See CHAPTER 8 in OMM.**

Hydraulic Temperature Sensor

The hydraulic temperature sensor (B21) sends an analog signal to terminal R2 of CCU connector X5B. The CCU will send the signal through the CAN data line to the MDU where the signal is digitally displayed in the menu structure. **For information on accessing the menu structure of the MDU, See CHAPTER 8 in OMM.**

When the hydraulic temperature reaches 90° C (194° F) the red Service indicator on the MDU will flash, audible alarm (H1) will sound intermittently and the Hydraulic Temperature Light on the MDU will flash.

When the hydraulic temperature reaches 95° C (203° F) the red Service indicator will flash, audible alarm (H1) will sound continuously, and the Hydraulic Temperature Light will flash.

**NOTE:1. The hydraulic temperature status is digitally displayed in the menu structure of the MDU, when accessed. For more information on accessing the menu on the MDU - menu function, See CHAPTER 8 in OMM.**

The temperature sensor varies resistance with respect to temperature as follows:

- 40° C (104° F) = 287.4 Ohms
- 50° C (122° F) = 193.6 Ohms
- 60° C (140° F) = 134.0 Ohms
- 70° C (158° F) = 95.2 Ohms
- 80° C (176° F) = 69.1 Ohms
- 90° C (194° F) = 51.3 Ohms
- 100° C (212° F) = 38.6 Ohms
- 110° C (230° F) = 29.4 Ohms
- 120° C (248° F) = 22.7 Ohms

Wet Disc Brake Temperature Sensor (B40D Only)

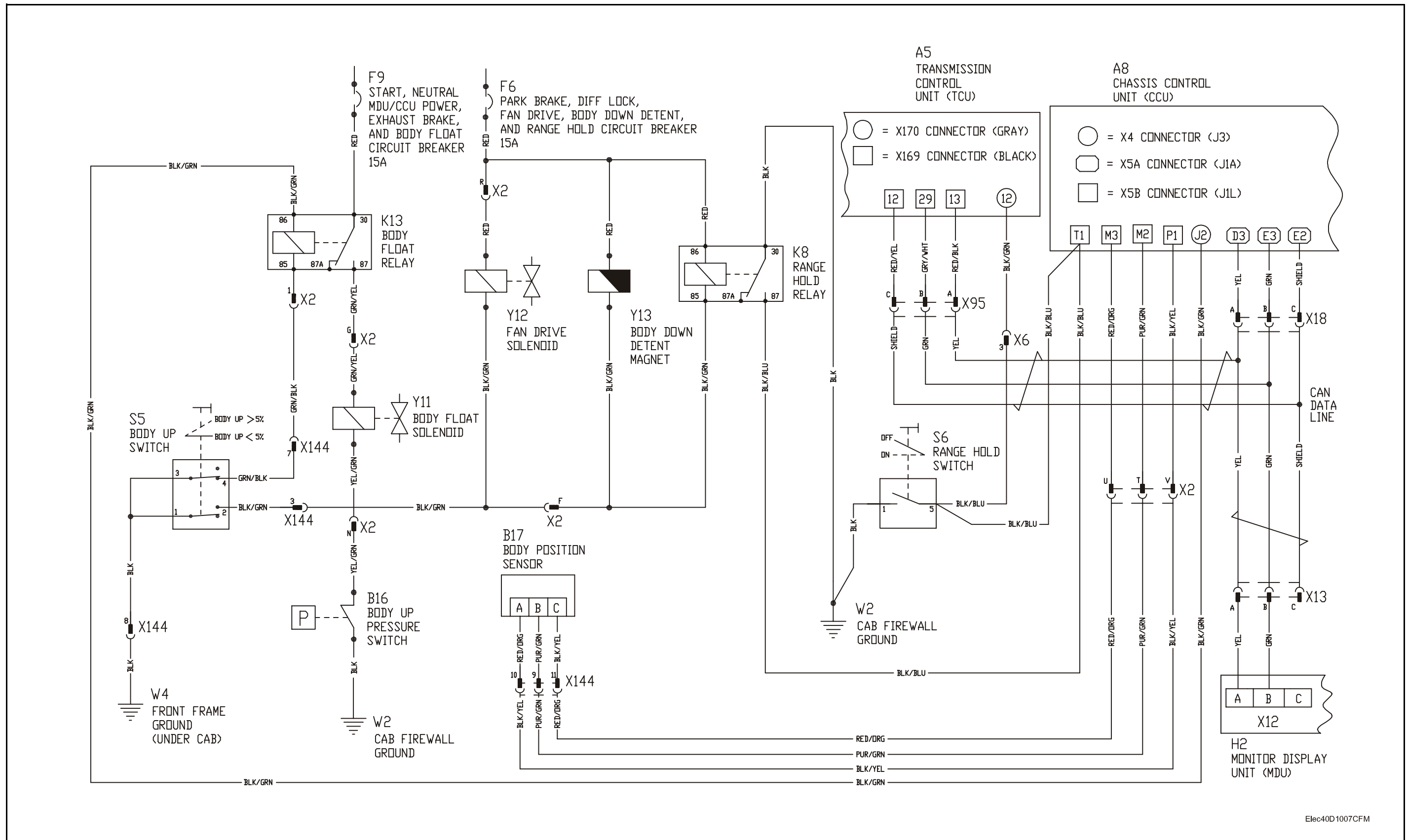
The wet disc brake temperature sensor(B22) sends an analog signal to terminal R1 of CCU connector X5B.

When the brake temperature reaches a predetermined temperature, the CCU will send a signal through the CAN data line to the MDU, causing the Brake Temperature Light to come **ON**.

**1. The wet disc brake temperature status is digitally displayed in the menu structure of the MDU, when accessed. For information on accessing the menu structure, See CHAPTER 8 in the OMM.**  
**2. The specifications (Resistance/temperature) for wet disc brake temperature sensor (B22) are the same as hydraulic temperature sensor (B21).**

LEFT BLANK INTENTIONALLY

## BIN CONTROL, FAN DRIVE AND RANGE HOLD CIRCUIT THEORY OF OPERATION



Elec40D1007CFM

Figure 3-7

Bin and Fan Drive Control Circuit

When the key switch is in the **ON** position, power from circuit breaker (F9) is available to terminal 30 of body float relay (K13).

Power from circuit breaker (F6) is available to fan drive solenoid (Y12), body down detent magnet (Y13) and range hold relay (K8).

Bin Up Mode

Moving the bin control lever to the Bin Up position sends air pressure to the bin hydraulic control valve, which in turn, sends hydraulic oil to the body lift cylinders to raise the bin.

**NOTE:**For information on the hydraulic control of the bin, See “Bin Control Valve Operation” on page 364.

When air pressure in the Bin Up side of the bin pneumatic control circuit reaches 550 kPa (5.5 bar) (79.8 psi), the contacts of bin up pressure switch (B16) open. With the contacts of switch (B16) open, ground is no longer available to bin float solenoid (Y11).

When the angle of the bin increases to more than 5%, as sensed by bin position sensor (B17), the following occurs:

1. The actuator rod of bin up switch (S5) no longer makes contact with the bin causing the following to occur:

- Ground is provided to fan drive solenoid (Y12), energizing the solenoid.
- Ground is provided to bin down detent magnet (Y13), energizing the magnet.
- Ground is provided to range hold relay (K8), energizing the relay.
- Ground is removed from bin float relay (K13), de-energizing the relay.

2. The CCU removes power from terminal J2 of connector X4 to ensure bin float relay (K13) is de-energizing when body angle is more than 5%.

With fan drive solenoid (Y12) energized, the hydraulic oil flow through the fan motor is blocked, giving priority oil flow to the bin lift cylinders as the bin is being raised. For more information on the fan drive, See “Fan Drive System Operation” on page 362.

With range hold relay (K8) energized, the transmission is prevented from upshifting to a higher gear. For more information, See “Range Hold Circuit” on page 75.

With bin down detent magnet (Y13) energized, the bin tip control lever can be held in the Bin Down position by the detent magnet.

Bin Down Mode

When the bin tip control lever is moved to the Neutral or Bin Down position, air pressure exhausts from the Bin Up side of the Bin pneumatic control circuit, causing the contacts of bin up pressure switch (B16) to close.

With the bin tip control lever in the Bin Down position, the energized bin down detent magnet (Y13) will hold the bin tip control lever in the Bin Down position. The detent magnet holds the control lever in this position until the bin contacts the actuator rod of the bin up switch (S5) or if the operator moves the lever.

Float Mode

When the actuator rod of bin up switch (S5) makes contact with the bin the following occurs:

- Ground is removed from bin down detent magnet (Y13) causing the relay to de-energize. Bin tip control lever returns to Neutral position.
- Ground is removed from fan drive solenoid (Y12) causing the relay to de-energize. (Fan now operates normally).
- Ground is removed from range hold relay (K8) causing the relay to de-energize. (Transmission is allowed to upshift).
- Ground is provided to coil of bin float relay (K13).

When bin position sensor (B17) senses the angle of the bin to be 5% or less, the CCU sends power out terminal J2 of connector X4 to the coil of bin float relay (K13), energizing the relay.

With relay (K13) energized and the contacts of bin up pressure switch (B16) closed, current flows from circuit breaker (F9) to bin float solenoid (Y11), energizing the solenoid.

With solenoid (Y11) energized, oil at the head end of the bin tip cylinders will bypass the hydraulic control valve and flow directly to the oil reservoir. This allows the bin to gently lower (float) to the frame when the bin tip control lever is in the neutral position.

Range Hold Circuit

When in range hold mode, the TCU prevents the transmission from upshifting to a higher gear than the gear selected at the time of activation, thus preventing any further increase in machine speed. Normal down shifting is allowed when in range hold mode.

Putting range hold switch (S8) in the ON position or energizing range hold relay (K8) will connect terminal 12 of C connector X170 to ground, thus putting the TCU in range hold mode.

The range hold switch allows the operator to manually activate range hold mode. The range hold relay allows the bin up circuit to activate range hold mode.

Activation of the range hold circuit by the bin up circuit automatically prevents the transmission from upshifting when the bin is in the raised position.

## PARK BRAKE AND EXHAUST BRAKE CIRCUIT THEORY OF OPERATION

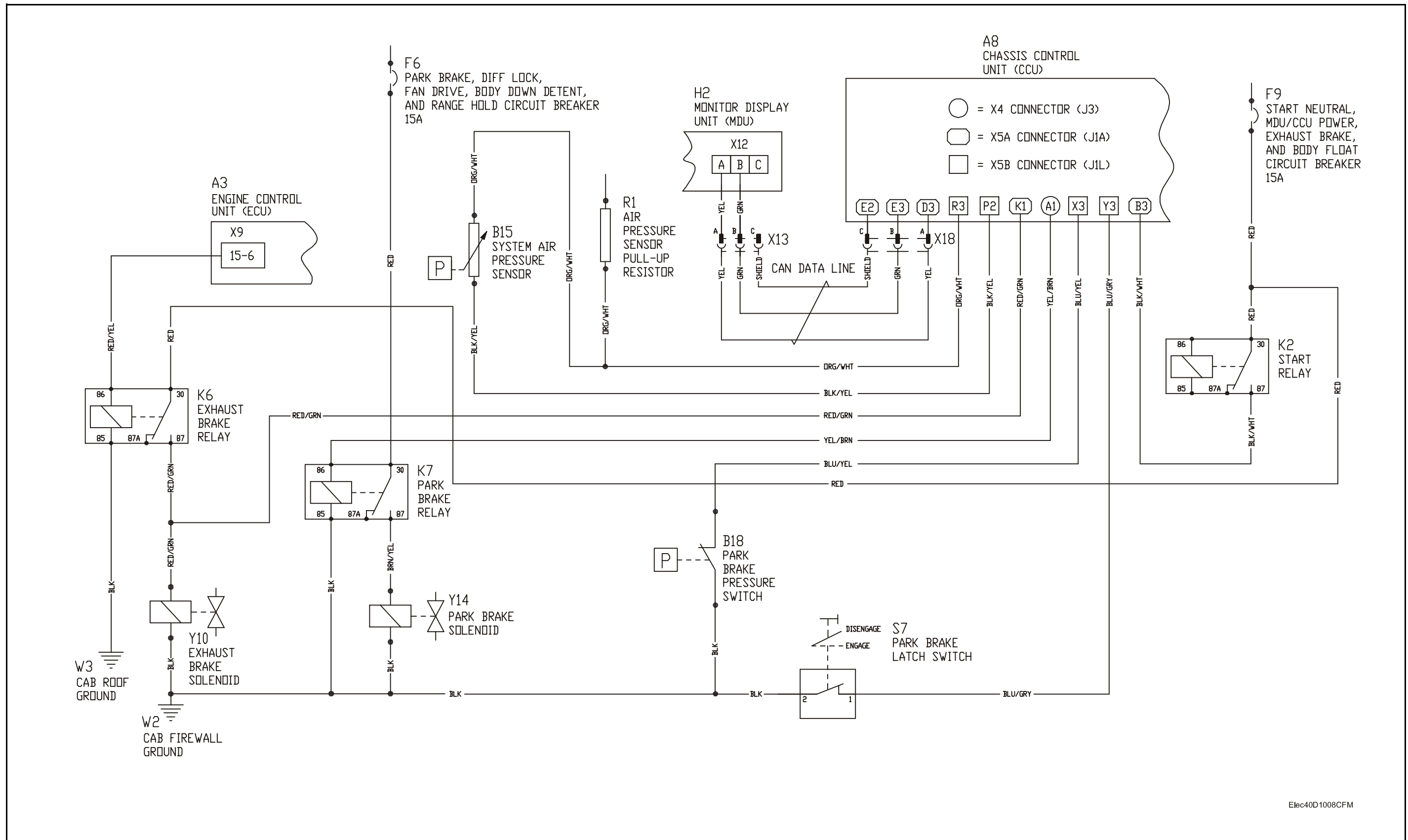


Figure 3-8

Park Brake Circuit

**NOTE:**The park brake is spring applied, pneumatically released.

The park brake will engage if any of the following events occur:

- Park brake lever moved to the PARK position.
- Key switch turned to the OFF position.
- Engine speed becomes less than 50 r.p.m. and ground speed less than 1 km/h (0.62 m.p.h.).
- System air pressure drops to less than 550 kPa (5.5 bar) (79.8 psi)
- Starting the engine (input exists at terminal B3 of connector X5A).

If any of these events occur, the chassis control unit (CCU) (A8) will not allow an output at terminal A1 of CCU connector X4. With no output at terminal A1, park brake relay (K7) will not energize and thus park brake solenoid (Y14) will not energize.

The de-energized solenoid blocks air pressure to the park brake actuator. It also allows the air in the actuator to vent to atmosphere, ensuring the spring inside the actuator applies the park brake.

The park brake pressure switch (B18) is located between park brake solenoid and park brake actuator. Because of this, switch (B18) senses only atmospheric pressure during the time solenoid (Y14) is de-energized.

This causes the contacts of switch (B18) to close, allowing terminal X3 of CCU connector X5B to connect to ground. When this happens and if the key switch is in the ON position, the CCU will send a signal though the CAN data line to the MDU, which in turn, causes the Park Brake Light to come **ON**.

To release the park brake, the CCU (A8) must detect the following:

- An “engine running” signal from the ECU (sent through the CAN data line).
- An analog signal at terminal R3 of CCU connector X5B indicating system air pressure is more than 550 kPa (5.5 bar) (79.8 psi).
- A signal at terminal Y3 of CCU connector X5B indicating the park brake lever is in the Park Release position. (This signal must be received only after the analog signal at terminal R3 indicates air pressure is more than 550 kPa (5.5 bar) (79.8 psi).

The analog signal at terminal R3 comes from system air pressure sensor (B15). When the analog input indicates system air pressure is more than 550 kPa (5.5 bar) (79.8 psi), the CCU starts monitoring the input at terminal Y3 connector X5B.

The park brake latch switch (S7) is mechanically connected to the park brake lever valve. Because of this, moving the park brake lever to the Park Release position causes switch (S7) to send a signal to terminal Y3.

If this signal is present before system air pressure reaches specification, the CCU will not allow an output at terminal A1 of connector X4. With no output at terminal A1, park brake relay (K7) will not energize, thus the park brake will not release.

When this happens, the park brake lever must first be returned to the Park position, then moved to the Park Release position to release the park brake.

When satisfied, the CCU will allow current to flow out terminal A1 of connector X4 to the coil of park brake relay (K7), energizing the relay. With relay (K7) energized, current flows from circuit breaker (F6) to park brake solenoid (Y14), energizing the solenoid.

With park brake lever valve in the Park Release position and solenoid (Y14), energized, air pressure is supplied to the park brake actuator. When air pressure in the park brake actuator reaches 550 kPa (5.5 bar) (79.8 psi), the contacts of park brake pressure switch (B18) open, interrupting the ground to terminal X3 of CCU connector X5B. This causes the CCU to send a signal through the CAN data line to the monitor display unit, which in turn, causes the Park Brake Light to go **OFF**.

Exhaust Brake Circuit

During machine operation, the exhaust brake will apply whenever engine speed is above 900 r.p.m., the torque converter is locked up, and the accelerator pedal position is less than 10%. The exhaust brake will also apply if engine speed exceeds 2500 r.p.m. (engine overspeed condition) regardless of position of accelerator pedal or even if torque converter is not locked up.

When an engine overspeed condition is detected, the red Engine Overspeed Light on the MDU comes **ON**.

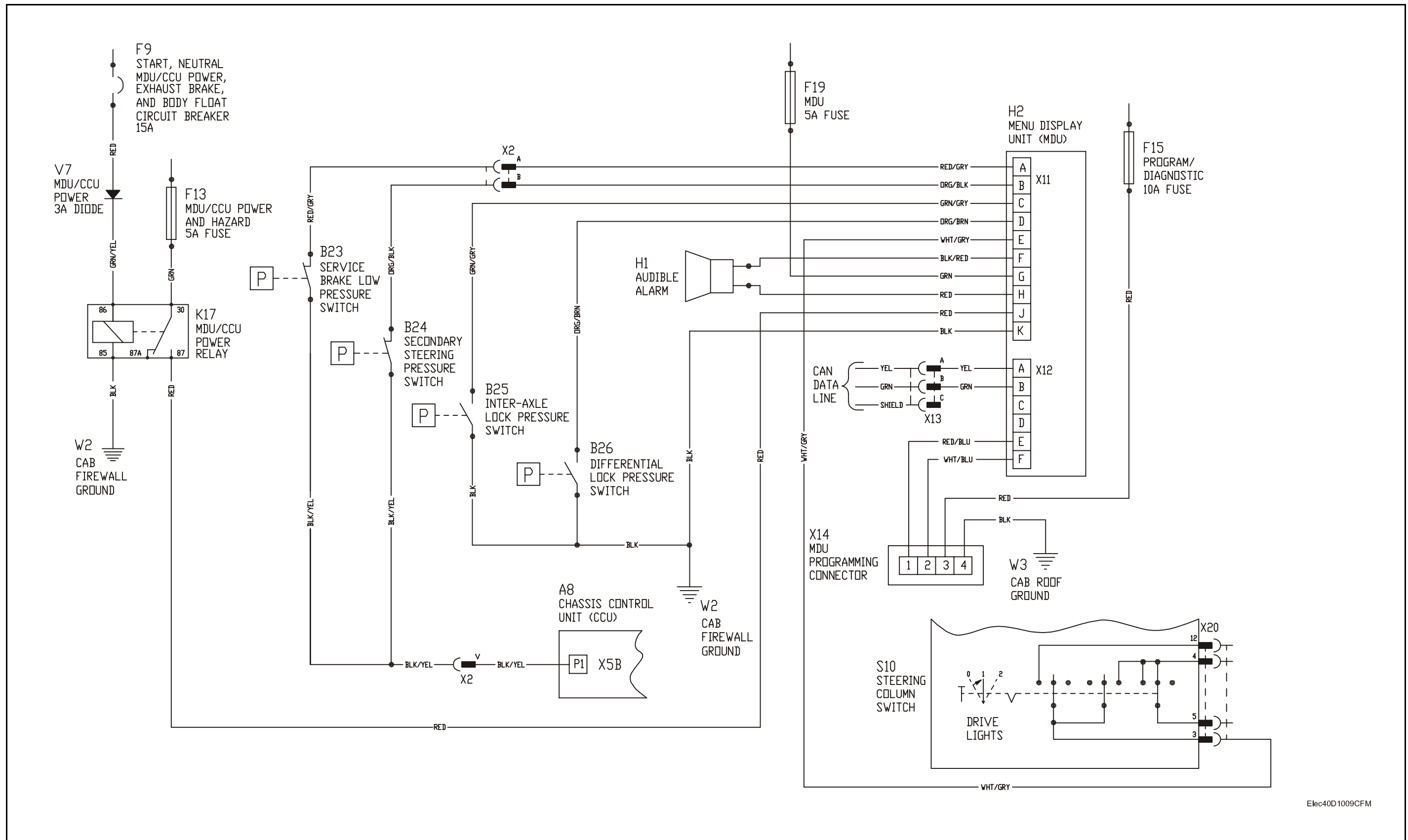
The ECU (A3) monitors engine speed and the accelerator pedal position. For more information on the accelerator pedal position sensor and the ECU, **See “ENGINE CONTROL UNIT CIRCUIT THEORY OF OPERATION” on page 64.**

When the accelerator pedal position is less than 10%, torque converter is locked up and engine speed is more than 900 r.p.m., the ECU energizes exhaust brake relay (K6). With relay (K6) energized, current is allowed to flow from circuit breaker (F9) to exhaust brake solenoid (Y10), thus energizing the solenoid.

With solenoid (Y10) energized, air pressure is directed to the exhaust flapper valve actuator and each of the exhaust valve brakes (EVB) located inside the cylinder heads. For more information of operation of the flapper valve and the EVB, **See “ENGINE” on page 41.**

With relay (K6) energized, current from circuit breaker (F9) also flows to terminal K1 of CCU connector X5A, causing the CCU to activate the stop lights. For information on operation of the stop lights, See “Stop Light Circuit Theory of Operation” on page 84.

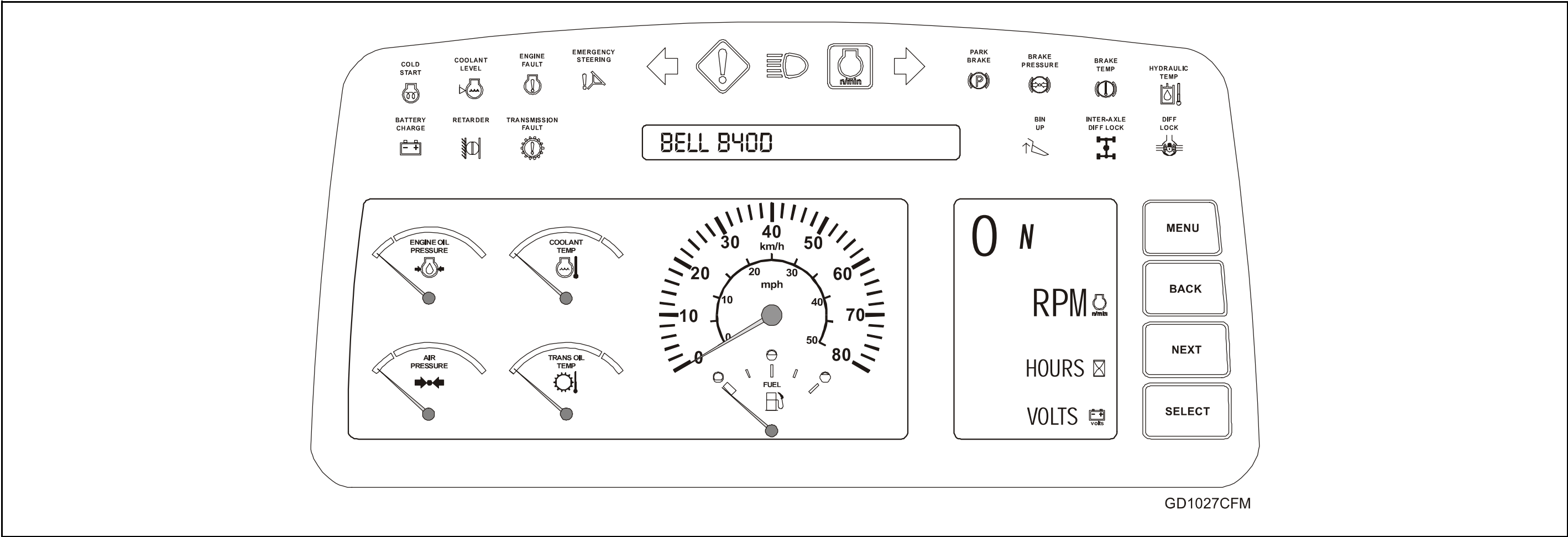
## MENU DISPLAY UNIT CIRCUIT THEORY OF OPERATION



Elec40D1009CFM

Figure 3-9

Menu Display Unit



**NOTE:**For a description of all the MDU indicators and their function, See Instrument Panel Functions in CHAPTER 8 of the OMM.

The MDU (H2) is used to display the status of machine functions. It is controlled by signals received from the TCU, CCU (A8) and ECU. The signals are transmitted across the CAN data line.

Unswitched power is available at terminal G of MDU connector X11 and terminal 30 of MDU/CCU Power Relay (K17). Turning the key switch to the **ON** position, sends current from circuit breaker (F9) to the coil of MDU/CCU power relay (K17), energizing the relay. With MDU/CCU power relay (K17) energized, current from MDU/CCU power and hazard fuse (F13) flows to terminal J of MDU connector X11.

If the MDU detects switched system voltage at terminal J of MDU connector X11 to be less than 17.5 ± 5 volts, the MDU will assume that a power down is in process.

If the MDU is writing data to memory, it sends a signal to energize an internal relay. This relay uses unswitched power from terminal G of MDU connector X11 so that the write operation can be completed.

When two seconds have elapsed, and if the write operation is completed, the MDU signal is disabled causing the internal relay to de-energize and the MDU to shut down.

When the head light switch is in the **ON** position and the drive lights switch inside steering column switch (S10) is set to High Beam position, terminal E of MDU connector X11 is connected to ground. When this happens, the High Beam indicator on the MDU will come **ON**.

MDU programming connector (X14) is provided so software can be down loaded to the MDU using an RS232 interface and laptop computer.

**CAUTION**

When a critical warning is detected, the red Service light will come ON (or flash) and the audible alarm will sound. The machine and engine must be stopped immediately or serious damage may result. The flashing Service light and audible alarm alerts the operator to a critical service code condition indicated on the MDU display.

**Gauges**

The MDU contains a speedometer and the following gauges:

- Engine Oil Pressure.
- System Air Pressure.
- Engine Coolant Temperature.
- Transmission Oil Temperature.
- Fuel Level.

The sensors for these gauges provide analog inputs to CCU (A8). The CCU calculates the temperature, pressure and fuel level then sends the data across the CAN data line to the MDU. When the MDU receives the sensor data, it displays the value on the appropriate gauge as a needle position, then moves the associated needle to such position.

The needle of the fuel, pressure and temperature gauges will deflect to the far left of the scale when communications across the CAN data line are lost or if a sensor error is detected.

Engine Oil Pressure

The red Service indicator will flash and audible alarm (H1) will sound continuously when the engine oil pressure is less than a specified pressure at a given engine r.p.m.

- 50 r.p.m. = 20 kPa {0.2 bar (3.0 psi)}
- 600 r.p.m. = 50 kPa {0.5 bar (7.3 psi)}
- 1000 r.p.m. = 90 kPa {0.9 bar (13.0 psi)}
- 1400 r.p.m. = 130 kPa {1.3 bar (18.9 psi)}
- 1800 r.p.m. = 160 kPa {1.6 bar (23.2 psi)}
- 2200 r.p.m. = 200 kPa {2.0 bar (29.0 psi)}
- 2600 r.p.m. = 250 kPa {2.5 bar (36.3 psi)}
- 3000 r.p.m. = 250 kPa {2.5 bar (36.3 psi)}

Engine Coolant Temperature

When the engine coolant temperature reaches 103° C (217.4° F) (gauge needle at start of red), the red Service indicator will come **ON** and audible alarm (H1) will sound intermittently. **“ENG TEMP TOO HIGH”** will show on the message display.

When the engine temperature reaches 108° C (226.4° F) (gauge needle at middle of red), the red Service indicator will come **ON** and audible alarm (H1) will sound continuously. **“ENG TEMP TOO HIGH”** will show on the message display.

Transmission Oil Temperature

When the transmission temperature reaches 110° C (230° F) (gauge needle at start of red), the red Service indicator will come **ON** and audible alarm (H1) will sound intermittently. **“TRANS TEMP TOO HIGH”** will show on the message display.

When the transmission temperature reaches 115° C (239° F) (gauge needle at middle of red), the red Service indicator will come **ON** and audible alarm (H1) will sound intermittently. **“TRANS TEMP TOO HIGH”** will show on the message display.

Air System Pressure

When the system air pressure is at 550 kPa {5.5 bar (79.8 psi)} (gauge needle at start of red) or less, the red Service indicator will flash and audible alarm (H1) will sound intermittently. **“SYS AIR PRES TOO LOW”** will show on the message display.

Speedometer

The speedometer is calibrated to show the machine speed in Km/h and m.p.h. The transmission output shaft speed sensor sends a signal to the TCU representing the speed of the output shaft. The TCU transmits the speed sensor data to the MDU across the CAN data line. The MDU uses the data to move the speedometer needle in correlation to machine travel speed.

**If speedometer seems to be miscalibrated, check machine model on the MDU at start-up and check the tire size in the menu structure of the MDU. For information on accessing the menu structure, See CHAPTER 8 in the OMM.**

Pressure Switches

The following pressure switches send their signals directly to the MDU:

- Service Brake Low Pressure Switch (B23).
- Secondary Steering Pressure Switch (B24).
- Inter-Axle Lock Pressure Switch (B25).
- Differential Lock Pressure Switch(B26).

Service Brake Low Pressure Switch

The contacts of service brake low pressure switch (B23) are open during normal operation. When oil pressure in the service brake system decreases to 12 300 kPa (123 bar) (1784 psi), the contacts of pressure switch (B23) will close, sending a signal to terminal A of MDU connector X11.

When this happens, the Brake Pressure Light on the MDU will come ON, the Service light will flash, and audible alarm (H1) will sound.

Secondary Steering Switch

The contacts of secondary steering pressure switch (B24) are open during normal operation.

When oil pressure in the main hydraulic system decreases to 500 kPa {5 bar (72.5 psi)} the contacts of pressure switch (B24) close, sending a signal to terminal **B** of MDU connector X11.

When this happens, the secondary steering (marked EMERGENCY STEERING) light on the MDU will come **ON**, the service light on the MDU will come **ON**, the Service light will flash and audible alarm (H1) will sound.

Inter-Axle Lock Pressure Switch

When the inter-axle lock is engaged, the air pressure to the inter-axle lock actuator is sensed by the inter-axle lock pressure switch (B25).

When the air pressure reaches 550 kPa {5.5 bar (79.8 psi)} the pressure switch contacts close, connecting terminal “**C**” of MDU connector X11 to ground.

When this happens the “Inter-Axle DIFF LOCK) light on the MDU will come **ON**.

Differential Lock Pressure

When the differential lock is engaged, the air pressure to the differential Lock actuator is sensed by differential lock pressure switch (B26).

When the air pressure reaches 550 kPa {5.5 bar (79.8 psi)} the pressure switch contacts X11 to ground. When this happens, the Diff Lock light on the MDU will come **ON**.

## Turn Signal And 4-Way Flasher Circuit Theory of Operation

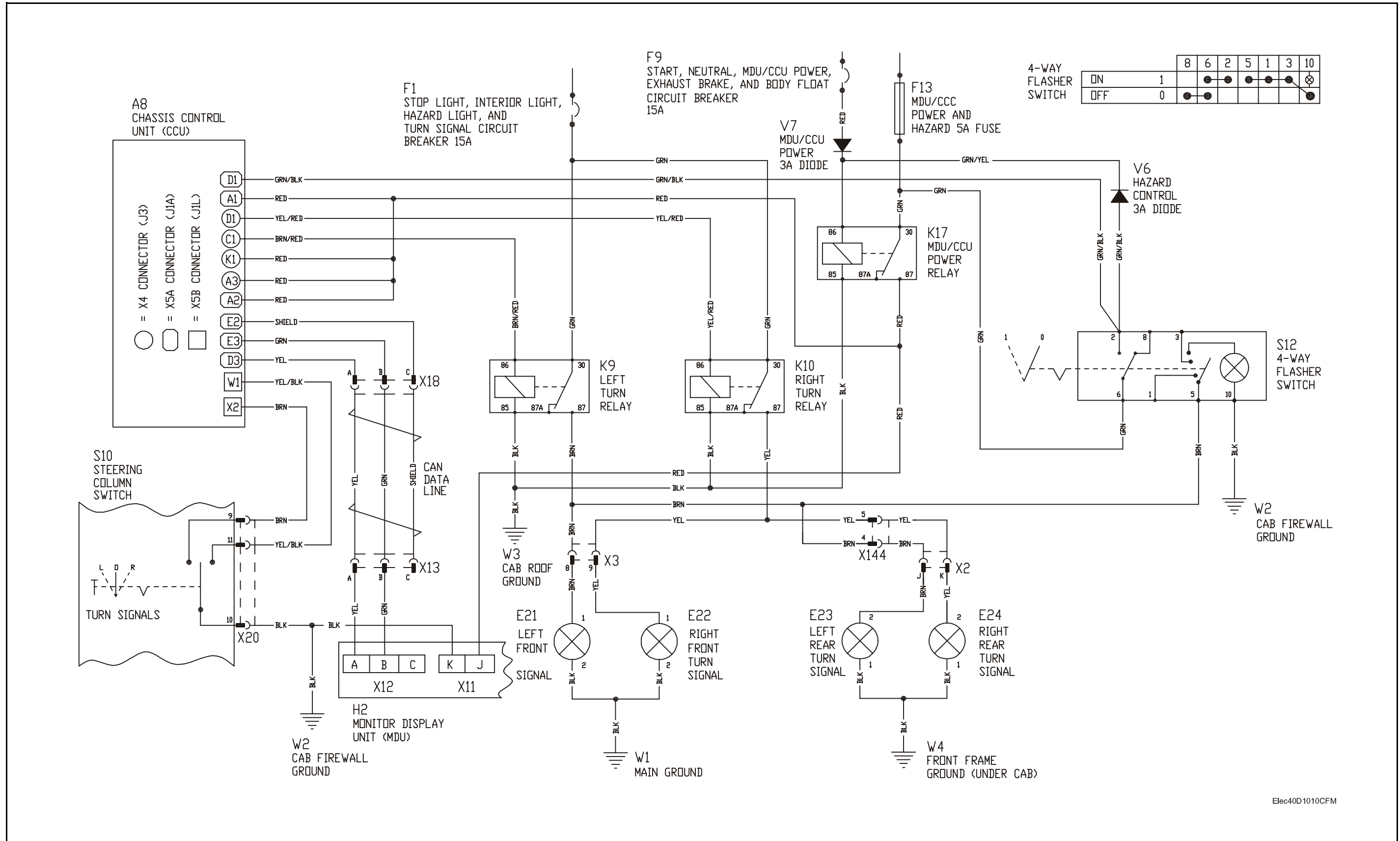


Figure 3-110

Unswitched power from circuit breaker (F1) is available at terminal 30 of left turn relay (K9) and right turn relay (K10). Unswitched power from MDU/CCU power and hazard fuse (F13) is available at terminal 6 of 4-way flasher switch (S12) and terminal 30 of MDU/CCU power relay (K17).

Turn Signal

Moving the lever of steering column switch (S10) to the left-turn position connects terminal X2 of CCU (A8) connector X5B to ground.

When this happens, the CCU sends pulsing DC current out terminal C1 of connector X4 to the coil of left turn relay (K9), causing the relay to continuously energize and de-energize.

The energizing and de-energizing relay causes current from circuit breaker (F1) to pulse as it flows to left front turn signal (E23), causing these lights to flash. The CCU also sends a signal across the CAN data line to the MDU, causing the Left Turn Arrow to flash.

Moving the lever of steering columns witch (S10) to the right-turn position connects terminal W1 of CCU connector X5B to ground.

When this happens, the CCU sends pulsing DC current out terminal D1 of connector X4 to the coil of the right turn relay (K10), causing the relay to continuously energize and de-energize.

The energizing and de-energizing relay causes current from circuit breaker (F1) to pulse as it flows to right front turn signal (E22) and right rear turn signal (E24), causing these lights to flash.

The CCU also sends a signal across the CAN data line to the MDU, causing the Right Turn Arrow to flash.

Four-Way Flasher

Because the CCU and MDU are essential for the 4-way flashers to function, it is necessary that the CCU and MDU receive power during 4-way flashers activation whether key switch is in the **ON** or **OFF** position.

When the key switch is in the ON position, current from circuit breaker (F9) flows to the coil of the MDU/CCU power relay (K17), energizing the relay.

With relay (K17) energized, current from MDU/CCU power and hazard fuse (F13) flows to the CCU and MDU, powering the controllers.

If the key switch is in the OFF position, but 4-way flasher switch (S12) is moved to the ON position, unswitched current from fuse (F13) flows into terminal 6 of 4-way flasher switch (S12), then flows out terminal 2 to the coil of relay (K17), energizing the relay.

With relay (K17) energized current from fuse (F13) flows to the CCU and MDU.

During this time the 4-way flasher switch provides the necessary power to the CCU and MDU.

From terminal 2 of 4-way flasher switch (S12), current also flows to terminal D1 of CCU connector X5A.

When this happens, the CCU sends pulsing current out both terminals C1 and D1 of connector X4.

The pulsing current simultaneously energizes and de-energizes left turn relay (K9) and right turn relay (K10).

The relays, in turn, cause current from circuit breaker (F1) to pulse as it flows to turn signals (E21 - E24), causing all four lights to flash.

This pulsing current also flows back to 4-way flasher switch (S12) at terminal 5, causing the light in the 4-way flasher switch to flash.

The CCU also sends a signal across the CAN data line to the MDU, causing both the Left Turn Arrow and the Right Turn Arrow to flash.

If the lever of the steering column switch (S10) is moved to left-turn position with the 4-way flasher switch in the **ON** position, the CCU causes the left turn signals to flash while the right turn signals stay continuously lit.

The opposite is true when the steering column switch lever is moved to the right-turn position with 4-way flasher switch in the **ON** position.

## Stop Light Circuit Theory of Operation

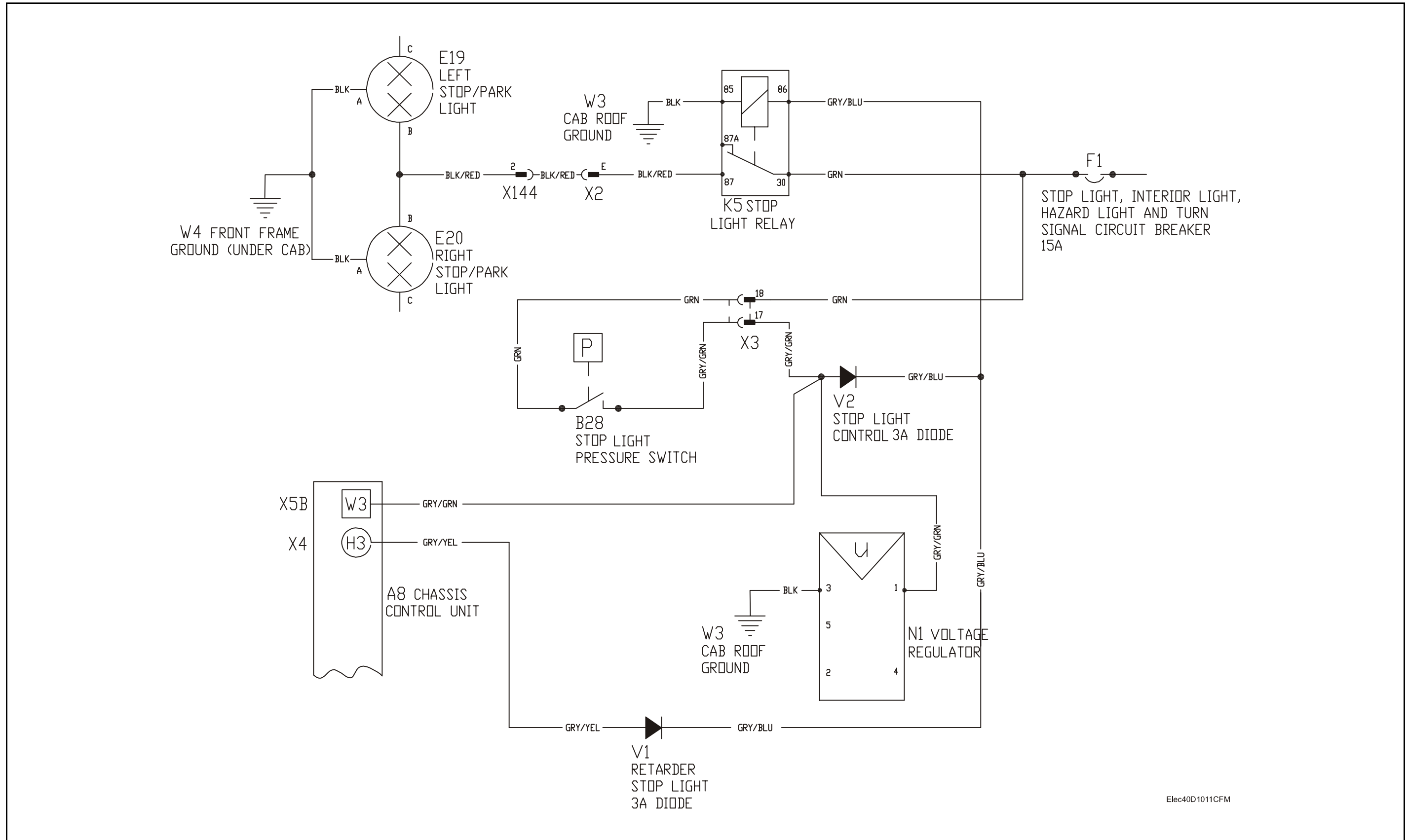


Figure 3-111

Unswitched power from circuit breaker (F1) is available at stop light pressure switch (B28) and terminal 30 of stop light relay (K5).

When the service brakes are applied, hydraulic pressure closes the contacts of stop light pressure switch (B28), allowing current from circuit breaker (F1) to flow to the coil of stop light relay (K5), thus energizing the relay.

With relay (K5) energized, current flows from circuit breaker (F1) to left stop/park light (E20), causing the stop lights to come **ON**.

**NOTE:Contacts of stop light pressure switch (B28) open and close at 500 kPa {5 bar (72.5 psi)}.**

With the contacts of stop light pressure switch (B28) closed, current also flows to terminal W3 of CCU (A8) connector X5B and terminal 1 of retarder voltage regulator (N1).

The signal to the CCU lets the control system know the service brakes are applied.

The signal to voltage regulator (N1) puts the retarder system at 100% retardation.

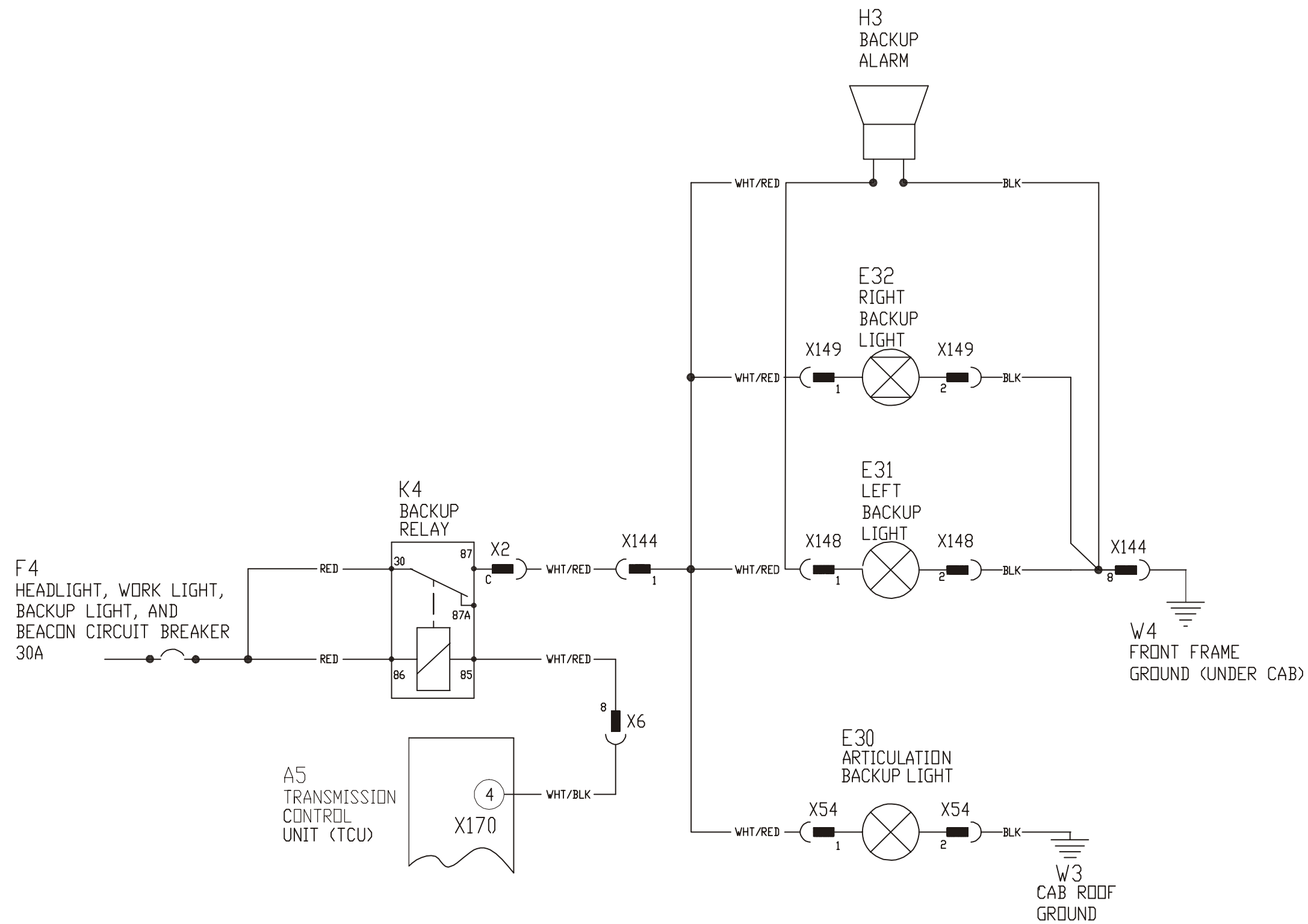
For more information on the retarder system, **See “TRANSMISSION CONTROL UNIT AND RETARDER CIRCUIT THEORY OF OPERATION” on page 66.**

The retarder and/or exhaust brake will activate the stop lights if the service brakes are not applied. During the time the retarder and/or exhaust brake is active, the CCU sends current out terminal H3 of connector X4 to the coil of the stop relay (K5), energizing the relay, which causes the stop lights to come **ON**.

The retarder stop light control diode (V1) prevents current from stop light pressure switch (B28) from reaching terminal H3 of CCU connector X4 whenever the service brakes are applied.

Stop light control diode (V2) prevents current flowing from terminal H3 of CCU connector X4 from reaching terminal 1 of voltage regulator (N1) and terminal W3 of CCU connector X5B whenever the retarder and/or exhaust brake is active, but service brakes are not applied.

## Backup Alarm and Backup Light Circuit Theory of Operation



Elec40D1012CFM

Figure 3-112

When the key switch is in the **ON** position, power from circuit breaker (F4) is available to terminal 30 and 86 of backup relay (K4).

When the operator selects revers gear, the TCU (A5) supplies a ground to relay(K4), energizing the relay.

With relay (K4) energized, current flows to left and right backup lights (E31 and E32) and, if equipped, to articulation backup light (E30), causing the lights to come **ON**.

Current also flows to backup alarm (H3), activating the backup alarm.

Wiper/Washer Circuit Theory of Operation

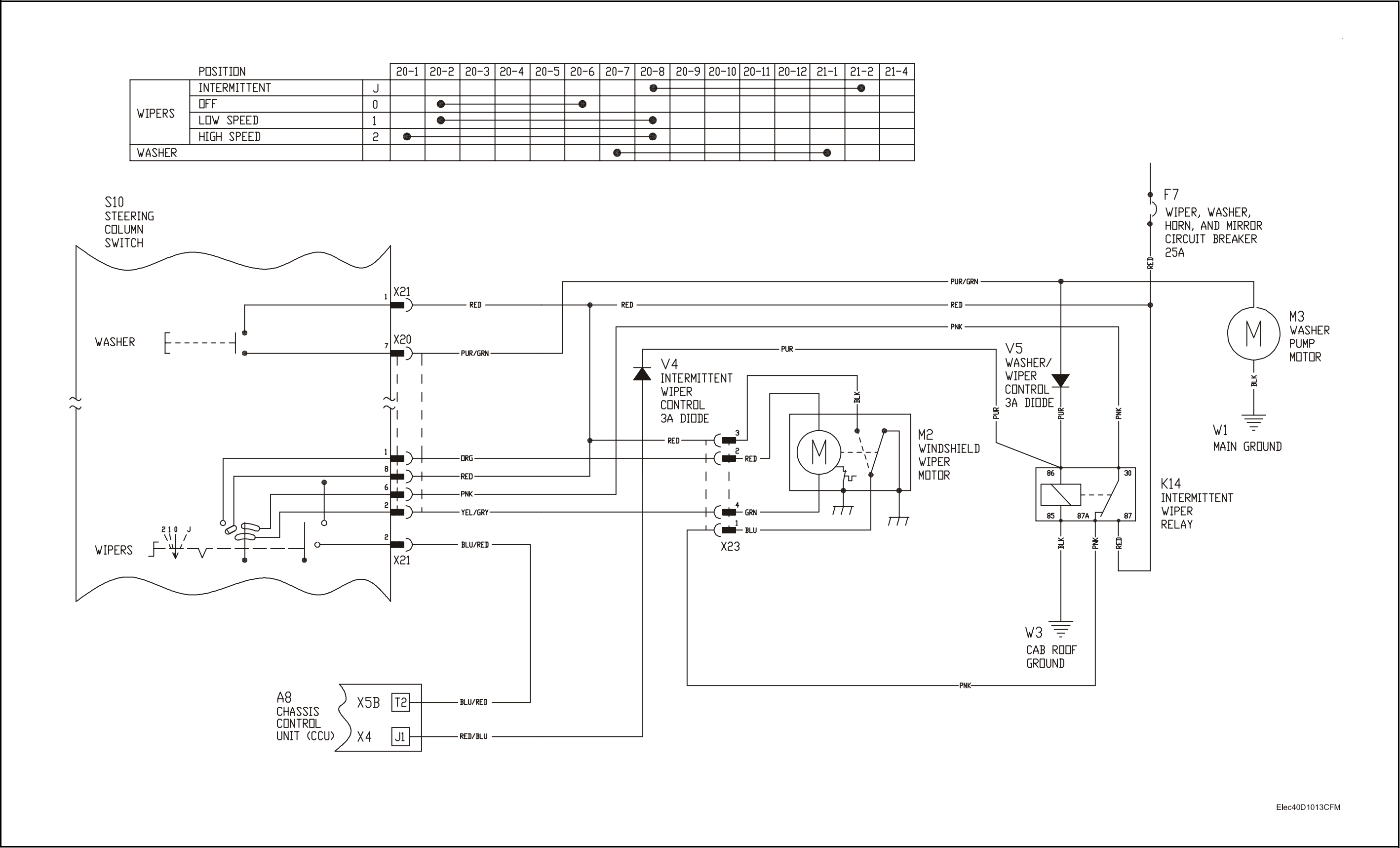


Figure 3-113

When the key switch is in the ON position, power from circuit breaker (F7) is available at the following locations:

- Intermittent Wiper Relay (K14) - Terminal 87
- Steering Column Switch (S10) - Terminal 8 of connector (X20)
- Steering Column Switch (S10) - Terminal 1 of connector (X21)
- Windshield Wiper Motor (M2) - Terminal 3 of connector (X23)

**Intermittent Wiper Control**

When the wiper control sleeve on the steering column switch lever is turned to position “J”, current from circuit breaker (F7) flows in terminal 8 of connector X20, then out terminal 2 of connector X21, to terminal T2 of CCU (A8) connector X5B.

The CCU will then send an intermittent current out terminal J1 of connector X4 to the coil of intermittent wiper relay (K14), energizing the relay intermittently.

During the time intermittent wiper relay (K14) is energized, current from circuit breaker (F7) will flow across the relay contacts, to terminal 6 of connector X20.

The current then flows out terminal 2 of wind shield wiper motor (M2), activating the motor intermittently.

The purpose of intermittent wiper control diode (V4) is to block current flow to terminal J1 of CCU connector X4 when only the washer circuit is activated.

The timing intervals of the intermittent wipers can be adjusted so the wiper will actuate anywhere between 3 and 20 seconds.

**NOTE:**The intermittent wipers status and timing is digitally displayed in the menu structure of the MDU, when accessed. For information on accessing the menu structure, See MDU - Menu Function CHAPTER 8 in the OMM.

**Low and High Speed Wiper Control**

When the wiper control sleeve on the steering column switch lever is turned to position “I”, current from circuit breaker (F7) flows in terminal 8 of connector X20, then out terminal 2 of connector X20 to terminal 4 of connector X23 on wind shield wiper motor (M2), activating the motor in low speed.

When the wiper control sleeve on the steering column switch lever is turned to position “II”, current from circuit breaker (F7) flows in terminal 8 of connector X20, then out terminal 1 of connector X20 to terminal 2 of connector X23 on wind shield wiper motor (M2), activating the motor in high speed.

**Washer Control**

Pushing the momentary wind shield washer button allows current from circuit breaker (F7) to flow in terminal 1 of connector X21, then out terminal 7 of connector X20 to washer pump motor (M3), activating the washer pump motor.

At the same time, current flows through washer/wiper control diode (V5) to the coil of intermittent wiper relay (K14), energizing the relay.

With relay (K14) energized, current from circuit breaker (F7) will flow across the relay contacts, to terminal 6 of connector X20.

The current then flows out terminal 2 of connector X20 to terminal 4 of connector X23 on wind shield wiper motor (M2), temporarily activating the wiper motor.

The purpose of washer/wiper control diode (V5) is to block current flow to the washer pump when only the intermittent wiper circuit is activated.

**Wiper Park Control**

When the wiper control sleeve on the steering column switch lever is turned to position “0” and the wiper is not at Park position, the contacts in wind shield wiper motor (M2) are closed.

With the wiper motor contacts closed, current from circuit breaker (F7) is allowed to flow to terminal 3 of wiper motor connector X23, across the wiper motor contacts, then out terminal 1 of connector X23 to terminal 87A of intermittent wiper relay (K14).

The current flows across the normally closed relay contacts to terminal 6 of connector X20.

Because the wiper switch is in the OFF position, current will flow out terminal 2 of connector X20 to terminal 4 of connector X23, activating the wiper motor.

When the wiper reaches the Park position, the wiper motor contacts open, thus deactivating the wiper motor.

Battery Balancer And 12-Volt Accessory Circuit Theory of Operation

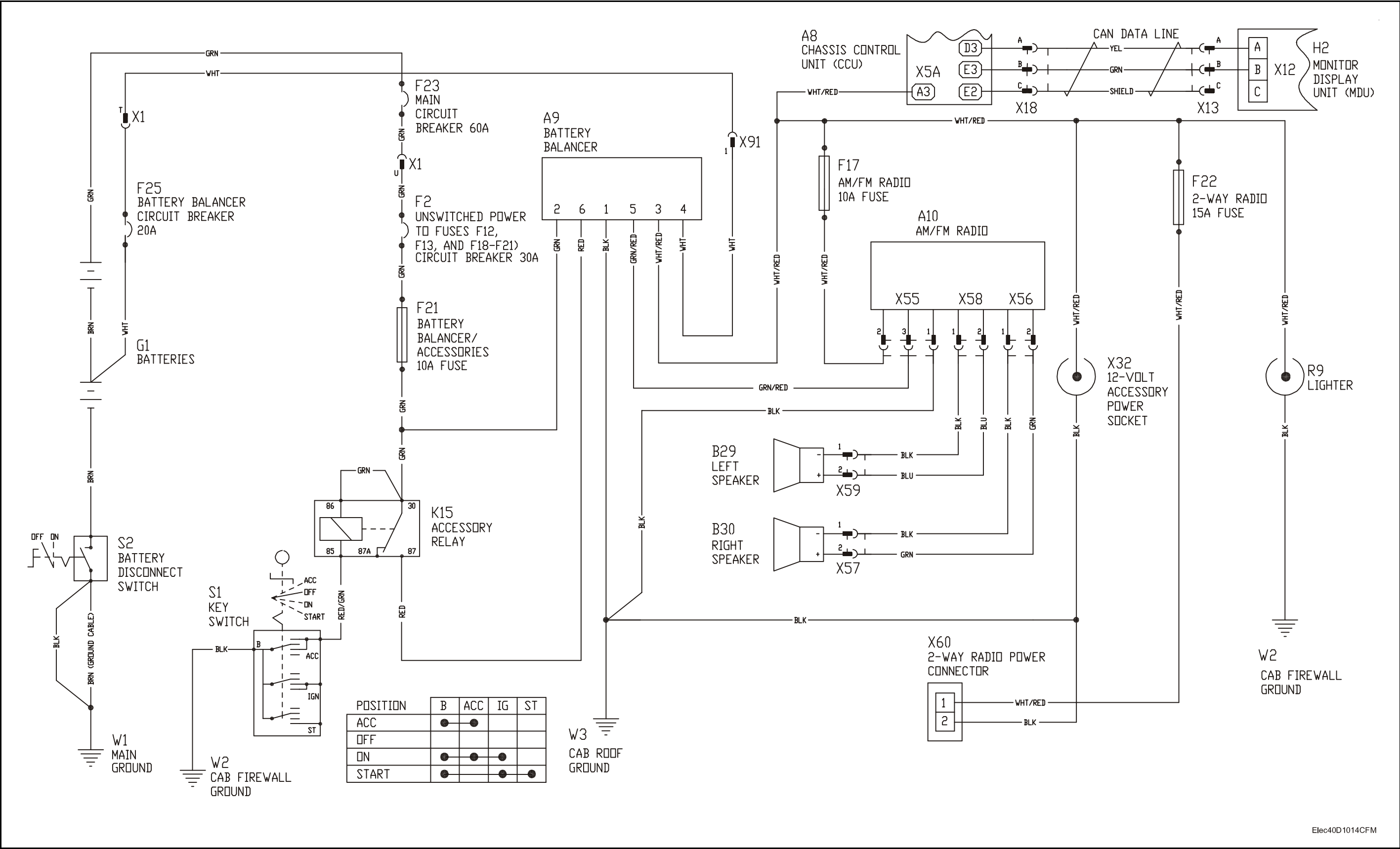


Figure 3-114

The main function of battery balancer (A9) is to equalize the charge between the two batteries. It does this by directing more charging current to the bottom battery voltage equals 1/2 system voltage.

The battery balancer accomplishes this by sensing unswitched single battery voltage (12+ volts) at terminal 4. It divides the system voltage by two, then compares the results with the single battery voltage.

If a difference exists, the battery balancer will take current available at terminal 2 and send the extra current out terminal 4 to the bottom battery until the batteries are “balanced” within 0.5 volts.

Turning the key switch to the ON position, sends system voltage to terminal 6 of the battery balancer. The voltage at terminal 6 energizes an internal relay that connects terminals 3 and 4 of the battery voltage balancer.

When this happens, the single battery voltage (12+ volts) is sent to the AM/FM radio (A10) 12-Volt accessory power socket (X32), lighter (R9), 2-way radio power connector (X60) and to terminal A3 of connector X5A on CCU (A8).

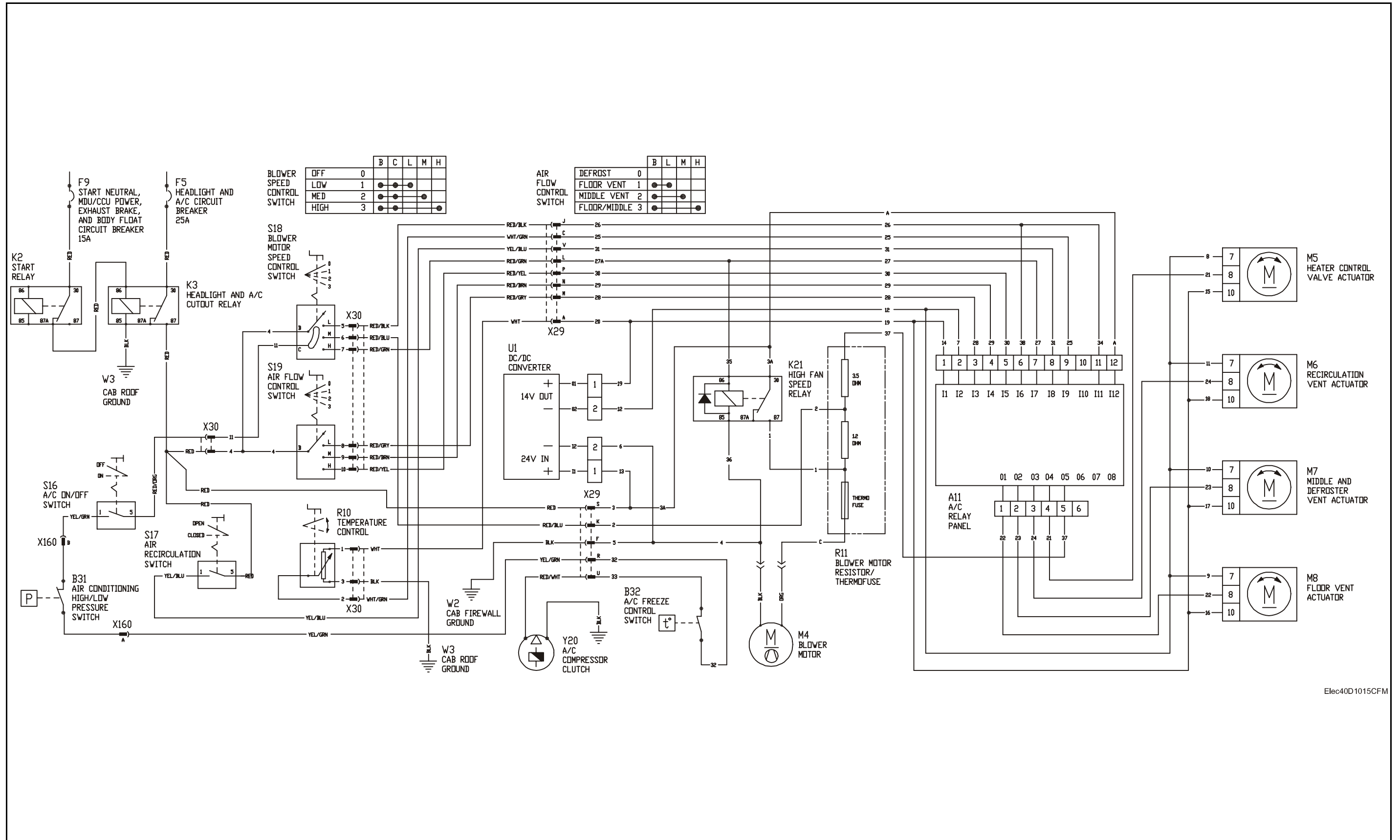
The CCU senses the single battery voltage (12+ volts) from terminal 3 and also the system voltage (24+ volts).

It then divides the system voltage by two, then compares the results with the single battery voltage.

If the difference is more than 1.5 volts, the CCU sends a signal through the CAN data line to the MDU (H2), causing the Battery Charge Light to come **ON**.

**NOTE:**1. The battery charge voltage is digitally displayed in the MDU, when accessed. For more information on accessing the menu structure, see MDU function, CHAPTER 8 in the OMM.  
2. When the battery disconnect switch is turned to OFF position, there is no 12-volt power available for the AM/FM radio station memory presets and clock. As a result, any station preset and clock setting are lost. The station presets will need to be reprogrammed and the clock reset when the battery disconnect switch is turned to the ON position.

## Air Conditioning Circuit Theory of Operation



Elec40D1015CFM

Figure 3-115

When the key switch is in the **ON** position, current flows from circuit breaker (F9), across the normally closed contacts of start relay (K2), to the coil of head light and A/C cut-out relay (K3), energizing the relay. With relay (K3) energized, current from circuit breaker (F5) is available at the following components:

- Air re-circulation switch (S17).
- Blower motor speed control switch (S18).
- Air flow control switch (S19).
- DC/DC convertor (U1).
- High fan speed relay (K21).
- A/C relay panel (A11).

Whenever the engine is cranked, current flowing from circuit breaker (F9) to the coil of head light and A/C cut-out relay (K3) is interrupted, causing the relay to de-energize.

With relay (K3) de-energized, the air conditioning system de-activates so the starting load on the engine is reduced. For more information on the starting circuit, **See “STARTING AND CHARGING CIRCUIT AND THEORY OF OPERATION” on page 58.**

**Air Conditioning System**

For the air conditioning system to operate, A/C on/off switch (S16) must be in the **ON** position and blower motor speed control switch (S18) must be in any position but the **OFF** position.

As long as the contacts of air conditioning high/low pressure switch (B31) and A/C freeze control switch (B32) are closed, current from circuit breaker (F5) will flow to blower motor speed control switch (S18) at terminal B.

The current flows out terminal C of the blower switch, through A/C on/off switch (S16) and A/C freeze control switch (B32), to A/C compressor clutch (Y20), energizing the clutch.

**Air Conditioning High/Low Pressure Switch**

The air conditioning high/low pressure switch (B31) protects the A/C system if the refrigerant pressure becomes too high. It also protects the A/C system if the pressure becomes too low caused by loss of refrigerant. If either of these conditions occur, the switch contacts will open and cause A/C clutch compressor (Y20) to de-energize.

**A/C Freeze Control Switch**

The A/C freeze control switch (B32) senses the temperature in the evaporator core through a gas-filled capillary tube. The switch closes when the evaporator temperature is above the switch setting and opens when the evaporator is cooled to the switch setting.

**DC/DC Converter**

The heater valve actuator and the tree vent actuators require approximately 14 volts to operate.

Because of this, DC/DC convertor (U1) is needed to convert the system voltage (27.5 ± 1.5 volts) to the required voltage.

The 14 volts is supplied to terminal I-1 of A/C relay panel (A11), terminal 1 of temperature control(R10) and to terminal 10 on all the actuators.

**Blower Motor Speed Control Switch**

When the blower motor speed control switch (S8) is in the **LOW** position, current flows from terminal 5 of the blower switch to terminals I-6 and I-11 of A/C relay panel (A11).

The current at terminal I-11 energizes a relay on the A/C relay panel.

With this “onboard” relay energized, current is allowed to flow in terminal I-12 of the A/C relay panel, then out terminal O-5 to Blower Motor Resistor/Thermofuse (R11).

The current flows through the 3.5 ohm resistor, the 1.2 ohm resistor and the thermofuse, then to blower motor (M4), activating the motor in low speed.

At the same time, current at terminal I-6 energizes another onboard relay that directs current from the 14 volt system out terminal O03, to terminal 8 of re-circulation vent actuator (M6).

If air re-circulation switch (S17) is in the ON position, the vent actuator will cause the re-circulation flapper door to move to the fully open position, thus allowing outside air to enter the cab.

When the blower motor speed control switch (S18) is in the **MEDIUM** position, current flows from terminal 6 of the blower switch directly to blower motor resistor/thermofuse (R11). The current flows through the 1.2 ohm resistor and the thermofuse, then to blower motor (M4), activating the motor in medium speed.

If air re-circulation switch (S17) is in the **ON** position and blower speed switch in the **MEDIUM** position, the re-circulation flapper door will move to the half-way position.

When the blower motor speed control switch (S18) is in the HIGH position, current flows from terminal 7 of the blower switch to the coil of high fan speed relay (K21), energizing the relay.

With relay (K21) energized, current flows to blower motor resistor/thermofuse (R11).

The current only flows through the thermofuse, then to blower motor (M4), activating the motor in high speed.

At the same time, current flows to terminal I-7 of A/C relay panel (A11), energizing an onboard relay that connects system ground to terminal O-3.

If air re-circulation switch (S17) is in the **ON** position, the ground is supplied to terminal 8 of Re-circulation vent actuator (M6), causing actuator (M6) to move the re-circulation flapper door to the fully closed position. Air is re-circulated through the cab.

**Air Re-circulation Switch**

When air re-circulation switch (S17) is in the OFF position, no current flows from the switch.

The re-circulation flapper door stays in the fully open position regardless of blower speed setting.

When the air re-circulation switch is in the **ON** position, current flows to terminal I-8 of A/C relay panel (A11).

The current energizes an onboard relay that directs current from the 14 volt system out terminal O-3 to terminal 8 of re-circulation vent actuator (M6), activating the vent actuator.

The vent actuator moves the re-circulation flapper door to the fully closed position, causing the air to re-circulate through the cab.

**Air Flow Control Switch**

When air flow control switch (S19) is in the **DEFROST** position, no vent actuators are activated. Air flow is directed to the wind shield.

When the air flow control switch is in the **FLOOR VENT** position, current flows out terminal I-3 of A/C relay panel (A11).

The current energizes an onboard relay that directs current from the 14 volt system out terminal O-1 to terminal 8 of floor vent actuator (M8), activating the vent actuator and causing air flow to be directed to the floor vents.

When the air flow control switch is in the **MIDDLE VENT** position, current flows out terminal 9 of air flow switch to terminal I-4 of the A/C relay panel.

The current energizes an onboard relay that directs current from the 14 volt system out terminal O-2 to terminal 8 of the middle and de-froster vent actuator (M7), activating the vent actuator and causing air flow to be directed to the middle vents.

When the air flow control switch is in the **FLOOR/MIDDLE VENT** position, current flows out terminal 10 of air flow switch to terminal I-5 of the A/C relay panel.

The current energizes an onboard relay that directs current from the 14 volt system out terminal O-1 and O-2 to terminal 8 of middle and defroster vent actuator (M7) and floor vent actuator (M8), activating both vent actuators and causing air flow to be directed to both the middle vents and the floor vents.

### Temperature Control

The temperature control (R10) is a variable resistor that sends an analog current from the 14 volt system to terminal I-9 of A/C relay panel (A11).

The current flows through an onboard fixed resistor, out terminal O-4 of the relay panel, to terminal 8 of heater control valve actuator (M5), activating the valve actuator.

The actuator opens and closes a valve in the heater core line. The movement of the valve corresponds directly with the position of temperature control (R10).