TABLE OF CONTENTS

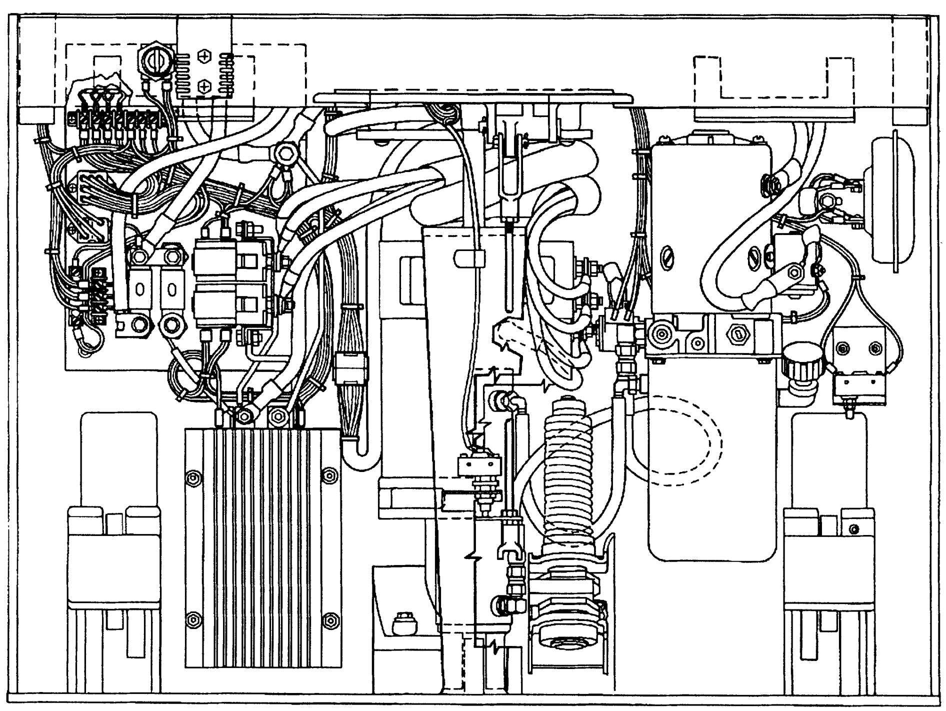
General

This section describes the operation, checks, repairs, and troubleshooting of the Curtis PMC 1204 or 1205 series. It also covers the 1207 series and the new series of the 1243 motor controller. See Figure 1, Figure 2, and Figure 4. This transistor motor controller is used to control the operation of some 24- and 36-volt electric lift trucks. The controllers are made for Hyster Company by a division of Curtis Instruments, Inc.

The controller for the traction system uses digital logic. Digital logic uses transistors to operate like very fast switches. The transistors are controlled by electrical gate pulses. Electrical noise is also high voltage pulses caused by momentarily operating other electrical devices. Digital logic cannot understand the difference between control pulses and electrical noise. Filter capacitors are connected between the B+ and B− terminals in the controller to prevent electrical noise from entering the logic and causing errors.

The logic of the controller also checks the following functions:

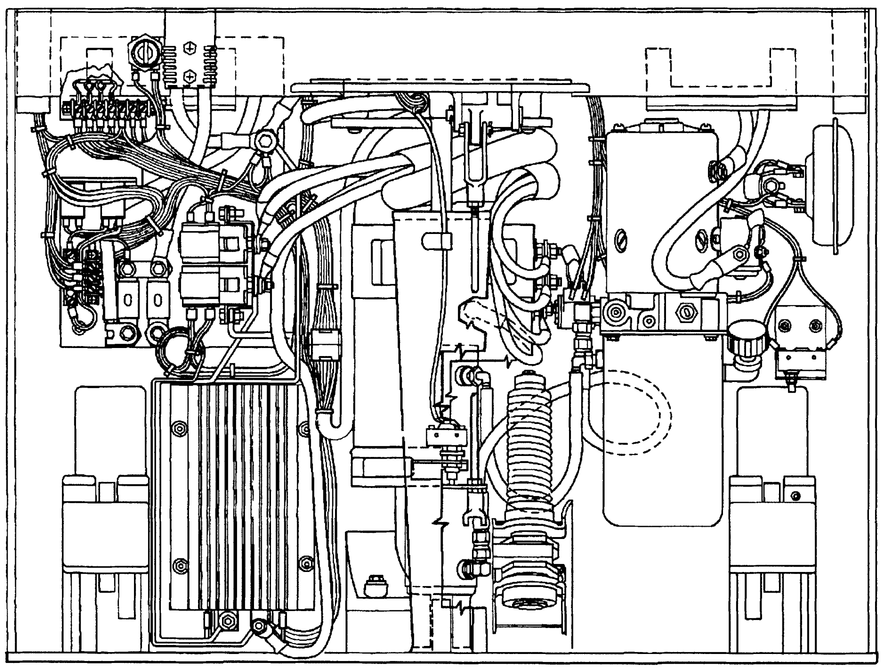
1. Checks the temperature and gives both low and high temperature thermal protection to the controller.
2. Electrically checks that an operator follows the correct starting sequence to help prevent unexpected operation. This function has been called Static-Return-To-Off (SRO) in other Hyster motor controller Service Manual sections.
3. Electrically checks the traction circuit for certain malfunctions. This function prevents lift truck operation if a failure is sensed.
4. Checks the current in the motor circuit and automatically decreases the motor voltage to reduce the current and prevent damage. The plugging circuit is also controlled for smoother operation.



NOTE: B60-80XT SHOWN. W45XT, W60-80XT, C60-80XT, AND T5XT MODELS SIMILAR.

Figure 1. Transistor Controller on Truck (Early Production)

Additional information showing how the motor controller is electrically connected in the lift truck is shown in the section **Diagrams** 8000 SRM 457 for the walkie low lift motorized hand trucks, **Diagrams Curtis Transistor** 8000 SRM 495 for N30FR units, **Diagrams Curtis Transistor** 8000 SRM 475 for R30ES units, **Diagrams** 8000 SRM 653 for the walkie high lift motorized hand trucks, and **Diagrams** 8000 SRM 923 for the R30XM2/XMA2/XMF2/XMS2 units.



NOTE: B60-80XT SHOWN. W40XT, W45XT, W60-80XT, C60-80XT, AND T5XT MODELS SIMILAR.

Figure 2. Transistor Controller on Truck (Late Production)

Principles of Operation

GENERAL

A motor controller for an electric lift truck controls the speed of the traction motor by making a variation in the applied voltage. This controller uses solid-state electronic devices to permit efficient control of the applied voltage.

The motor controller also generates a high current flow in the traction motor while keeping a low current draw from the battery. A battery is less efficient at a high current draw. A battery will not give all of its electrical power at a high current draw. The traction motor is a series wound motor that generates torque. This torque is proportional to the current moving through the motor. The speed of the motor is controlled by the voltage and mechanical load connected to the motor.

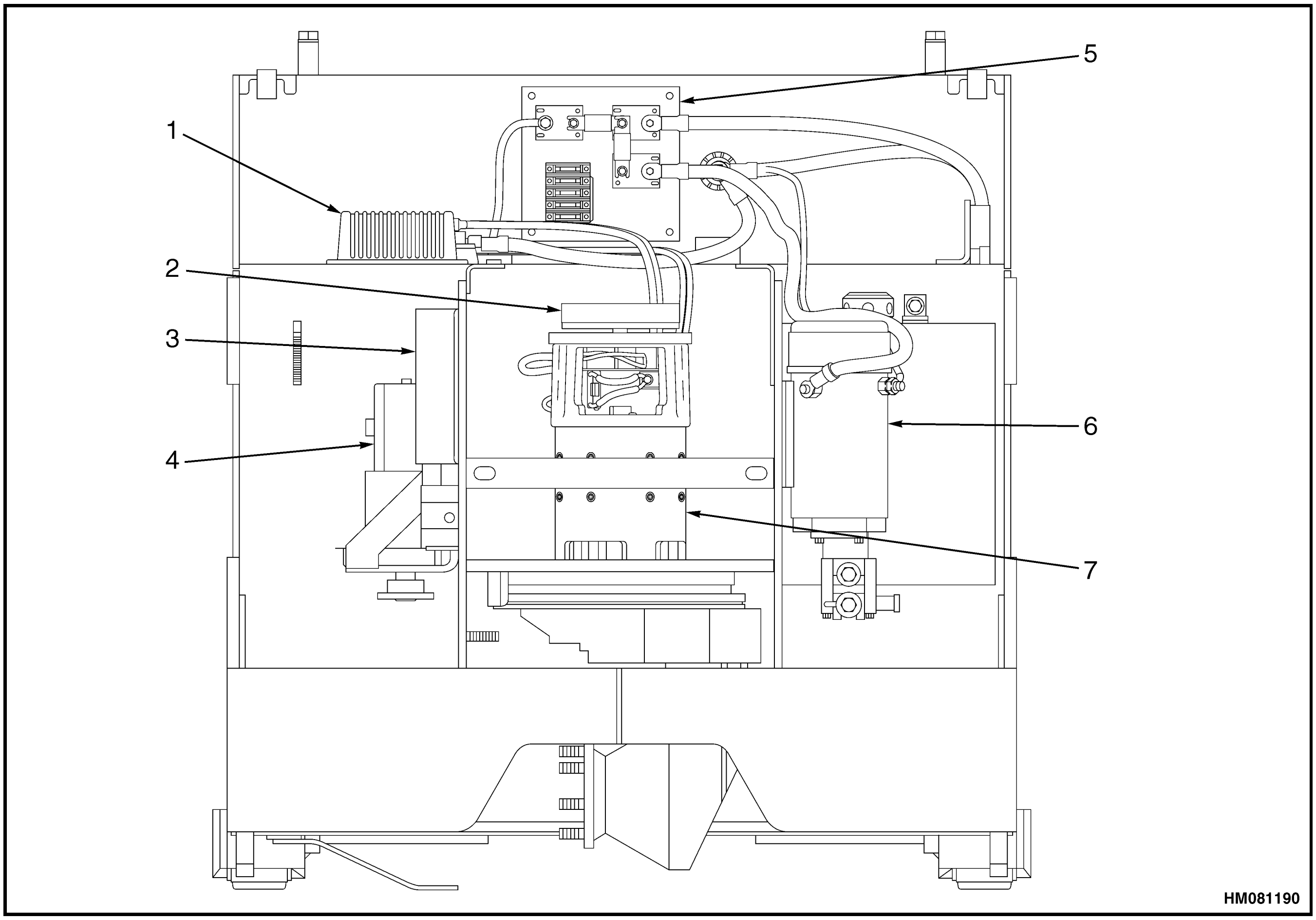
The motor will accelerate until the mechanical load equals the torque required. If the torque increases, the current and acceleration will increase.

The two functions look like a problem of opposite needs. How a solid-state electronic controller balances those needs with efficiency is described in this section.

TRANSISTOR MOTOR CONTROLLER

The motor controller controls the speed of the traction motor. The direction of rotation of the motor is controlled by the Forward/Reverse switch and contactors. See Figure 3, Figure 4, and Figure 5. The controller is sealed in an aluminum case and has no parts that can be repaired or replaced. The complete unit must be replaced if correct troubleshooting methods show that the unit is damaged.

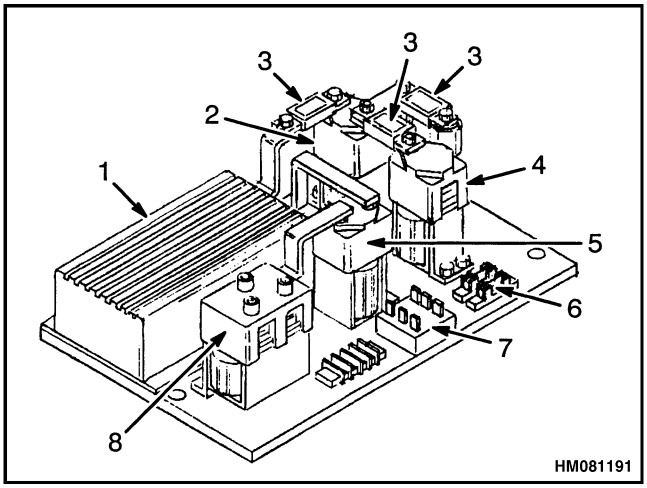
External contactors are used to control the direction of rotation of the traction motor. Contactors are electrical switches that use an electromagnet to operate the power contacts of the switch. A small electric signal is used to energize the electromagnet to close the power contacts and control the large current flow needed for the motor circuit. The electromagnetic field in the coil moves the armature against spring pressure to close the power contacts. When the coil is de-energized, the spring pressure moves the armature and opens the contacts. When a spring holds the contacts of a switch open, the switch is called normally open (NO). If the switch spring holds the contacts of a switch closed, the switch is called normally closed (NC).



1. PMC
2. ELECTRIC BRAKE
3. APS
4. STEERING MOTOR
5. CONTACTOR PANEL
6. HYDRAULIC PUMP MOTOR
7. DRIVE MOTOR

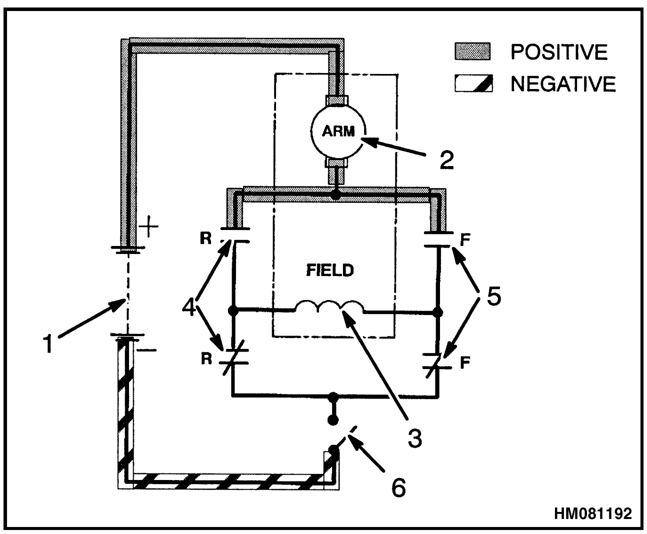
Figure 3. Transistor Controller on Truck (New Production)

(More Content includes: Brake system, Capacities, and specifications, Frame, Hydraulic, System, Industrial battery, Main control, Valve, Mast repair, Fasteners, Schematics diagrams, Steering axle, Steering system, Wire harness repair And more)



1. CONTROLLER
2. LC CONTACTOR
3. POWER FUSE
4. LIFT PUMP CONTACTOR
5. 1A CONTACTOR
6. CONTROL FUSES
7. TIMER
8. FORWARD/REVERSE CONTACTOR

Figure 4. Transistor Controller Panel (W/B40-60XL Units)



1. BATTERY
2. TRACTION MOTOR ARMATURE
3. TRACTION MOTOR FIELD
4. REVERSE CONTACTOR CONTACTS
5. FORWARD CONTACTOR CONTACTS
6. FETS SWITCH

Figure 5. Basic Traction Motor Circuit

There are two contactors that control the direction of rotation of the traction motor. Each direction contactor has two sets of contacts on the same plunger assembly. Each contactor has a set of NO contacts and a set of NC contacts. When one set of contacts is closed, the other set of contacts must be open. This arrangement prevents the wrong sequence of closed contacts that could cause an open circuit. This arrangement of contactors also permits current flow through the motor field in either direction. See Figure 5 and Figure 6. One set of contacts causes the motor armature to rotate in one direction. The other set of contacts causes the motor armature to rotate in the opposite direction. See Figure 7. Other contactors used for control functions on the lift truck only have one set of contacts because a forward and reverse operation is not required. An example is the hydraulic pump motor contactor.

Contactors are used to energize and de-energize motors, but cannot control the speed. The transistor motor controller applies battery voltage in short, fast pulses to a DC motor to control the speed. How this circuit controls the speed of a motor with pulses is described in this section.

The direction and speed control operates the FWD/REV switch to energize the direction contactor. The control also supplies the speed input to the motor controller.

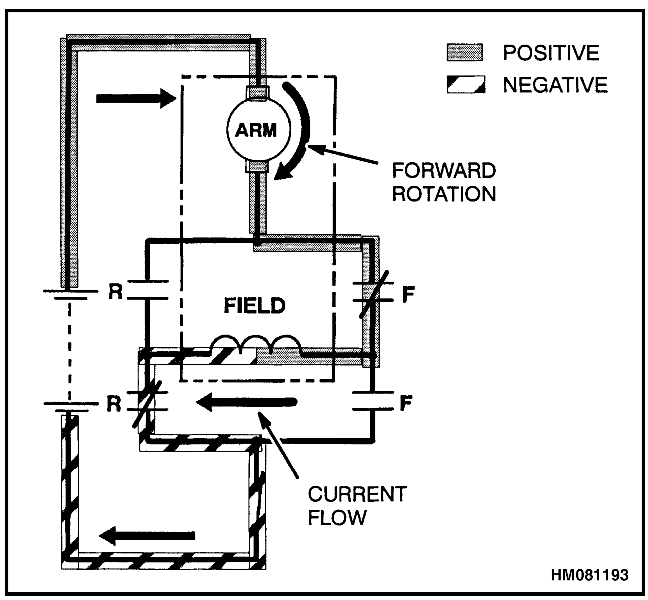


Figure 6. Current Flow Through Field in FORWARD Direction

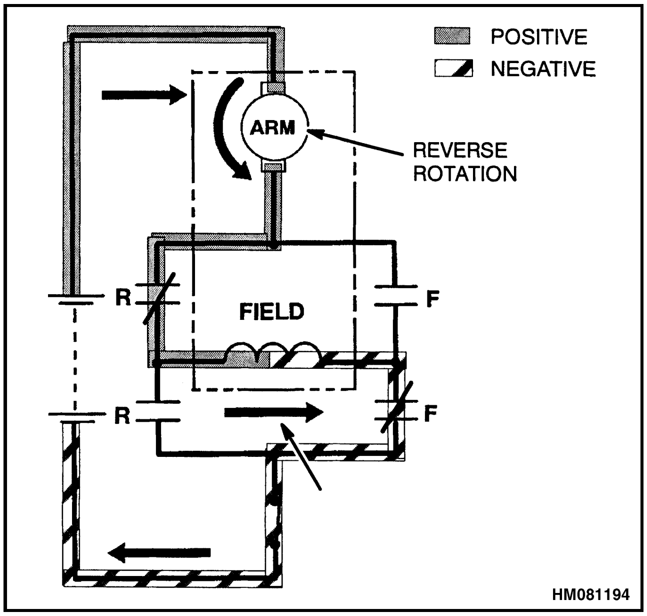


Figure 7. Current Flow Through Field in REVERSE Direction

Basic Controller Operation

This transistor motor controller has a power section and a logic section with solid-state electronic circuits that control the operation of a DC motor. The speed of DC motors is controlled by the average applied voltage. The higher the average applied voltage, the faster the motor will rotate. If a switch is put in the traction motor circuit (see Figure 4) and the switch is changed to **OFF** and **ON** quickly (see Figure 9) the traction motor will rotate. The speed of rotation increases as the time the switch is **ON** increases. The speed of rotation will decrease if the **ON** time decreases. **OFF** time will increase at the same time. The speed of the motor can be controlled using this principle.

This controller uses an electronic device called a Field Effect Transistor (FET) to generate the rapid **ON** and **OFF** pulse times. It has no moving parts. The FETs are turned on and off by the logic circuits in the controller to act as the switch. Several power FETs are connected in parallel to carry the necessary motor current.

Field Effect Transistor (FET)

A FET is a solid-state device that operates like a very fast switch. A FET is a transistor that has an element called a gate. FETs are electronic devices that permit electricity to flow as long as there is a gate voltage. See Figure 8. Electricity flows easily from the input to the output. A FET will only permit current flow when there is a positive voltage at the input, a negative voltage at the output AND a positive voltage applied to the gate. A FET will permit electricity to flow from the input to the source as long as there is the signal voltage at the gate. The FETs **ON** time is the same as the gate pulse **ON** time as shown in Figure 9. Current flows as shown in Figure 8. The FET stops conducting when the signal voltage is removed from the gate.

When FETs are used as a switch:

a. The FETs are **ON** when the electric current flows through them (gate voltage applied).

b. The FETs are **OFF** when the electric current cannot flow through them (no gate voltage).

Motor Circuit That Operates With Pulses

A schematic that shows the controller and FETs in a traction circuit is shown in Figure 8. When a signal is applied to the gate of the FETs, the FETs are **ON** and current flows from the battery through the motor. When the gate signal is removed, the FETs are changed to **OFF**.

The battery voltage is applied to the motor in pulses. The pulses of energy through the FETs to the motor are very fast (15,000 on/off cycles per second). The motor cannot follow each pulse, but the motor runs smoothly based on the average voltage generated by the **ON** and **OFF** times. The average motor voltage applied to the traction motor is shown in Figure 9. The length of the **ON TIME** of the pulses changes the average motor voltage. As the **ON TIME** of each pulse increases (**OFF TIME** decreases), the average motor voltage increases. This change in the ratio of **ON TIME** to **OFF TIME** of the pulses is called pulse width modulation.

The control circuit has an oscillator and a pulse width modulator. The oscillator generates a saw tooth waveform at a constant frequency of 15,000 cycles per second (15 kHz). The pulse width modulator uses this saw tooth waveform to generate a pulse output that can be smoothly changed from a full **ON** to a full **OFF** condition. This pulse output is used by the gate driver circuit for the high pulse currents needed to turn the FETs **ON** and **OFF**. The pulse width modulator controls the **ON** and **OFF** times of the FETs through the gate driver. The ratio of **ON TIME** to **OFF TIME** sets the average motor voltage and the motor speed.

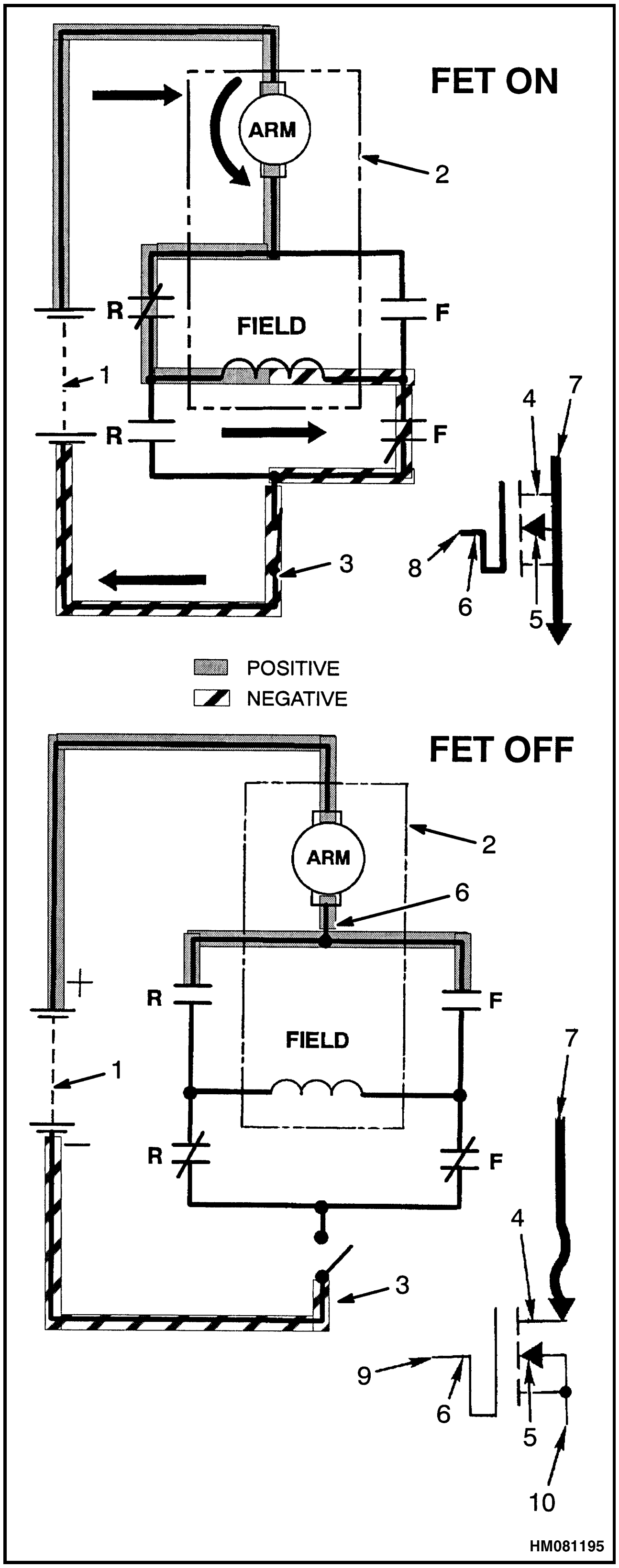


Figure 8. Transistor Control

Legend for Figure 8

1. BATTERY
2. TRACTION MOTOR
3. GATE DRIVE
4. FET INPUT (+)
5. FET OUTPUT (−)
6. FET GATE (+)
7. POSITIVE SUPPLY THROUGH MOTOR
8. POSITIVE GATE VOLTAGE
9. NO GATE VOLTAGE
10. NO GATE SIGNAL

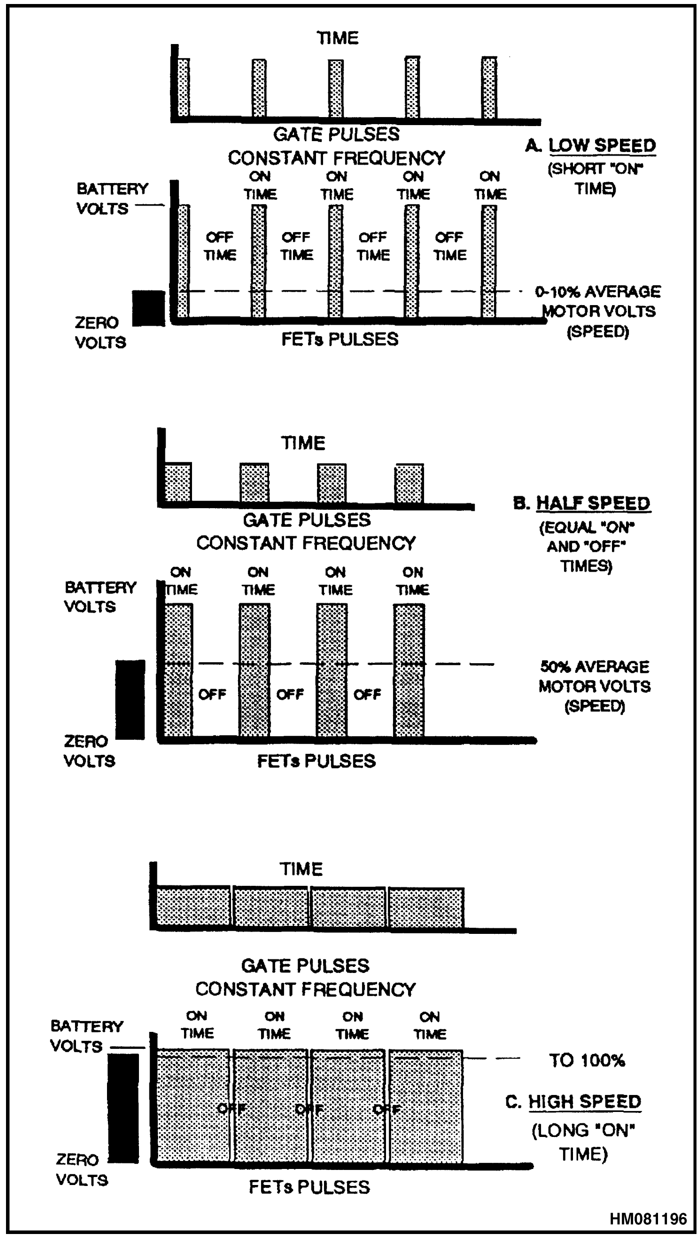


Figure 9. Average Motor Voltage

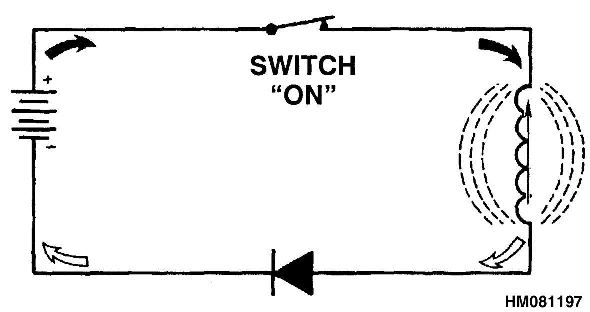
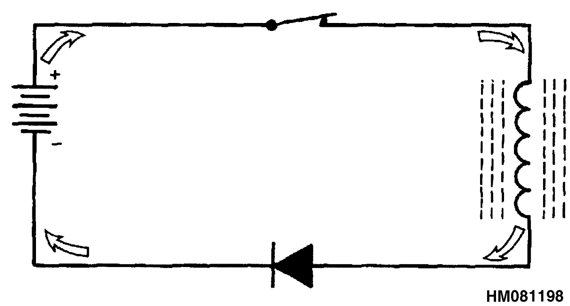
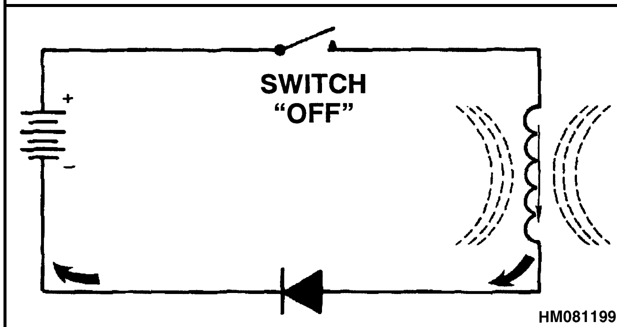
The accelerator potentiometer, at the speed control of the lift truck, regulates a voltage that changes as the operator sets the speed of operation. This voltage is an input to the controller and the pulse width modulator. As the voltage changes with the selected speed, a direct change in the ratio of FET **ON TIME** to FET **OFF TIME** also occurs. The voltage for maximum speed changes the ratio to pulses with the maximum **ON TIME**, to produce a maximum average motor voltage. See Figure 9. The pulse rate (15 kHz) stays the same for all speeds.

Induction Current From Motor

When a DC motor is controlled by a pulsed circuit, the magnetic field in the armature and field windings is continuously expanding and decreasing. The fields expand when voltage is applied (**ON TIME**) and decreases when the voltage is removed (**OFF TIME**). The voltage causes an increasing current flow through the windings to make the expanding magnetic field. When the voltage is removed, the decreasing magnetic field causes current to flow in the same direction through the windings. See Table 1. This expansion and decrease of the magnetic field is lost energy for doing work unless the controller is designed to use this energy. A Flyback Diode (sometimes called a Freewheel Diode) is in the controller circuit for this purpose.

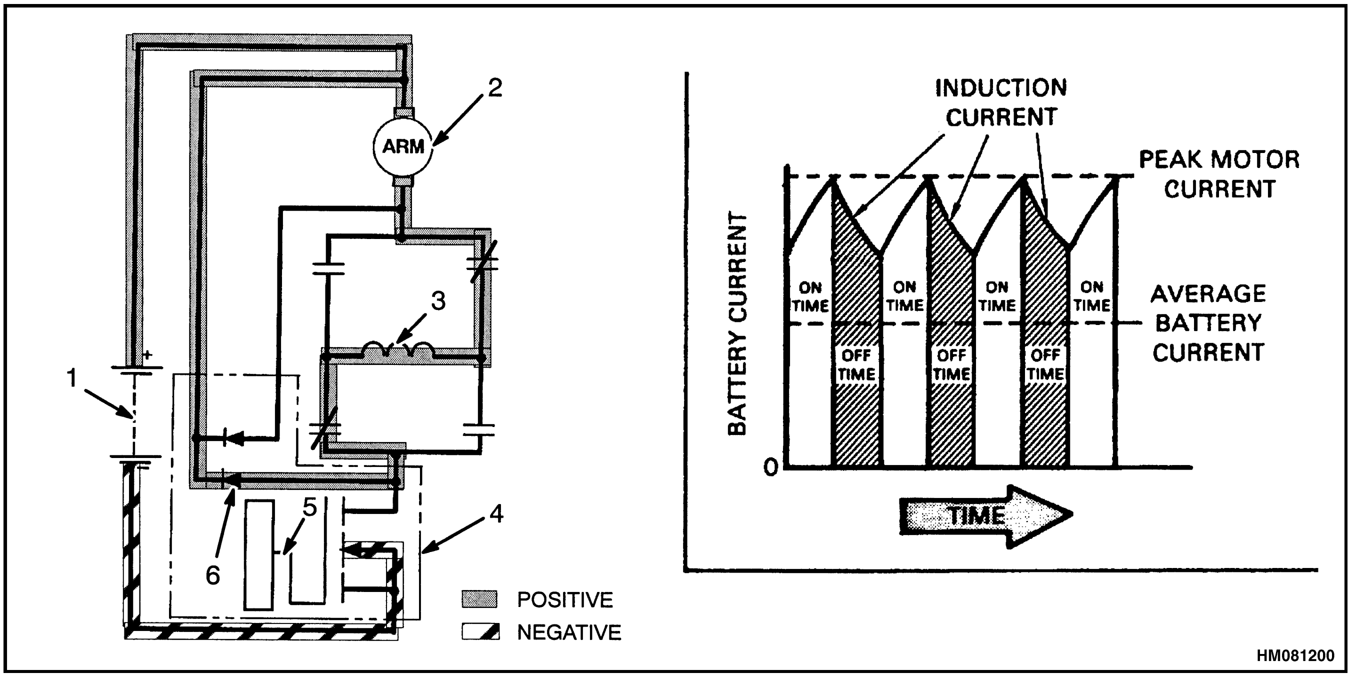
The Flyback Diode permits the current, from the decreasing magnetic field, to flow through the field and armature again to do work. The torque of a series DC motor is directly proportional to the amount ofcurrent flowing through it. At slower speeds, the **OFF** times are longer. When the FETs are **OFF**, the decreasing magnetic field generates a voltage and current in the motor.

Table 1. Inductance

	Beginning conditions as the switch is closed: **1.** Large current flow from battery through inductor. **2.** Increasing magnetic field generates reverse voltage within inductor. **3.** Reverse voltage decreases current through inductor. Current energy changed to energy in magnetic field.
	Constant conditions after switch is closed for a short time period: **1.** Voltage and current flow is the same in all parts of the circuit. **2.** Magnetic field is constant.
	Ending conditions as the switch is opened: **1.** Decreasing magnetic field generates voltage within inductor. **2.** Decreasing magnetic field generates current flow in original direction.

This current is often called the flyback current. The Flyback Diode permits the current to flow through the field and armature again to do work. At slower speeds, the motor current is part battery current and part flyback current. There is less battery current used for the specific torque requirement. High current draw from the battery is to be avoided, if possible, because it is less efficient. At higher speeds, the **OFF** time is less, so that less induction current (flyback current) is generated. Most of the motor current must come from the battery at higher speeds. However, the torque and current requirements are also usually less.

The typical induction current during equal **ON** and **OFF** times of the FETs is shown in the graph in Figure 10.



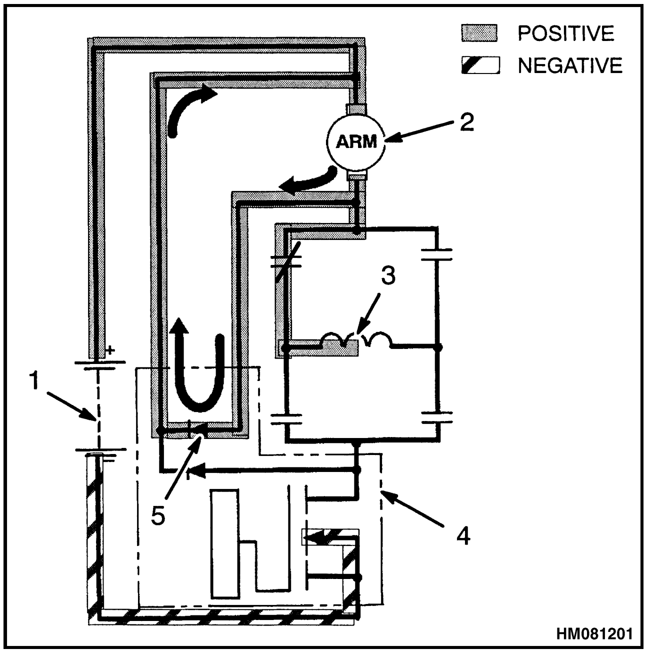
1. BATTERY
2. MOTOR ARMATURE
3. MOTOR FIELD
4. CONTROLLER
5. FETS (NOT ON)
6. FLYBACK DIODE

Figure 10. Induction Motor Current

Plugging

The plugging circuit is an added feature of the controller that provides smooth electrical braking when the operator wants to change the truck's direction of travel. See Figure 11. The plugging feature also saves wear and tear on the drive tires and the drive unit gears.

Plugging occurs when the truck is traveling in one direction but the operator has switched the directional control to the opposite direction. In this instance, the motor armature is rotating in one direction while the magnetic forces of the fields are trying to force the armature the other way. This reaction generates current that is allowed to flow through a loop formed by the plugging diode in the controller. This generated current helps to slow the truck's speed magnetically in the same manner that compression in a gas engine will help to control the speed of an automobile when it is coasting. When a lift truck is in the plugging mode, the pulse rate of the controller must be maintained at a slow rate. To accomplish this the logic section of the controller signals that the truck is in a plugging mode and controls the oscillating rate. The oscillating rate pulses slowly no matter what position the directional control is in on a controller with fixed plugging. Some controllers are furnished with throttle position plugging and the oscillating rate can vary.



1. BATTERY
2. MOTOR ARMATURE
3. MOTOR FIELD
4. CONTROLLER
5. PLUG DIODE

Figure 11. Plugging Current Circuit

The plugging function of the controller is designed to allow the truck to travel 1 to 2 times the length of the lift truck after the truck is plugged before it reverses direction.

During plugging, the oscillating rate is decreased from 15 kHz to 1 kHz. The controller regulates the pulse widths of the pulses to the motor field for the correct amount of plugging. The accelerator circuit is also set to a low speed so that normal acceleration in the opposite direction will occur. The plugging distance is adjustable. The plugging adjustment on the controller changes the amount of motor field current allowed. The plugging adjustment can be changed as needed for an application. See Adjustments.

Plugging an electric lift truck is not a harmful practice, however, avoid plugging the drive motor when the drive wheel is jacked off the ground.

Control Circuit

The control circuit has operator inputs from the key and brake switches as well as the accelerator potentiometer. The circuit also has internal inputs from the power circuit for thermal protection, plugging sensing, low voltage protection and motor current (current limit). The control circuit uses the inputs to regulate the **ON TIME** pulses to the FETs for speed control, current limit and plugging strength.

Static-Return-To-Off (SRO) Function

The control circuit includes a function to prevent the operation of the lift truck if the starting sequence is not correct. The function uses the inputs to the control circuit to make sure the operator is ready to operate the controls. The starting sequence is as follows:

1. Turn the key switch to the **ON** position. The key switch supplies battery voltage to the brake switch.
2. The operator must close the brake switch. Battery voltage is now supplied to the control circuit.
3. Rotate the Direction/Speed control in the desired direction of travel to select travel direction and speed.

If Step 3 is done before both Step 1 and Step 2 are complete, the lift truck will not move in either direction. The control circuit must get battery voltage through both the key and brake switches before it gets a speed signal from the accelerator potentiometer. If the starting sequence is not correct, the control circuit will not send a gate pulse to the FETs for traction motor current.

The SRO function also prevents the lift truck from going to full speed operation because of a malfunction in the accelerator circuit. On the B/W40-60XL units, an open circuit in the accelerator circuit is normally sensed as a full speed signal by the control card. If this malfunction exists, the SRO function will prevent the start of traction pulses. If the malfunction occurs during normal operation, the control circuit senses an accelerator potentiometer input of more than 7000 ohms (open circuit) and stops the traction pulses. The circuit will return to normal operation after the malfunction is repaired.

Thermal Protection Function

There is a sensor to sense the heat within the controller housing. If the controller gets too hot or too cold for correct operation, the control circuit will reduce the **ON TIME** of the pulses to decrease the current to protect the controller. The lift truck will still operate at a slower speed to permit it to be moved to a location out of the work area. The controller can then return to a normal operating temperature. The controller is designed to operate with an internal temperature between 85°C (185°F) and −25°C (−13°F). Controller performance will be reduced when the controller is in Thermal Protection.

Low Voltage Protection Function

This function protects the controller and the battery. The controller will not operate correctly if there is not a minimum voltage from the battery. The battery current drain increases as the battery voltage decreases. Too large a battery drain will damage the battery. If the battery voltage is low, the control circuit will decrease the **ON TIME** of the pulses to decrease the current drain. The battery can still operate the lift truck to move it for battery charging or replacement. The controller requires a minimum of 9 volts on the 12-volt controllers and a minimum of 16 volts on the 24-volt controllers for the system to function properly.

Current Limit Protection Function

The control circuit limits the traction motor current to a maximum value to protect the controller, motor and battery. The control circuit will decrease the **ON TIME** of the motor pulses to keep the motor current less than the maximum value. The maximum value is set by the manufacturer.

Power Circuit

The power circuit is controlled by the control circuit. See Figure 12. The complete power circuit is inside the controller and has the following parts:

- Field Effect Transistors
- Flyback Diode
- Plug Diode
- Filter Capacitors

The parts in the power circuit cannot be replaced by users. Cables connect the battery and traction motor to the power circuit at the controller power terminals B+, A2, M−, and B−. All of the traction motor current flows through the power circuit of the controller.

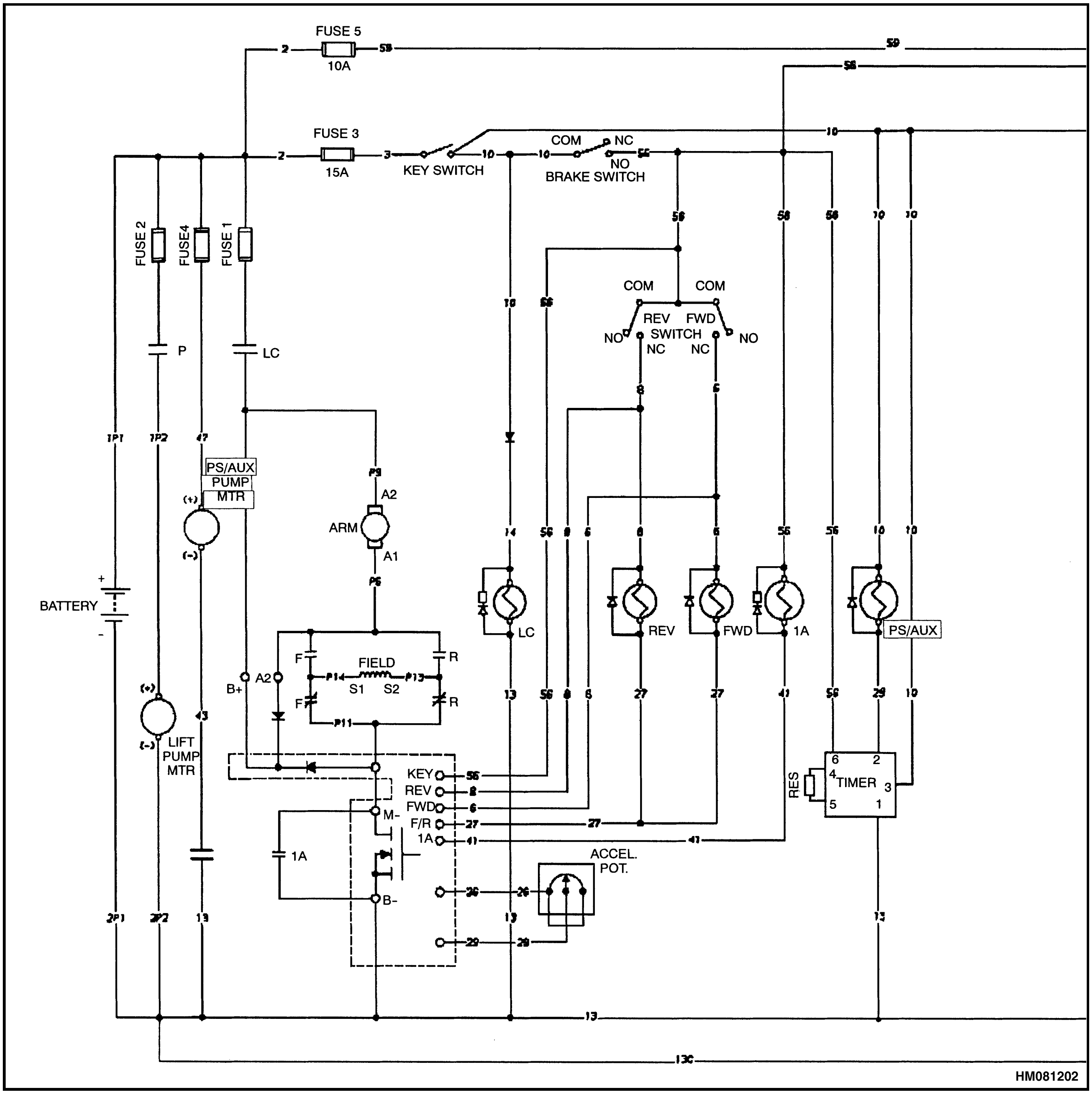


Figure 12. N30FR Transistor Controller Circuit Schematic

Sequence of Operation

The sequence of operation describes a complete cycle of the transistor traction circuit. A sequence of the beginning conditions and the FET cycle is shown in Figure 13.

NOTE: Gray lines on the circuit lines show positive voltage with respect to battery negative. Slash lines show negative voltage with respect to battery positive.

The line codes do not always indicate full battery voltage. The gray tone is used only for the circuits being described. Some parts of the energized circuit are not shown with gray tones or slashes. The thick (bold) lines show the traction power circuit. The thin lines show the control circuits.

NOTE: The following circuit schematics from the W40-60XL and B40-60XL lift trucks are used to describe the sequence of operation. Basic operation of the transistor controller for other lift truck models is similar. See the **Diagrams** sections for the complete schematics.

NOTE: The N30FR, W40-60XL, and B40-60XL lift trucks have an additional LC contactor that is energized when the key switch closes. The basic circuit operation is the same as described.

KEY SWITCH

Key Switch closed by moving key to the **ON** position. On N30FR units, the LC contactor is energized. Battery power to brake switch, lift, lower, horn and to optional heater and battery meter. See Figure 14.

BRAKE SWITCH

Brake switch must be closed by lowering steering handle (W/B40-60XL, W/B60-80XT, W20-40XTA, W20-40XTC, and W20-30XTR only); operator releasing brake handles (C60-80XT and T5XT); or operator stepping on brake switch (R30ES only) so that the FWD/REV switch, Traction Reverse switch (W/B40-60XL and W/B60-80XT only), Accelerator Potentiometer, and Control Circuit will have battery voltage when key switch is closed. See Figure 15.

CONTROL CIRCUIT

Battery positive to the Control Circuit, Hourmeter, Traction Reverse switch (W/B40-60XL and W/B60-80XT only), and Direction switch through the key and brake switches. Hourmeter begins to operate. Circuit checks that there is no speed signal from the accelerator potentiometer. If there is a speed signal as battery power is applied, the control circuit will prevent the gate signal from going to the FETs. See Figure 15.

FWD/REV SWITCH CLOSED

Forward contacts of FWD/REV switch close. Accelerator potentiometer speed signal to control circuit. Battery positive voltage available to Forward contactor. See Figure 16.

FORWARD CONTACTOR ENERGIZED

Normally open contacts of Forward contactor close. Normally closed contacts open. Battery positive voltage is applied to FETs through traction motor. FETs are still **OFF**, so there is no current flow and the traction motor does not operate. See Figure 17.

GATE PULSE TO FETS

Gate Driver of control circuit sends gate **ON** pulse to FETs gate. **ON TIME** (pulse width) set by accelerator potentiometer signal. See Figure 18.

FETS ON FOR TIME OF GATE PULSE

FETs conduct to provide power pulse to the traction motor. Traction motor starts to operate. Pulse **ON TIME** is the same as gate **ON TIME**. See Figure 18.

GATE PULSE REMOVED

FETs stop conducting when gate pulse is removed. Power pulse is removed from traction motor. Pulse **OFF TIME** is set by the time remaining for one cycle at 15 kHz. See Figure 19.

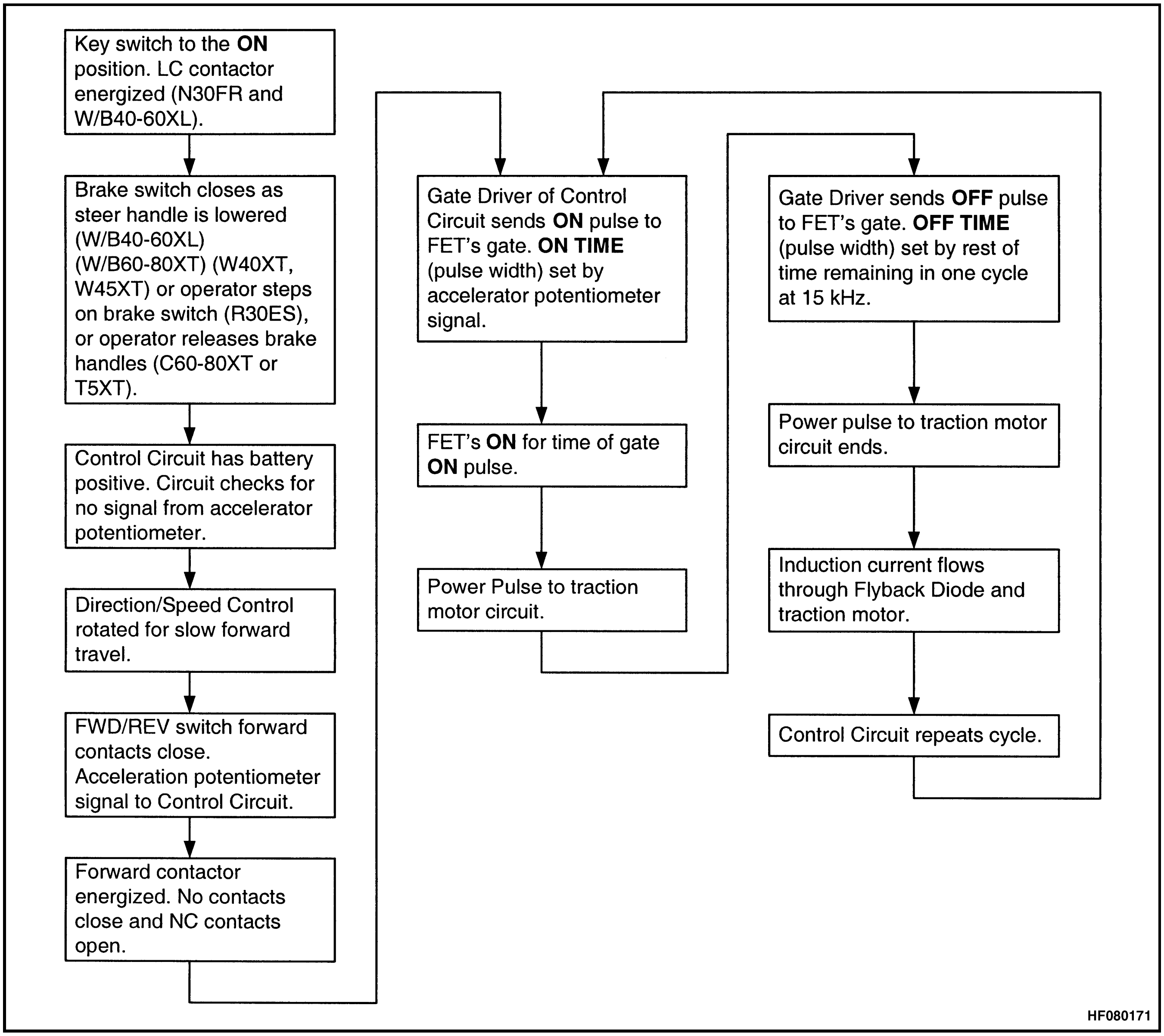
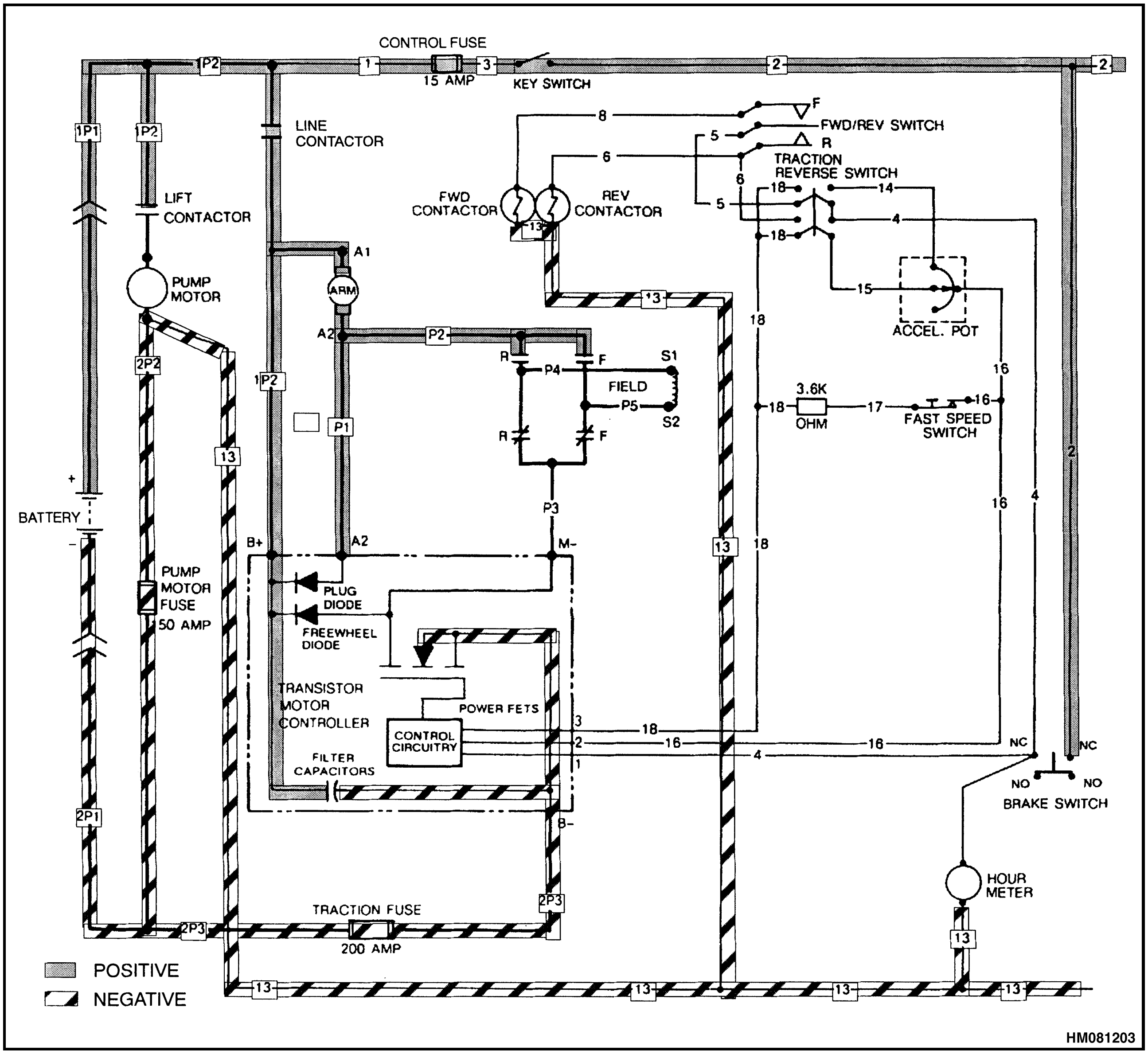


Figure 13. Sequence of Operation



NOTE: W/B40-60XL SHOWN. OTHERS SIMILAR.

Figure 14. Sequence of Operation - Key Switch Closed