Nebraska Public Power District

Power Drive

Understanding the Electrical System
Teacher Edition

Table of Contents

Objectives

Unit Objectives

When finished with this unit the student will be able to define terms used in electronics, locate and label components, wire an electrical system, and measure volts and amps. The student will demonstrate these competencies by completing the assignment sheets and lab activities and by scoring a minimum of 85 percent on the written test.

Specific Objectives

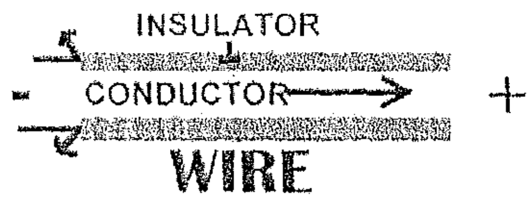
1. Define Volts.
2. Define Amps.
3. Define Ohms.
4. Define Series.
5. Define Parallel
6. Define electrical symbols.
7. List and describe electrical components of an electric vehicle.
8. Explain how each component of an electrical vehicle work together to make the vehicle functional.
9. Wire an electric vehicle correctly. (Using a module)
10. Measure Amps used to rotate motor.
11. Measure Volts in electrical system.

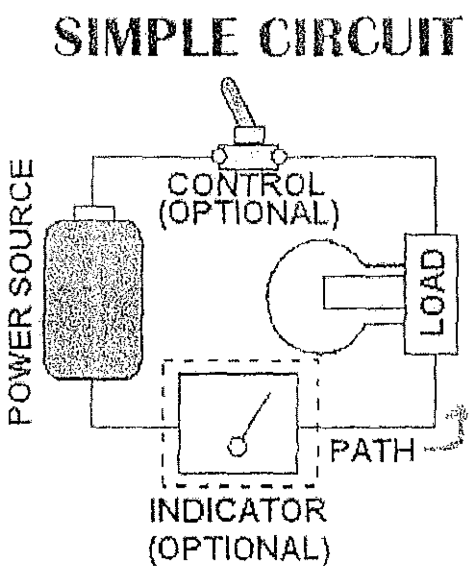
Basic Electronic Circuits

Circuit – Path for electrons to flow through. The path is form a power sources negative terminal, through the various components and on to the positive terminal.

Think of it as a circle. The paths may split off here and there but they always from a line form the negative to the positive.

Conductor – Material (usually a metal such as copper) that allows electrical current to pass easily through. The current is made up of electrons. This is opposed to an insulator which prevents the flow of electricity thorough it.





Simple Circuit

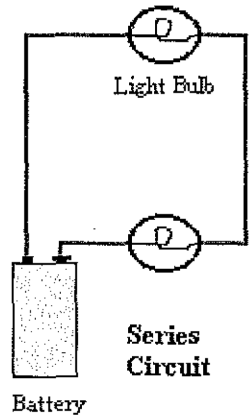
If we break a circuit down to it's elementary blocks we get:

1) A power source – Battery
2) A path – Wire
3) A load – Lamp / Motor
4) A control – Switch
5) An indicator – Meter

Series / Parallel

Series – An electric circuit connected so that current passes through each circuit element in turn without branching.

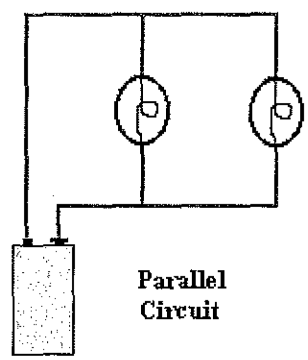
A **series circuit** has more than one resistor *(anything that uses electricity to do work)* and gets its name from **only having one path for the charges** to move along. Charges must move in "series" first going to one resistor then the next. If one of the items in the circuit is broken then no charge will move through the circuit because there is only one path. There is no alternative route. Old style electric holiday lights were often wired in series. If one bulb burned out, the whole string of lights went off.



Series Circuit

Parallel – An electric circuit connected that current can pass through different paths of the circuit.

A **parallel circuit** has more than one resistor *(anything that uses electricity to do work)* and gets its name from having multiple (**parallel**) paths to move along. Charges can move through any of several paths. If one of the items in the circuit is broken then no charge will move through that path, but other paths will continue to have charges flow through them. Parallel circuits are found in most household electrical wiring. This is done so that lights don't stop working just because you turned your TV off.



Parallel Circuit

Volts, Amps, and Ohms

The three most basic units in electricity are voltage (**V**), current (**I**) and resistance (**r**). Voltage is measured in **volts**, current is measured in **amps** and resistance is measured in **ohms**.

A neat analogy to help understand these terms is a system of plumbing pipes. The voltage is equivalent to the water pressure, the current is equivalent to the flow rate, and the resistance is like the pipe size.

There is a basic equation in electrical engineering that states how the three terms relate. It says that the current is equal to the voltage divided by the resistance.

I = V/r

Let's see how this relation applies to the plumbing system. Let's say you have a tank of pressurized water connected to a hose that you are using to water the garden.

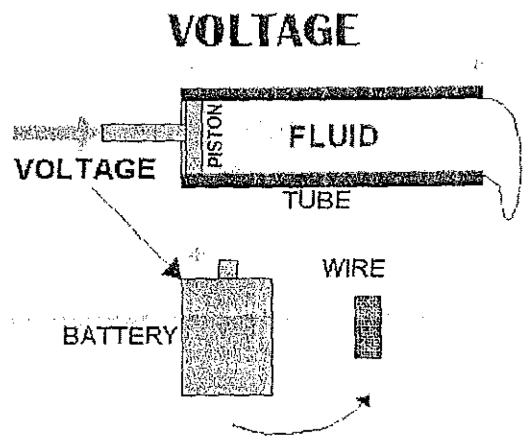
What happens if you increase the pressure in the tank? You probably can guess that this makes more water come out of the hose. The same is true of an electrical system: Increasing the voltage will make more current flow.

Let's say you increase the diameter of the hose and all of the fittings to the tank. You probably guessed that this also makes more water come out of the hose. This is like decreasing the resistance in an electrical system, which increases the current flow.

Volt – Measurement of electromotive force

Webster's:
The International System unit of electric potential and electromotive force, equal to the difference of electric potential between two points on a conducting wire carrying a constant current of one ampere when the power dissipated between the points is one watt.

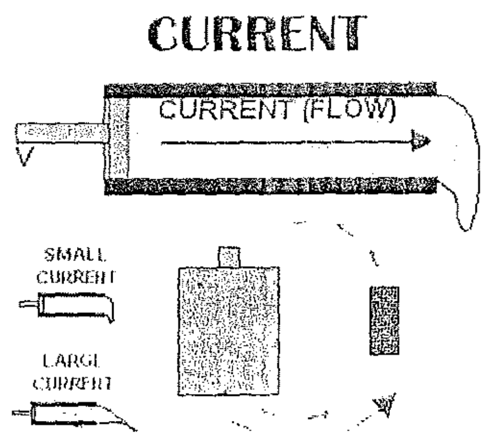
<u>**Voltage**</u> is the electrical force or "pressure" that causes current to flow in a circuit. It is measured in Volts. Take a look at the diagram. Voltage would be the force that is pushing the water forward.



Amp – Measurement of current of electrons flowing through a conductor

Webster's
The basic unit of electric current adopted under the System International d'Unites; "a typical household circuit carries 15 to 50 amps"

<u>**Current**</u> is the movement of electrical charge – the flow of electrons through the electronic circuit. Current is measured in Amperes (AMPS). Current would be the flow of water moving through the tube.



Ohm – Measurement of the resistance to the flow of current

Webster's
A unit of electrical resistance equal to that of a conductor in which a current of one ampere is produced by a potential of one volt across its terminals.

Electrical Symbols

	**Battery**		**Ammeter**	________	**Conductor**
	**Fuse**		**Voltmeter**		**Light**
	**Switch**		**Motor**		

Quiz 1

1. What is a conductor? ____

2. What is a series circuit? ______________________________________

3. What is an amp? ____

4. What is a circuit? ____

5. What is the difference between a series circuit and a parallel circuit? _________

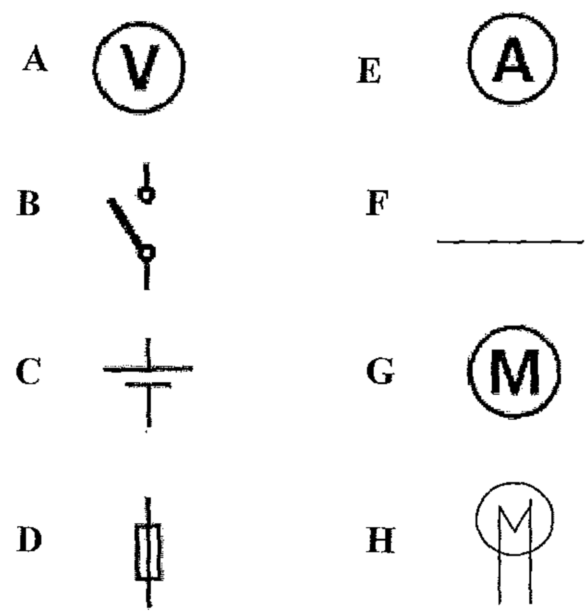
   ____

6. Voltage is the ______ that causes current to flow in a circuit? ______________

7. What is the measurement of the resistance to the flow of current called? _______

Matching

8. Fuse ________
9. Light ________
10. Motor ________
11. Switch ________
12. Ammeter ________
13. Conductor ________
14. Voltmeter ________
15. Battery ________



Quiz 1 Answer Key

1. What is a conductor? **Material that allows electrical current to pass through it**

2. What is a series circuit? **Circuit that is connected that current travels without branching.**

3. What is an amp? **Measurement of current**

4. What is a circuit? **Path for electrons to flow**

5. What is the difference between a series circuit and a parallel circuit?

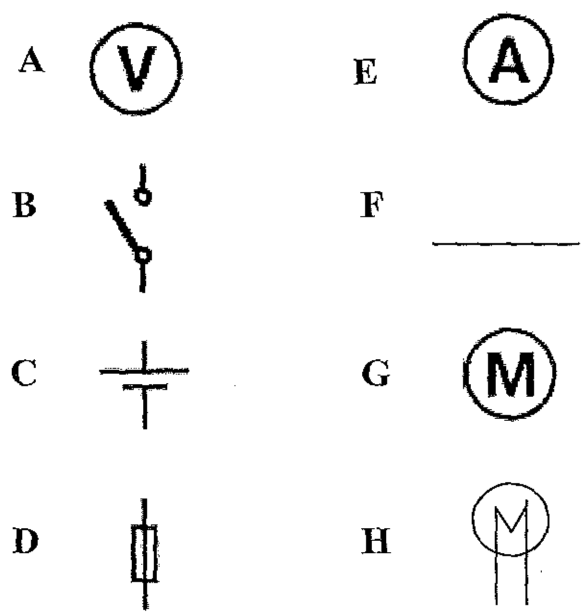
In series, current goes thorough each element without branching. Parallel current can pass through different paths of the circuit.

6. Voltage is the ______ that causes current to flow in a circuit? **Electrical Force**

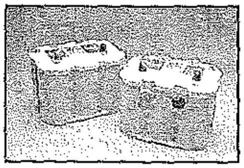
7. What is the measurement of the resistance to the flow of current called? **Ohm**

Matching

8. Fuse **D**
9. Light **H**
10. Motor **G**
11. Switch **B**
12. Ammeter **E**
13. Conductor **F**
14. Voltmeter **A**
15. Battery **C**

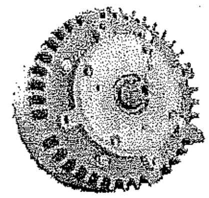


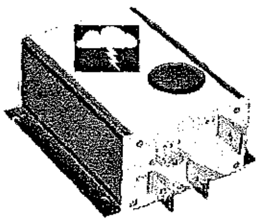
Components of Electric Vehicles



Batteries- Power Drive vehicles are powered by 2 – 12 volt batteries. These batteries supply the energy for the vehicle to move.

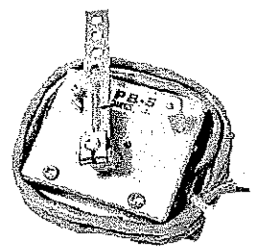
Motor - A permanent magnet motor propels Power Drive vehicles.

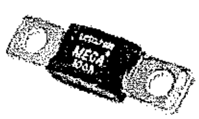




Controller – This controls the amount of current that is supplied to the motor from the batteries,

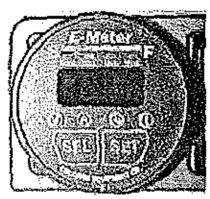
Potentiometer – This sends a resistance signal to the controller to tell the controller how much current to allow to pass through it. Also call a pot box.

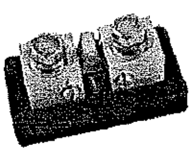




Fuse – This assures that excessive current doesn't pass through the system and damage components.

Ammeter / Voltmeter– This shows how much current it passing through the circuit, displayed in Amps. It also shows how much voltage is left in the batteries to use.





Shunt – Tells the ammeter the amount of current that is passing through the circuit.

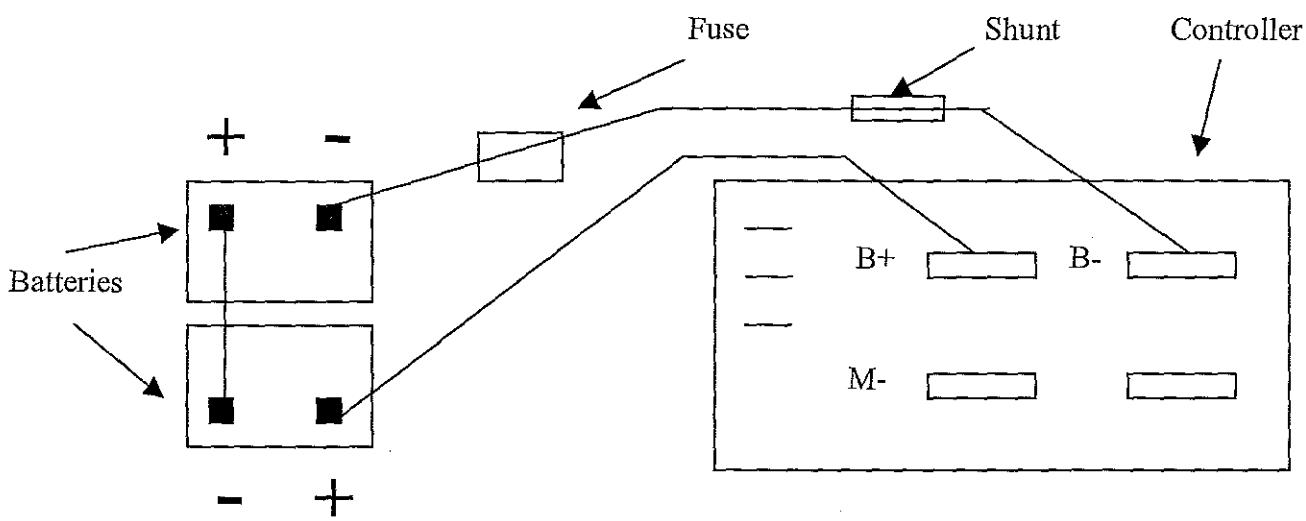
How the Components of Electric Vehicles Work Together

The two 12 volt batteries supply the vehicle with the energy to move the vehicle. These batteries are connected in series to produce 24 volts, and are connected to the controller. In the cables connecting the batteries and the controller on the negative side, the fuse and shunt are placed. The fuse keeps the electrical components from damage due to excess current. The shunt tells the ammeter how many amps are passing through it at any time.

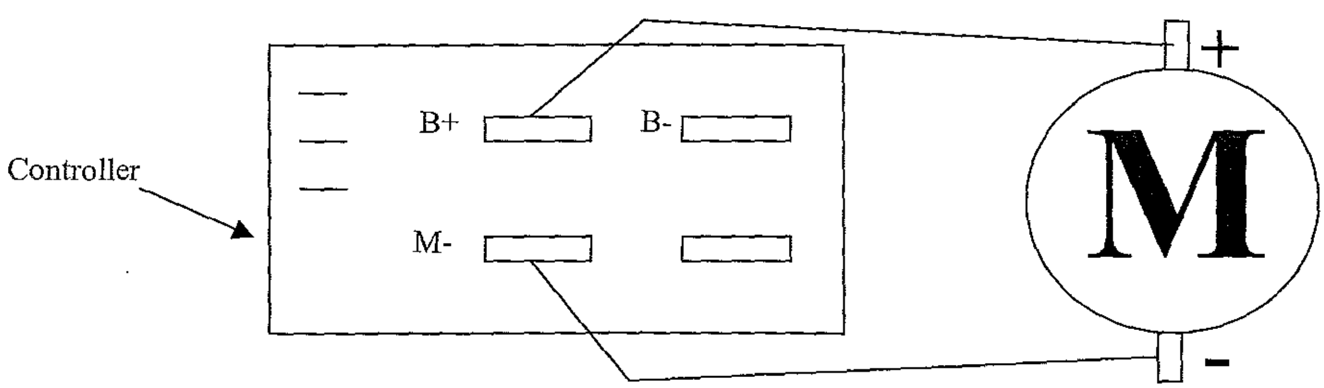
The controller regulates the amount of current that is passed from the batteries to the motor. The motor rotates when it receives electrical current. For the controller to work properly the potentiometer is connected to the controller. The potentiometer sends a resistance reading to the controller to tell how much current to pass through. Without the potentiometer you would have 100% current or no current going to the motor.

Wiring the Electric Vehicle

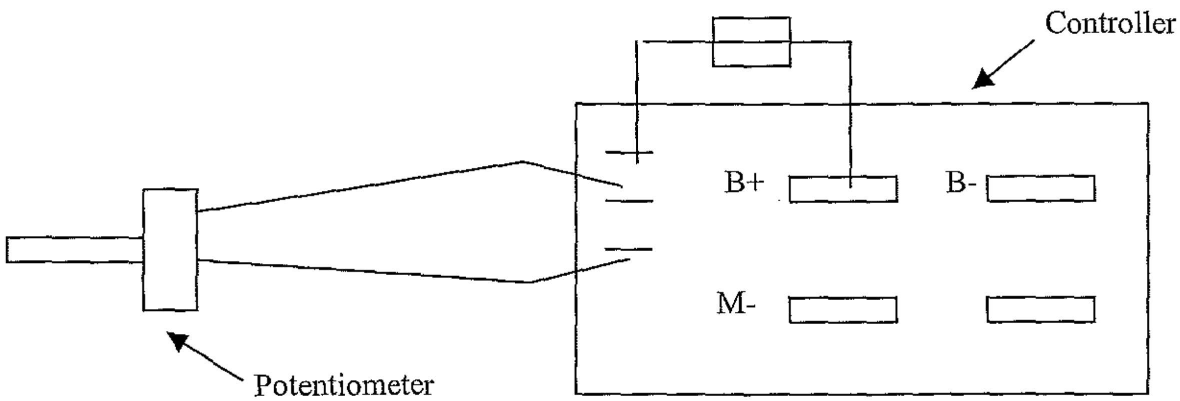
Connecting Batteries to the Controller
As stated earlier the batteries contain the energy needed to propel the vehicle. These two 12 volt batteries are connected to the controller in series, meaning that the circuit is 24 volts. (12 + 12 = 24) On the controller there are four large terminals. The terminal labeled B+ gets connected to the positive side of the batteries. The terminal labeled B- gets connected to the negative side of the batteries. You need to put you shunt in this cable. On one of the cables connecting the batteries to the controller you need to put a fuse in. This fuse will help you keep from damaging or destroying components.



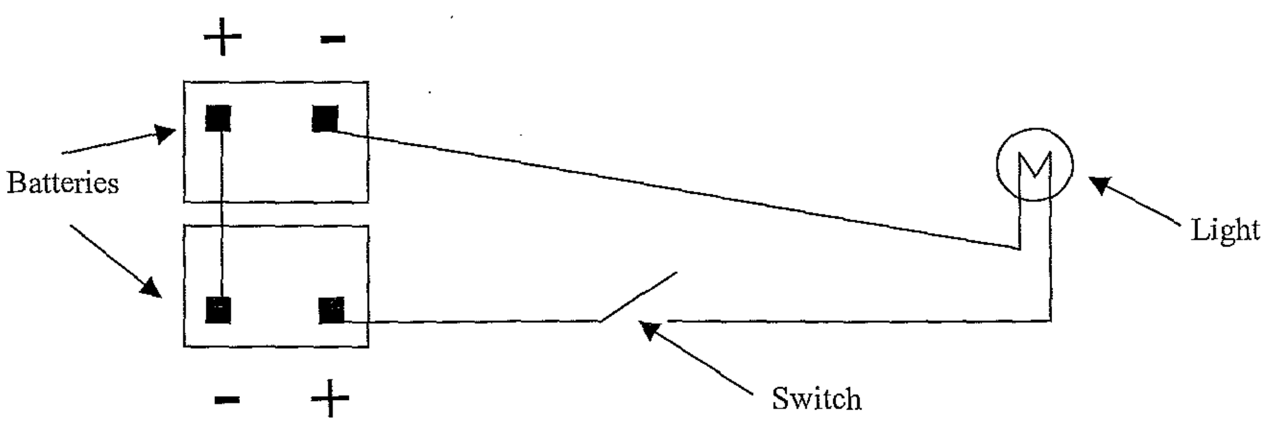
Connecting the Controller to the Motor
To connect the motor to the controller you need to connect the B+ terminal on the controller to the + (positive) terminal on the motor. Then connect the M- terminal to the – (negative) side of the motor.



Connecting the Potentiometer
First you need to connect the B+ terminal to the top small terminal. You need to put a 10 amp fuse in this connection. Next you need to connect the two leads from the potentiometer. Connect one lead to each of the bottom two small terminals.

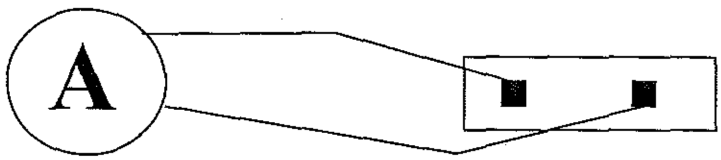


Connecting the Brake Light
You'll need a switch and a light for this. First run a wire from the positive terminal on the battery to the switch, making sure to put a fuse in. Then run a wire from the switch to the brake light and connect the wire to one of the leads on the light. Then connect a wire to the other lead and connect it to the negative terminal on the battery. Now when you flip the switch it should light up the light.



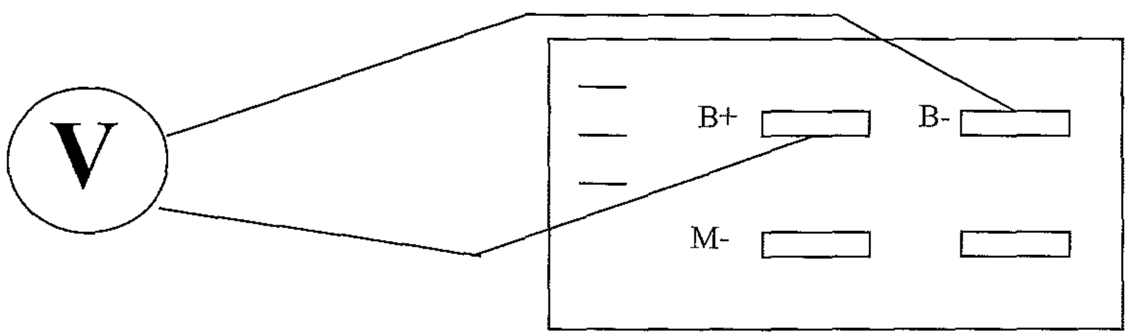
Connecting the Ammeter

Connect one of the leads of the ammeter to one side of the shunt. Then connect the other lead from the ammeter to the other side of the shunt.

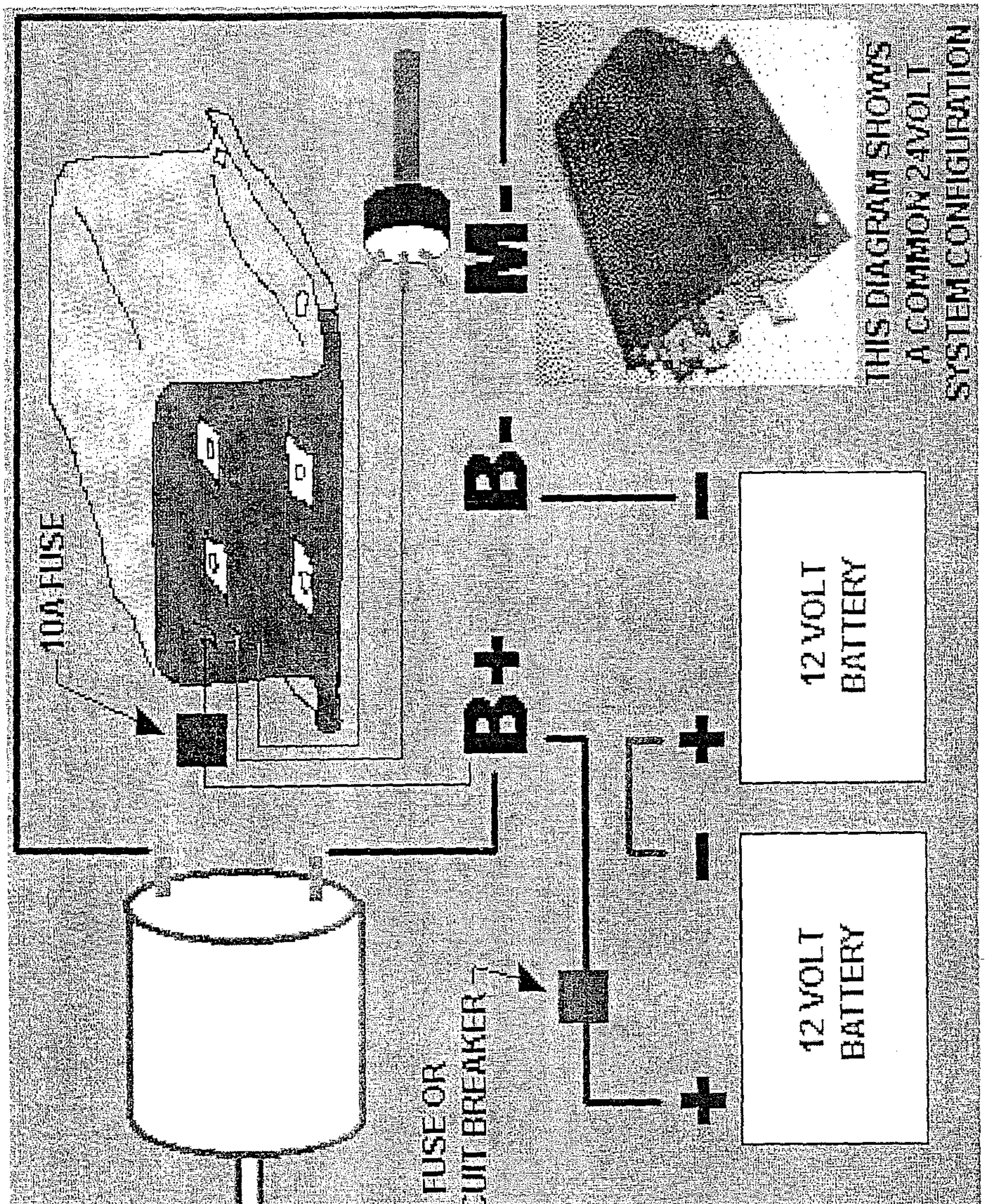


Connecting the Voltmeter

Connect the + positive lead of the voltmeter to the B+ terminal on the controller. Then connect the – negative lead of the voltmeter to the B- terminal on the controller.



Wiring Schematic



Assignment

Using the Power Drive Electrical System module, locate, and label each component. Next connect the components together to make the electrical system work properly.

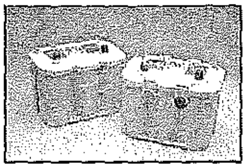
The following must be completed before assignment is done:

- Each component labeled correctly
- Proper connection of all battery cables
- Proper connection of motor cables
- Proper connection of Potentiometer
- Proper rotational direction of motor
- Functional brake light controlled by a switch
- Functional ammeter
- Functional voltmeter
- Read volts available in system
- Read amps being used in operation of motor

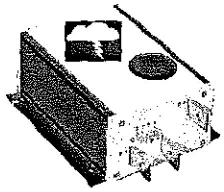
Following completion of this module, you must write a summary of what you learned from this activity, and any problems you encountered with this activity. Also list each component and tell what it does.

Assignment Answers

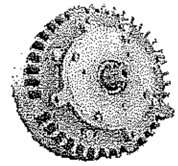
1.



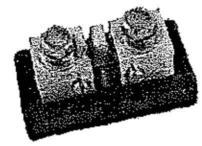
Batteries



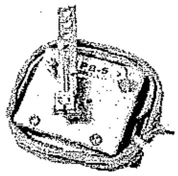
Controller



Motor

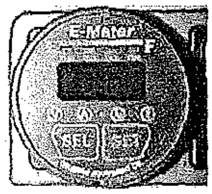


Shunt



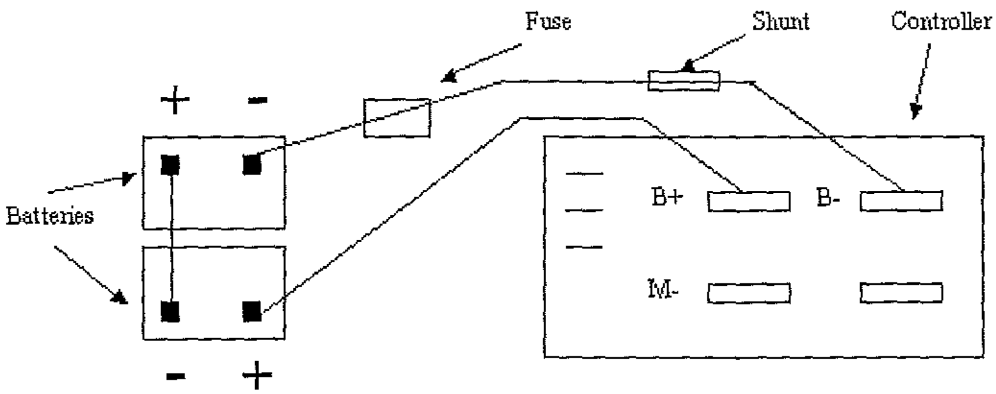
Potentiometer

Fuse

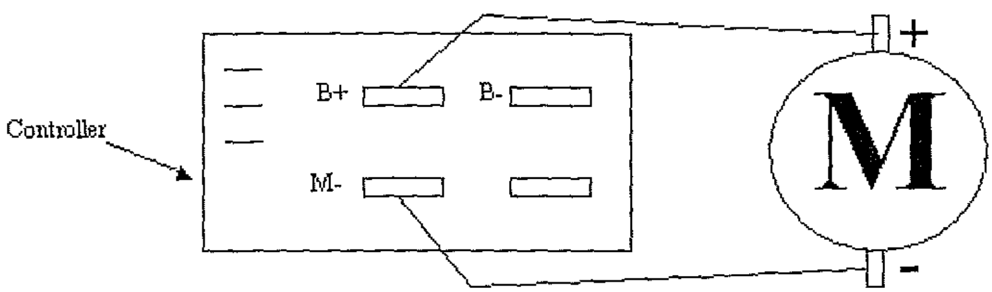


Ammeter / Voltmeter

2.

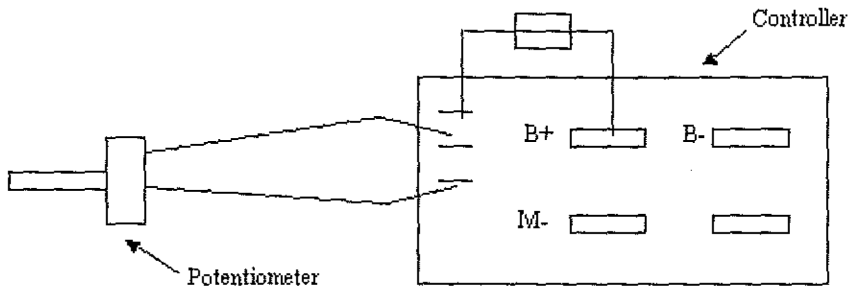


3.



Assignment Answers

4.



5. Should turn in direction on module.

6. See if brake light works
7. See if ammeter works
8. See if voltmeter works
9. Tell how many volts are in the system
10. Tell how many amps are being used

Test

1. What is the purpose of the fuse? ________________________________

2. To get 24 Volts the batteries must be wired in ______________________.

3. What is an Amp? ________________________________

4. What is the purpose of the shunt? ________________________________

5. A measurement of resistance is ______________________.

6. Pot Box is a nickname for what? ________________________________

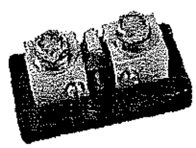
7. Draw the switch symbol. ________________________________

8. What is the main purpose of the controller? ________________________________

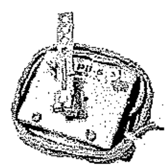
9. Briggs and Stratton make which motor? ________________________________

10. What is a Volt? ________________________________

11. Which component is this? ________________________________



12. Which component is this? ________________________________



13. What does parallel mean? ________________________________

14. What is the purpose of the component in question #13? ______________________

____

15. What symbol is this? ______ ________________________________

Test Key

1. What is the purpose of the fuse? Protects components from too much current and damage.

2. To get 24 Volts the batteries must be wired in Series .

3. What is an Amp? Measurement of current of electrons flowing through a conductor

4. What is the purpose of the shunt Tells the amount of current passing through the circuit

5. A measurement of resistance is Ohm .

6. Pot Box is a nickname for what? Potentiometer .

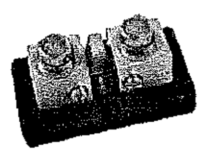
7. Draw the switch symbol.

8. What is the main purpose of the controller? Control current from batteries to motor

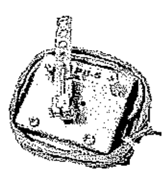
9. Briggs and Stratton make which motor? Etek .

10. What is a Volt? Measurement of electromotive force .

11. Which component is this? Shunt



12. Which component is this? Potentiometer .



13. What does parallel mean? Circuit connected that current can pass through different paths of the circuit.

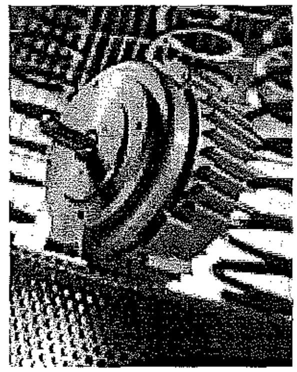
14. What is the purpose of the component in question #13? This sends a resistance signal to the controller to tell the controller how much current to allow to pass through it.

15. What symbol is this? Battery

Assessment

	Points Available	Points Earned
Lab activity	100 10 points for each part	
Written response	50	
Test	90 6 Points for each question	

Teacher Supplement



The Etek Brushless Motor System.
An evolution in advanced motor technology.

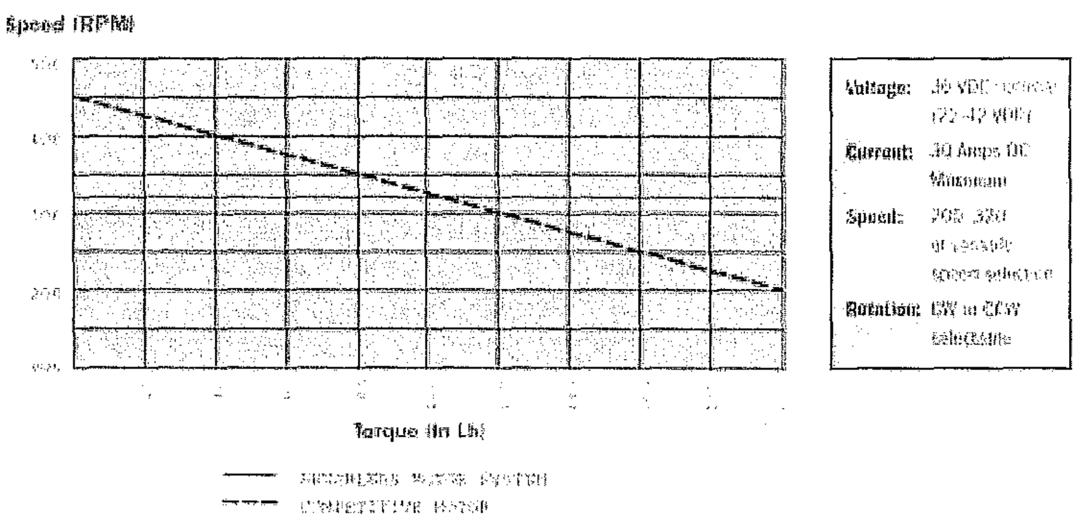
The Etek Brushless Motor System is just one more reason why leading commercial equipment manufacturers partner with us to deliver performance advantages.
This fully integrated electric motor system features an industry-first brushless, axial gap design and a programmable electronic motor controller. Because motor brushes require routine maintenance, their elimination in the Etek Brushless Motor System significantly minimizes maintenance and increases overall reliability. This in turn assures significant cost savings for the end-user over the life span of a piece of equipment.

The Motor

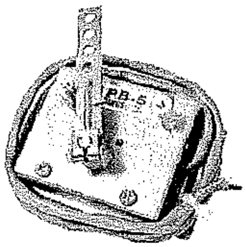
Featuring a pancake-style axial gap design, the motor utilizes high-strength Neodymium Iron Boron (NeFeB) magnets in a disc rotor arrangement to produce up to 15.0 HP (8.0 HP continuous). This arrangement assures higher torque at lower speeds in one compact package. Also contributing to enhanced productivity is a sealed aluminum motor housing. This housing provides durability, while working to keep contaminants out, which ensures peak motor efficiency under a variety of environmental conditions.

The Controller

The programmable electronic motor controller assures high performance and efficient power management. This innovative component electronically performs the function of brushes in traditional brush-type motors. The programmable nature of the electronic motor controller allows motor system performance to be maximized for a number of commercial equipment applications, and in some applications eliminates the need for a separate transmission.



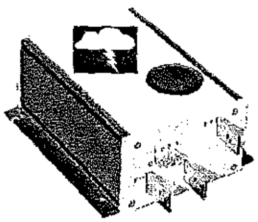
Student Supplement



Curtis PB-5 Style Pot Box, Potentiometer reads 0-5k Ohms

Dimensions: 3-3/4" high, 4" long, 2-1/16" deep

Weight – 0.89 LB **Price - $70.00**

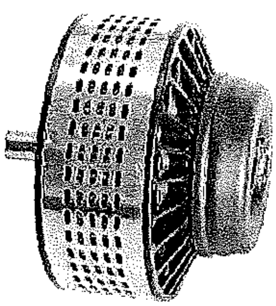


Alltrax, 24-48 volt, 300 amp, Fully Programmable Controller

Capable of changing settings such as voltage, amps, temperature, etc.

Programming functions: Throttle ramp, Throttle response rate, Battery over/under voltage cutback, maximum output current.

Weight – 5.50 LBS **Price - $279.45**

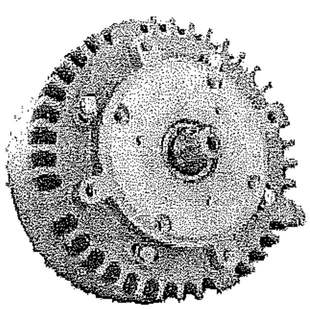


Lemco LEM-170 12 to 48 Volts DC Lynch Motor

This is the latest, second-generation design, which is imported from England.

Motor spins at 75 RPM's per Volt

Weight – 17.20 LBS **Price - $1,650.00**



Briggs and Stratton 24-48 Volt DC Etek Motor

Briggs and Stratton version of the Lynch motor.

Motor spins at 72 RPM's per Volt

Weight – 23 LBS **Price - $375.00**

Wiring Schematic from Curtis model 1204/5 Controller Manual

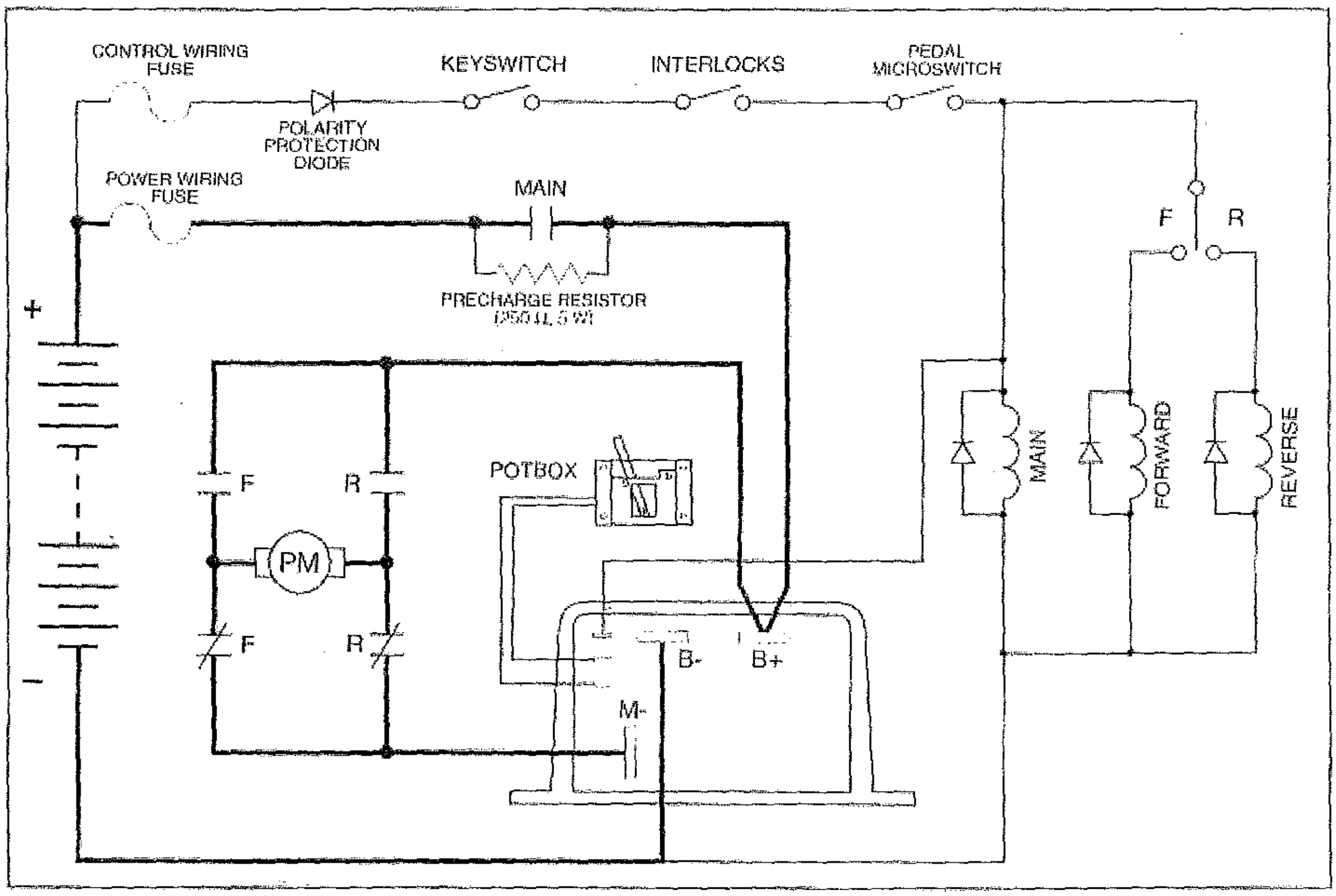


Fig. 15 *Basic wiring for use with PM motors.*

Maintenance Chapter in Curtis Controller Users Manual

4

MAINTENANCE & ADJUSTMENT

Curtis 1204/1205 controllers and potboxes require only minimal maintenance if properly installed. NOTE: The controllers are sealed and thus are not field serviceable.

CONTROLLER

Maintenance

CAUTION

It is recommended that the following two steps be performed occasionally. **First remove power by disconnecting the battery, and discharge the capacitors in the controller** (with a light bulb or a 2–10 Ω, 25 W resistor connected for a few seconds across B+, B-). Follow good safety practices: get the vehicle drive wheels off the ground, wear safety glasses, and use insulated tools *(see page 2)*.

1. Make sure the electrical connections to the controller (and to the motor, contactors, etc.) are tight. When checking the controller bus bar connections for tightness, use two opposing wrenches. This double-wrench technique will help avoid putting stress on the bus bars, which could crack the seals. **Always use insulated wrenches.**

2. Inspect all seals at the front and back of the controller. If necessary, use a moist rag to wipe these areas clean enough so that you can see the seals. Look for cracks and other signs of seal damage.

   If the seals are intact, clean the controller thoroughly either by washing it off or by wiping it clean with a moist rag. **Power must not be reapplied until the controller terminal area is completely dry.**

   If the seals have been damaged, there are several possible causes. Perhaps the double-wrench technique was not used when the cables were installed. Perhaps the vehicle's environment requires that the controller be better protected; either by mounting it in a different location, or by installing a protective cover.

   Damaged seals can lead to faulty operation. We strongly recommend replacing controllers that have faulty seals.

Adjustment

On some models, the plug braking current and acceleration rate settings are adjustable. On these adjustable controllers, the adjustment pots are located as shown in Figure 18.

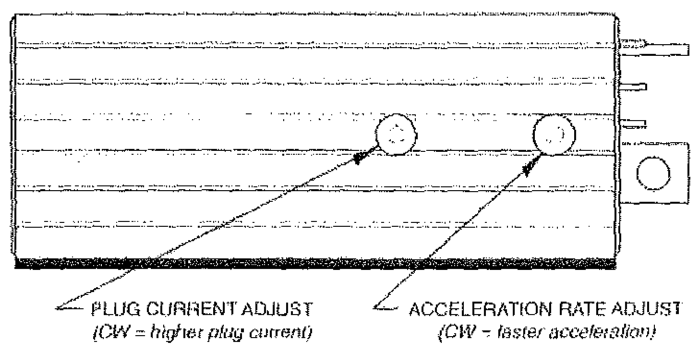


Fig. 18 *Adjustment pots.*

Use the following adjustment procedure. **The keyswitch should be <u>off</u> during adjustment.**

1. Remove the socket head screw (1/8" Allen) for the adjustment you want to make.

2. Adjust the internal potentiometer using a small **insulated** screw-driver *(available from Curtis).*

3. Replace the socket head screw and nylon seal washer. To prevent stripping, do not over-tighten.

POTBOX

Maintenance

Potbox maintenance is similar to controller maintenance: inspect for integrity of connections and mounting, and clean (with a moist rag) as required.

Adjustment

Curtis PMC potboxes are factory set and rarely require user attention. To test and adjust, connect an ohmmeter to the potbox wires and use this procedure:

1. With the spring holding the lever arm against the return stop, the resistance should be less than 50 ohms. Slowly move the lever. If the resistance abruptly starts to increase when the lever is 3 mm (1/8") from the stop (1.5 mm [1/16"] for potboxes without the microswitch), no adjustment is needed.

2. If adjustment is required, loosen the screw holding the lever on the pot shaft. Use a screwdriver to rotate the pot shaft slightly with respect to the lever. Recheck the point at which the resistance starts to increase and continue making adjustments until the increase occurs at 3 mm (1/8") [at 1.5 mm (1/16") for potboxes without the microswitch]. When adjustment is correct, tighten the screw holding the lever on the pot shaft, then recheck to see that this action did not disturb the adjustment. Make sure that the lever is still seated down on the pot shaft below the slight bevel on the end of the shaft.

3. Check the resistance with the lever pushed all the way to the other stop. It should be between 4500 and 5500 ohms. If it is outside this range, the potbox is faulty and should be replaced.

4. For potboxes equipped with a microswitch, check for correct switch operation. Use an ohmmeter, or simply listen for the slight click the switch makes. It should operate when the lever is 1.5 mm (1/16") from the return stop. If it does not, adjust by loosening the two screws holding the slotted microswitch mounting plate to the stop spacers and moving the plate. Recheck the switch operating point after tightening the screws.

5 TROUBLESHOOTING AND BENCH TESTING

Some behaviors that may seem to suggest controller malfunction do not, in fact, indicate a problem but rather are typical of normal operation. Before undertaking the diagnostic tests, check to see whether your problem is addressed in the first section, "Operational Notes." The diagnostic tests are designed to enable you to determine whether the trouble is in the controller or in some other part of the motor control circuitry. ***The controllers themselves are sealed and not field serviceable; contact your local Curtis PMC service center if the problem is in the controller.*** *The diagnostic section provides enough detail to enable you to track circuitry problems to their source and repair them. Finally, the bench tests will allow you to confirm controller operation in a simple, low-power test configuration. Bench testing is primarily intended for checking out a number of controllers on a regular basis.*

OPERATIONAL NOTES

Noise

Controller operation is normally silent. An exception is that a 1 kHz tone may be heard during plug braking. This noise is normal and indicates that plugging is taking place. The noise will stop when plug braking stops.

Inability of Vehicle to Plug Brake to a Stop on a Steep Ramp

If the vehicle is rolling backwards down a steep ramp in reverse and the throttle is applied demanding forward drive, the controller will attempt to plug the vehicle to a stop. If the ramp is so steep that the plugging current setpoint is insufficient to stop the vehicle, it will continue to be braked but will nevertheless roll down the ramp. If the mechanical brakes are applied, and the vehicle is stopped, the full drive current will be available when the throttle is applied and the vehicle will proceed up the ramp.

Sluggish Vehicle Behavior

Loss of power will be noticeable when the batteries become overly discharged. This is a normal response to low battery voltage. Curtis PMC 1204/1205 controllers are designed to protect against damage caused by low batteries. On 24–36 volt controllers, for example, power to the motor is cut back when the voltage goes below 16 volts. Refer to the specifications (Appendix C) for other models.

Hot Controller

If the controller gets hot, it does not necessarily indicate a serious problem. Curtis PMC 1204/1205 controllers protect themselves by reducing power to the motor if their internal temperature exceeds 75°C (167°F). Power output will be reduced for as long as the overheat condition remains, and full power will return when the unit cools.

In typical applications, overheating will rarely be a problem. However, operation with oversized motors and vehicle overloading may cause overheating, particularly if the controller is mounted so that heat cannot be conducted away from its case or if other heat-generating devices are nearby. If thermal cutback occurs often during normal operation, the controller is probably undersized and should be replaced with a higher current model.

Unintended Activation of HPD

Sudden applications of full throttle may activate the HPD feature, in applications where the pedal microswitch is wired in line with KSI. This happens if the pot is rotated well into its active stroke before the microswitch can cause the controller to power up. Normal nonabusive application of the throttle should not cause this action.

IN-VEHICLE DIAGNOSTIC TESTS

These tests require a general purpose volt ohmmeter; you can use either a conventional "V-O-M" or an inexpensive digital voltmeter.

The troubleshooting chart *(opposite)* serves as a guide to the procedures that follow. Before starting these tests, refer to the appropriate wiring diagrams and make sure your controller is hooked up properly.

CAUTION

> **Working on electric vehicles is potentially dangerous.** You should protect yourself while performing the diagnostic tests by jacking up the vehicle to get the drive wheels off the ground, opening the battery circuit before working on the motor control circuit, wearing safety glasses, and using properly insulated tools *(see page 2)*.

Fig. 19 *Guide to troubleshooting procedures.* [To use this guide, refer to the specified PROCEDURES.]

TEST 1 Check for power to the controller

Check voltage at CONTROLLER B- and BATTERY B+ terminals. **1-A, B, C**

It should read full voltage for system.

if NO → Bad, discharged, or miswired batteries, or corroded connections. **1-C**

if YES ↓

Check voltage at CONTROLLER B- and CONTROLLER B+ terminals. **1-D**

It should read 1 to 5 volts less than full battery voltage.

if NO → TOO HIGH: contactor is welded. TOO LOW: 250 Ω resistor or controller is defective. **1-D**

TEST 2 Check for main contactor operation and KSI

Check voltage at contactor and at KSI terminal. **2-A, B, C**

Contactor should read full rated voltage, and KSI must be above 8V.

if NO → Trace flow to locate problem. **2-D**

if YES ↓

Check voltage across contactor power terminals. **2-D**

There should be no measurable voltage drop.

if YES → If voltage drop occurs, contactor is defective. **2-E**

TEST 3 Check potbox circuitry (0-5kΩ throttles)

Check resistance at potbox wires while depressing pedal. **3-A**

Resistance should be between 0–50 ohms with pedal UP, and 4500–5500 ohms with pedal DOWN.

if NO → Defective potbox, broken wires to potbox, or improper mechanical operation. **3-B**

if YES ↓

Check for shorts between potbox wires and vehicle frame. **3-C**

Resistance should be at least 1 megohm.

if NO → If lower than 1 MΩ, wiring or potbox is defective. **3-C**

if YES ↓

Check voltage at upper throttle input terminal on controller. **3-E**

Voltage should be 3.6 to 4.2 volts with pedal UP, and 9.1 to 10.3 volts with pedal DOWN.

if NO → Terminal area is probably contaminated with acid or dirt. **3-E, F**

TEST 4 Check for controller output

Check voltage output while depressing pedal (B+ to M-). **4-A, B, C**

Voltage should be zero with pedal UP, and full battery voltage with pedal DOWN.

if NO → Controller is defective. **4-C**

if YES ↓

Check current in controller's M- (motor field) lead while depressing pedal. **4-D, E**

Current should be high, and motor should turn.

if NO → If no current, look for open circuit. If current is high but motor won't turn, check motor, wiring & plug diode. **4-F, G, H, I**

TEST 1 Check for power to the controller

1-A Leave the keyswitch off for these tests.

1-B Verify that battery (-) connects to the B- terminal of the controller. Connect voltmeter (-) lead to this point.

1-C Connect voltmeter (+) to the battery side of the main contactor. Check for full battery voltage. If it is not there, the trouble is in the battery pack, the cables to it, or the power fuse.

1-D Connect the voltmeter (+) lead to the controller B+ terminal. You should read a voltage 1 to 5 volts less than the full battery voltage. If this voltage is zero or close to zero, the trouble is either a bad controller, a bad 250 Ω resistor across the contactor, or an incorrectly connected cable between the contactor and the controller. Trace the cable to make sure it is hooked up right. Remove and test the 250 Ω resistor with an ohmmeter. If these check out, the controller is malfunctioning. If you see full battery voltage at this point, then the contactor has welded and must be replaced.

TEST 2 Check for main contactor operation and KSI

2-A Turn the key on, place the forward/reverse switch in forward or reverse, and depress the footpedal until its microswitch operates. (In these procedures, we assume the footpedal is equipped with the recommended microswitch.)

2-B This should cause the main contactor to operate with an audible click. Connect the voltmeter across the contactor coil terminals. You should see full battery voltage (minus the polarity diode drop).

2-C The controller KSI terminal should also be getting full battery voltage. Verify this by connecting the voltmeter (-) to the controller's B- terminal, and the voltmeter (+) to the controller's KSI terminal.

2-D If the contactor and KSI terminal are not getting voltage, that's the problem. Use the voltmeter to find out where it is not getting through. Connect the voltmeter (-) to the controller's B- terminal and check the following points with the voltmeter (+) lead to trace the flow:

1. First, check both sides of the control wiring fuse.
2. Check both sides of the polarity protection diode to make sure its polarity is correct.
3. Check both sides of the keyswitch.
3. Check both sides of the pedal microswitch.
4. Finally, check the contactor coil and controller KSI.

2-E If the contactor coil and KSI are getting voltage, make sure the contactor is really working by connecting the voltmeter across its contacts (the big terminals). There should be no measurable voltage drop. If you see a drop, the contactor is defective. (We assume the recommended precharge resistor is in place.)

TEST 3 Check the potbox circuitry

The following procedure applies to the standard throttle input configuration for these controllers, which is a nominal 5kΩ pot connected as a two-wire rheostat (0 = full off, 5 kΩ = full on), and also to 5kΩ–0 configurations. Some 1204/1205 controllers are sold with other input characteristics. If your installation uses a controller with a throttle input other than 0–5kΩ or 5kΩ–0, find out what its range is and use a procedure comparable to the one below to make sure your pedal/potbox is working correctly.

3-A With the <u>keyswitch off</u>, pull off the connectors going to the throttle input of the controller. Connect an ohmmeter to the two wires going to the potbox and measure the resistance as you move the pedal up and down. The resistance at the limits should be within these ranges:

	RESISTANCE (in ohms)	
	STANDARD 0–5kΩ POT	5kΩ–0 POT
Pedal up:	0 – 50	4500 – 5500
Pedal down:	4500 – 5500	0 – 50

3-B If these resistances are wrong, it is because the pot itself is faulty, the wires to the pot are broken, or the pedal and its linkage are not moving the potbox lever through its proper travel. Actuate the pedal and verify that the potbox lever moves from contacting the pedal-up stop to nearly contacting the pedal-down stop. If the mechanical operation looks okay, replace the potbox.

3-C While you have the potbox wires off the controller, use an ohmmeter to check for shorts between these wires and the vehicle frame. You should see a resistance of at least 1 megohm. If it is lower than that, inspect the wiring for damaged insulation or contact with acid. If necessary, replace the potbox.

3-D Push the wires back on the controller terminals. It doesn't matter which wire goes on which terminal.

3-E Inspect the terminal area of the controller closely. Occasionally a buildup of dirt or acid residue of a conductive nature causes electrical leakage between the throttle input terminals and the B- or M- terminals, leading to faulty controller operation. To check for this problem, measure the voltage at the appropriate throttle input terminal (upper for 0–5kΩ pots, lower for 5kΩ–0 pots), by connecting the voltmeter (-) lead to the controller's B- terminal. The keyswitch must be on and a direction selected for this test.

ACCELERATOR INPUT VOLTAGE (in volts)		
	STANDARD 0–5kΩ POT UPPER TERMINAL	5kΩ–0 POT LOWER TERMINAL
Pedal up:	3.8	4.3
Pedal down:	9.5	10.2

Compare your readings with these; if they are different by more than a few tenths of a volt, contamination is probably the cause.

3-F Carefully clean off the terminal area of the controller with a cotton swab or clean rag moistened with water, and dry thoroughly.

CAUTION **Be sure to turn everything off before cleaning.**

Now test the controller to see if proper operation is restored. If so, take steps to prevent this from happening again: dirt and water **must** be kept from reaching the terminal area of the controller. If the voltages are still out of range, the controller is at fault and should be replaced.

TEST 4 Check for controller output

4-A The first step is to measure the output drive voltage to the motor at the controller's M- terminal.

4-B Connect the voltmeter (+) lead to the controller's B+ terminal. Connect the voltmeter (-) lead to the controller's M- terminal.

4-C Turn on the keyswitch with the forward/reverse switch in neutral, and then select a direction and watch the voltmeter as you depress the pedal. The voltmeter should read zero (or close to zero) before you apply the pedal, and should read full battery voltage with the pedal fully depressed. If it does not, the controller is defective and must be replaced.

4-D The next step is to measure the current in the controller's M- lead. If you have a means of measuring this high dc current, such as a shunt/meter setup or a clamp-on dc ammeter, use it. If not, we recommend that you buy an inexpensive ammeter of the type that is simply held against the wire being tested. These are readily available at auto parts stores, and their accuracy is adequate for this test.

4-E Turn on the keyswitch with the forward/reverse switch in neutral, and then select a direction and watch the ammeter while depressing the pedal.

4-F If you see no current flowing in the M- lead, the problem is an open circuit in the motor or the wiring between the motor and the controller. Check the forward/reverse switch. If your vehicle uses contactors for reversing, check to see that they are operating and that their contacts are closing. If these are okay, check the motor armature and field for opens.

4-G If you do see a high current flowing in the M- lead, but the motor does not turn, the problem is a short in the motor circuit, a miswired motor, or a short in the controller's internal plug diode. Test the plug diode as follows:

1. Remove power by opening the battery circuit. Take the cable off the controller's A2 terminal.

2. Use an ohmmeter to check the resistance between the controller's A2 and B+ terminals. You are testing for the presence of a diode inside the controller, so swap the two leads of the ohmmeter and look for a low resistance one way and a much higher one the other way. If your meter has a diode test function, use it.

3. If you find the diode to be shorted, the controller is defective.

4-H Put the A2 cable back on the controller and reconnect the battery.

4-I If the plug diode is okay, there is a short in the motor circuit. The short could be in the forward/reverse switch, so look there first. Because the resistance of the motor is so low, the motor must be tested separately if it is suspected of having a shorted winding.

BENCH TESTING

First, before starting any bench testing, pick up the controller and shake it. If anything rattles around inside, the unit should be returned.

CAUTION

Protect yourself during bench testing. Wear safety glasses and use insulated tools.

Equipment Needed

The simple setup shown in Figure 20 is required for testing these controllers on the bench. You will need:

1. a POWER SUPPLY with a voltage equal to the rating of the controller you want to test. You can use either a string of batteries or a regulated line-operated power supply. Because only low power tests will be described, a 10 amp fuse should be wired in series with the batteries to protect both operator and controller against accidental shorts. A battery charger alone should not be used as a power supply, because without a battery load its output voltage may exceed the rating of the controller.

2. an ACCELERATOR POTBOX. For controllers with the standard input configuration (a 5 kΩ pot wired as a two-terminal rheostat), a Curtis PMC potbox or any 5 kΩ pot will work fine.

For controllers with other input options, use whatever kind of potbox is used on the vehicle.

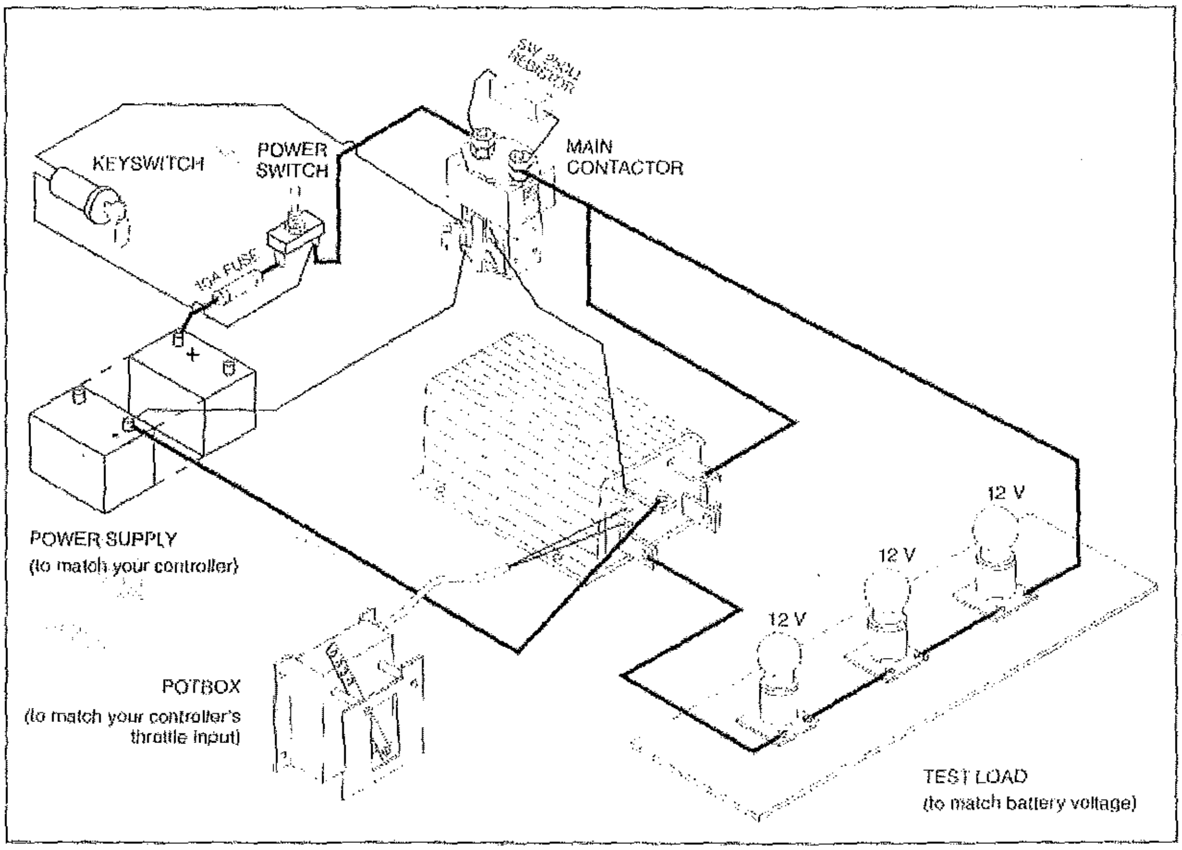
3. a POWER SWITCH to disconnect all power from the test setup.

4. a MAIN CONTACTOR with a 250 ohm, 5 watt resistor across its high-power contacts and a KEYSWITCH to turn it on and off.

5. a TEST LOAD consisting of incandescent light bulbs wired in series to get the same voltage as your power supply. (For example, with a 36 volt battery, use three 12 volt bulbs.)

6. a general purpose VOLT OHMMETER or DIGITAL VOLTMETER.

Fig. 20 *Setup for bench testing.*



Bench Test Procedure

A. Hook up the controller as shown. Connect the voltmeter leads to the controller's B+ and B- terminals.

B. Turn on the power switch (not the keyswitch) and watch the voltmeter. Its reading should build up slowly over several seconds to within a couple of volts of full battery voltage. If this voltage does not come up, the controller is bad.

C. Now turn on the keyswitch. The main contactor should turn on and the voltage at the controller's B+ and B- terminals should now equal the full battery voltage. Move the potbox lever through its range. The lamps should go smoothly from full off to full on with the pot.

D. If the controller has HPD, test this feature as follows:

   1. Turn off the keyswitch.
   2. Move the potbox lever about halfway.
   3. Turn the keyswitch switch on. Verify that the lamps do not come on until the potbox lever is moved most of the way toward OFF and then moved back up.

E. Test the controller's potbox fault protection feature by pulling off one of the potbox's two connections to the controller's throttle input terminals while the lamps are on (potbox lever in the ON position). The lamps should turn off. With the potbox lever still in the ON position, reconnect the wire. The lamps should smoothly increase in brightness to their previous level.

F. Finally, remove the controller from the test setup and check its internal plug diode, as described in Troubleshooting Procedure 4-G.

Power Drive

Understanding the Electrical System
Student Edition

Mr. Cantrell
Wayne State College

Table of Contents

Objectives

Unit Objectives

When finished with this unit the student will be able to define terms used in electronics, locate and label components, wire an electrical system, and measure volts and amps. The student will demonstrate these competencies by completing the assignment sheets and lab activities and by scoring a minimum of 85 percent on the written test.

Specific Objectives

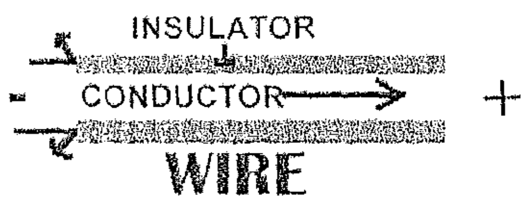
1. Define Volts.
2. Define Amps.
3. Define Ohms.
4. Define Series.
5. Define Parallel
6. Define electrical symbols.
7. List and describe electrical components of an electric vehicle.
8. Explain how each component of an electrical vehicle work together to make the vehicle functional.
9. Wire an electric vehicle correctly. (Using a module)
10. Measure Amps used to rotate motor.
11. Measure Volts in electrical system.

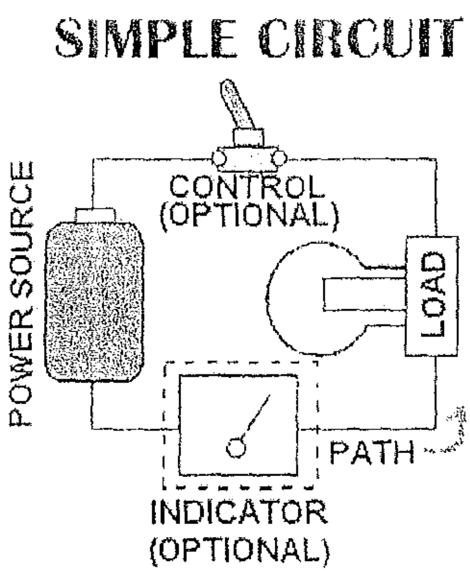
Basic Electronic Circuits

Circuit – Path for electrons to flow through. The path is form a power sources negative terminal, through the various components and on to the positive terminal.

Think of it as a circle. The paths may split off here and there but they always from a line form the negative to the positive.

Conductor – Material (usually a metal such as copper) that allows electrical current to pass easily through. The current is made up of electrons. This is opposed to an insulator which prevents the flow of electricity thorough it.





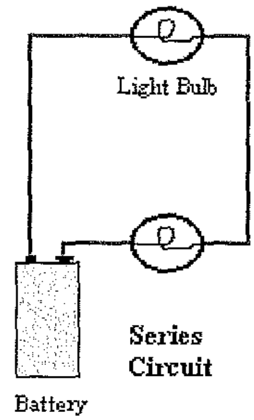
<u>Simple Circuit</u>
If we break a circuit down to it's elementary blocks we get:

1) A power source – Battery
2) A path – Wire
3) A load – Lamp / Motor
4) A control – Switch
5) An indicator – Meter

Series / Parallel

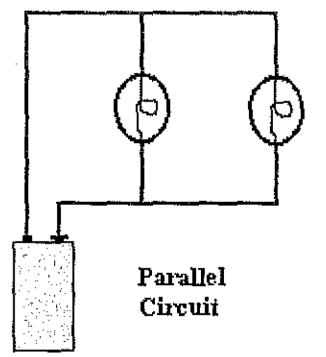
Series – An electric circuit connected so that current passes through each circuit element in turn without branching.

A **series circuit** has more than one resistor *(anything that uses electricity to do work)* and gets its name from **only having one path for the charges** to move along. Charges must move in "series" first going to one resistor then the next. If one of the items in the circuit is broken then no charge will move through the circuit because there is only one path. There is no alternative route. Old style electric holiday lights were often wired in series. If one bulb burned out, the whole string of lights went off.



Parallel – An electric circuit connected that current can pass through different paths of the circuit.

A **parallel circuit** has more than one resistor *(anything that uses electricity to do work)* and gets its name from having multiple **(parallel)** paths to move along. Charges can move through any of several paths. If one of the items in the circuit is broken then no charge will move through that path, but other paths will continue to have charges flow through them. Parallel circuits are found in most household electrical wiring. This is done so that lights don't stop working just because you turned your TV off.



Volts, Amps, and Ohms

The three most basic units in electricity are voltage (**V**), current (**I**) and resistance (**r**). Voltage is measured in **volts**, current is measured in **amps** and resistance is measured in **ohms**.

A neat analogy to help understand these terms is a system of plumbing pipes. The voltage is equivalent to the water pressure, the current is equivalent to the flow rate, and the resistance is like the pipe size.

There is a basic equation in electrical engineering that states how the three terms relate. It says that the current is equal to the voltage divided by the resistance.

I = V/r

Let's see how this relation applies to the plumbing system. Let's say you have a tank of pressurized water connected to a hose that you are using to water the garden.

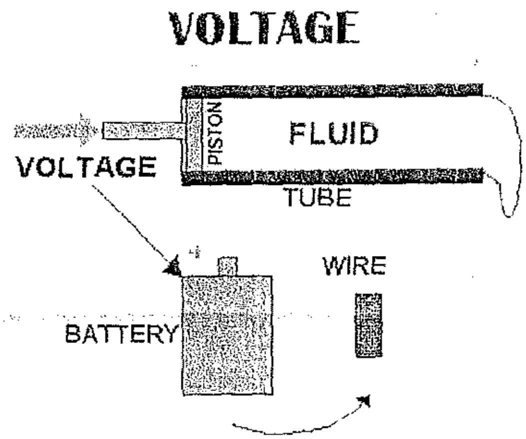
What happens if you increase the pressure in the tank? You probably can guess that this makes more water come out of the hose. The same is true of an electrical system: Increasing the voltage will make more current flow.

Let's say you increase the diameter of the hose and all of the fittings to the tank. You probably guessed that this also makes more water come out of the hose. This is like decreasing the resistance in an electrical system, which increases the current flow.

Volt – Measurement of electromotive force

Webster's:
The International System unit of electric potential and electromotive force, equal to the difference of electric potential between two points on a conducting wire carrying a constant current of one ampere when the power dissipated between the points is one watt.

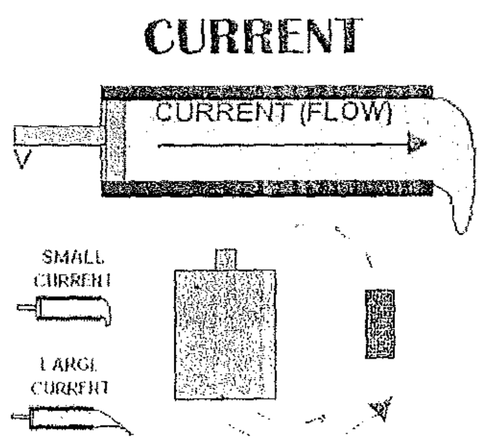
Voltage is the electrical force or "pressure" that causes current to flow in a circuit. It is measured in Volts. Take a look at the diagram. Voltage would be the force that is pushing the water forward.



Amp – Measurement of current of electrons flowing through a conductor

Webster's
The basic unit of electric current adopted under the System International d'Unites; "a typical household circuit carries 15 to 50 amps"

Current is the movement of electrical charge – the flow of electrons through the electronic circuit. Current is measured in Amperes (AMPS). Current would be the flow of water moving through the tube.



Ohm – Measurement of the resistance to the flow of current

Webster's
A unit of electrical resistance equal to that of a conductor in which a current of one ampere is produced by a potential of one volt across its terminals.

Electrical Symbols

Battery

Ammeter

Conductor

Fuse

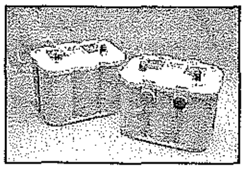
Voltmeter

Light

Switch

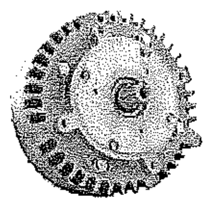
Motor

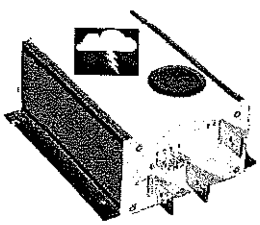
Components of Electric Vehicles



Batteries- Power Drive vehicles are powered by 2 – 12 volt batteries. These batteries supply the energy for the vehicle to move.

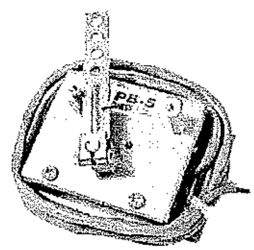
Motor - A permanent magnet motor propels Power Drive vehicles.





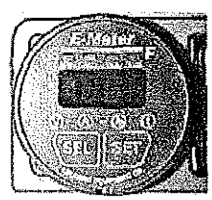
Controller – This controls the amount of current that is supplied to the motor from the batteries,

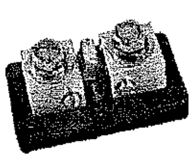
Potentiometer – This sends a resistance signal to the controller to tell the controller how much current to allow to pass through it. Also call a pot box.



Fuse – This assures that excessive current doesn't pass through the system and damage components.

Ammeter / Voltmeter– This shows how much current it passing through the circuit, displayed in Amps. It also shows how much voltage is left in the batteries to use.





Shunt – Tells the ammeter the amount of current that is passing through the circuit.

How the Components of Electric Vehicles Work Together

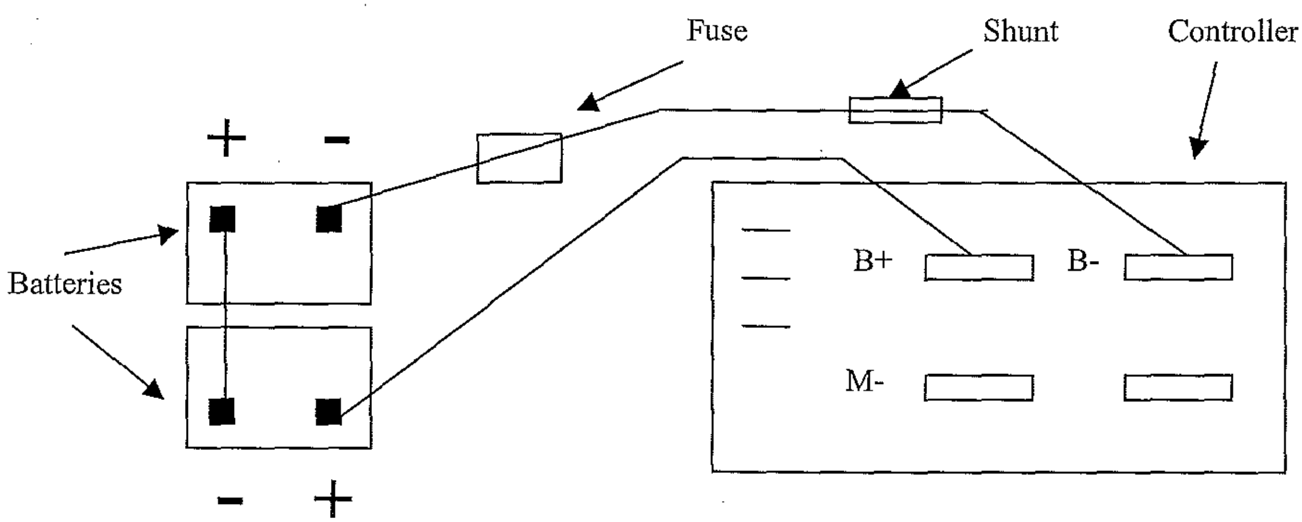
The two 12 volt batteries supply the vehicle with the energy to move the vehicle. These batteries are connected in series to produce 24 volts, and are connected to the controller. In the cables connecting the batteries and the controller on the negative side, the fuse and shunt are placed. The fuse keeps the electrical components from damage due to excess current. The shunt tells the ammeter how many amps are passing through it at any time.

The controller regulates the amount of current that is passed from the batteries to the motor. The motor rotates when it receives electrical current. For the controller to work properly the potentiometer is connected to the controller. The potentiometer sends a resistance reading to the controller to tell how much current to pass through. Without the potentiometer you would have 100% current or no current going to the motor.

Wiring the Electric Vehicle

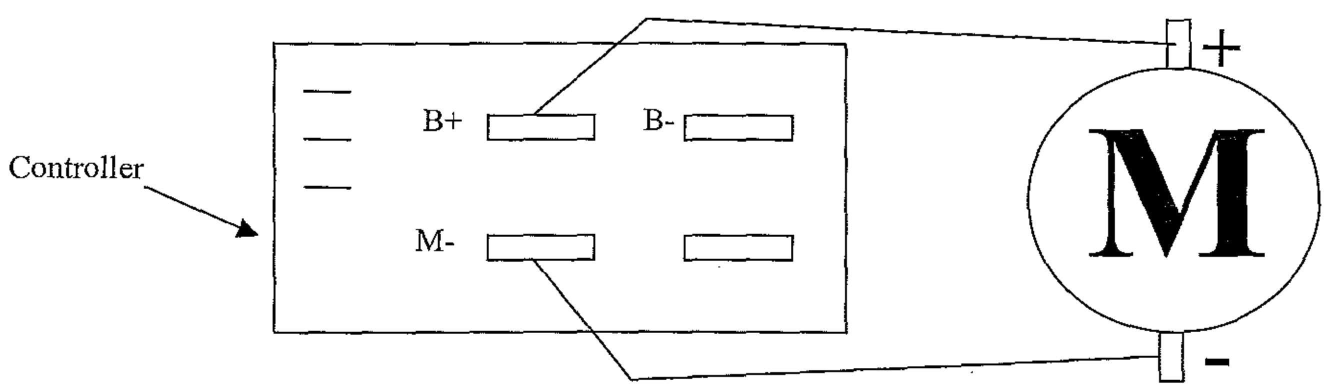
Connecting Batteries to the Controller

As stated earlier the batteries contain the energy needed to propel the vehicle. These two 12 volt batteries are connected to the controller in series, meaning that the circuit is 24 volts. (12 + 12 = 24) On the controller there are four large terminals. The terminal labeled B+ gets connected to the positive side of the batteries. The terminal labeled B- gets connected to the negative side of the batteries. You need to put you shunt in this cable. On one of the cables connecting the batteries to the controller you need to put a fuse in. This fuse will help you keep from damaging or destroying components.

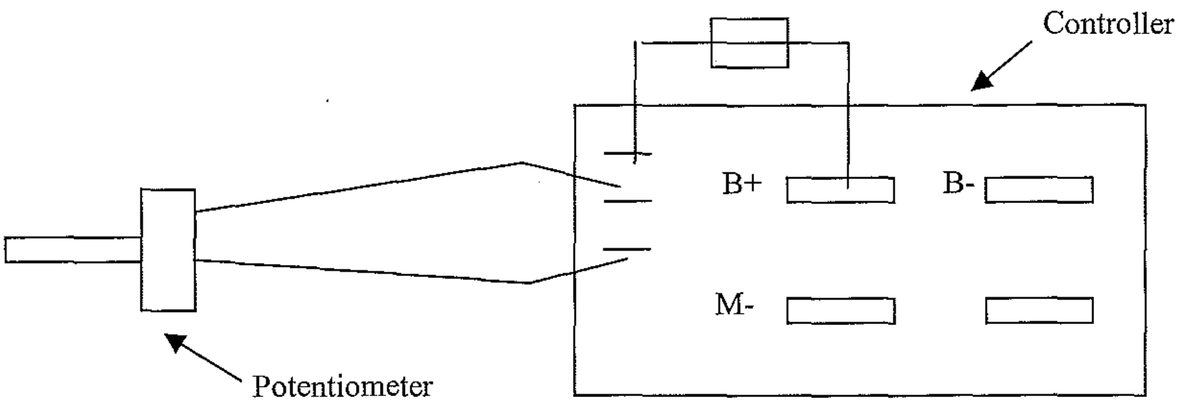


Connecting the Controller to the Motor

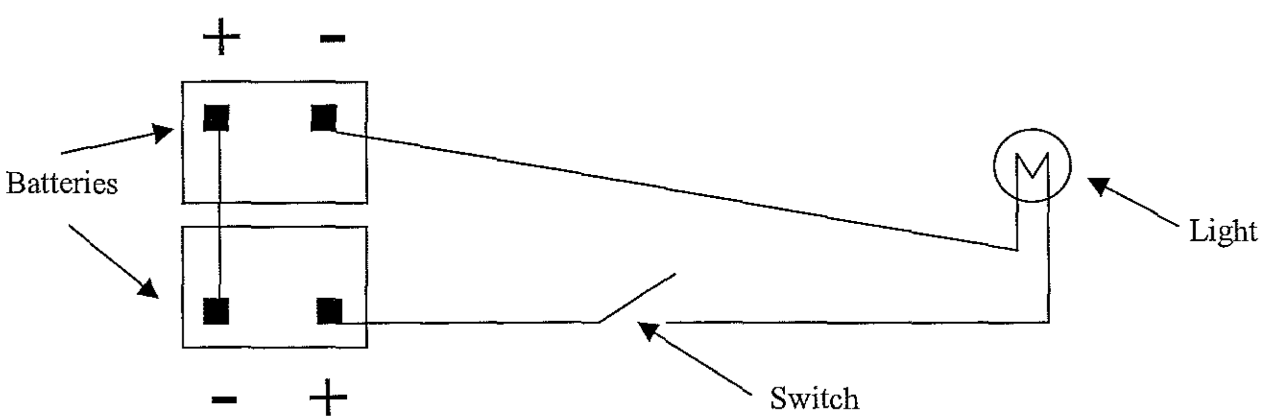
To connect the motor to the controller you need to connect the B+ terminal on the controller to the + (positive) terminal on the motor. Then connect the M- terminal to the – (negative) side of the motor.



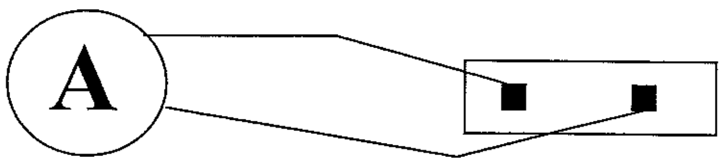
Connecting the Potentiometer
First you need to connect the B+ terminal to the top small terminal. You need to put a 10 amp fuse in this connection. Next you need to connect the two leads from the potentiometer. Connect one lead to each of the bottom two small terminals.



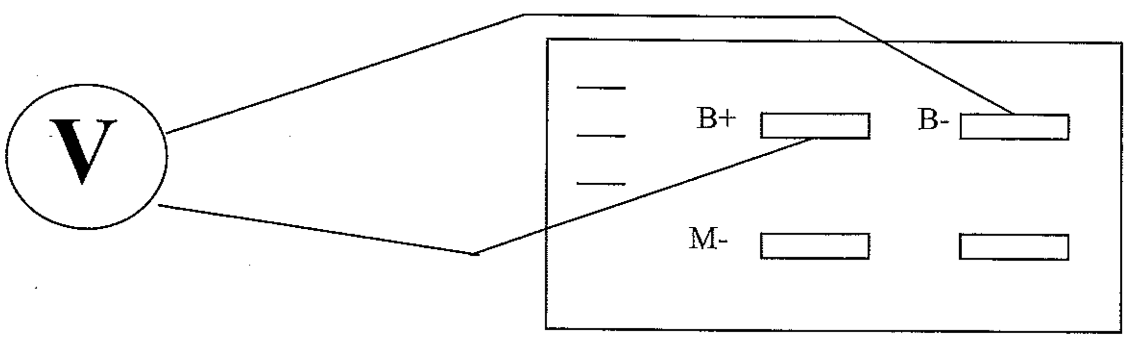
Connecting the Brake Light
You'll need a switch and a light for this. First run a wire from the positive terminal on the battery to the switch, making sure to put a fuse in. Then run a wire from the switch to the brake light and connect the wire to one of the leads on the light. Then connect a wire to the other lead and connect it to the negative terminal on the battery. Now when you flip the switch it should light up the light.



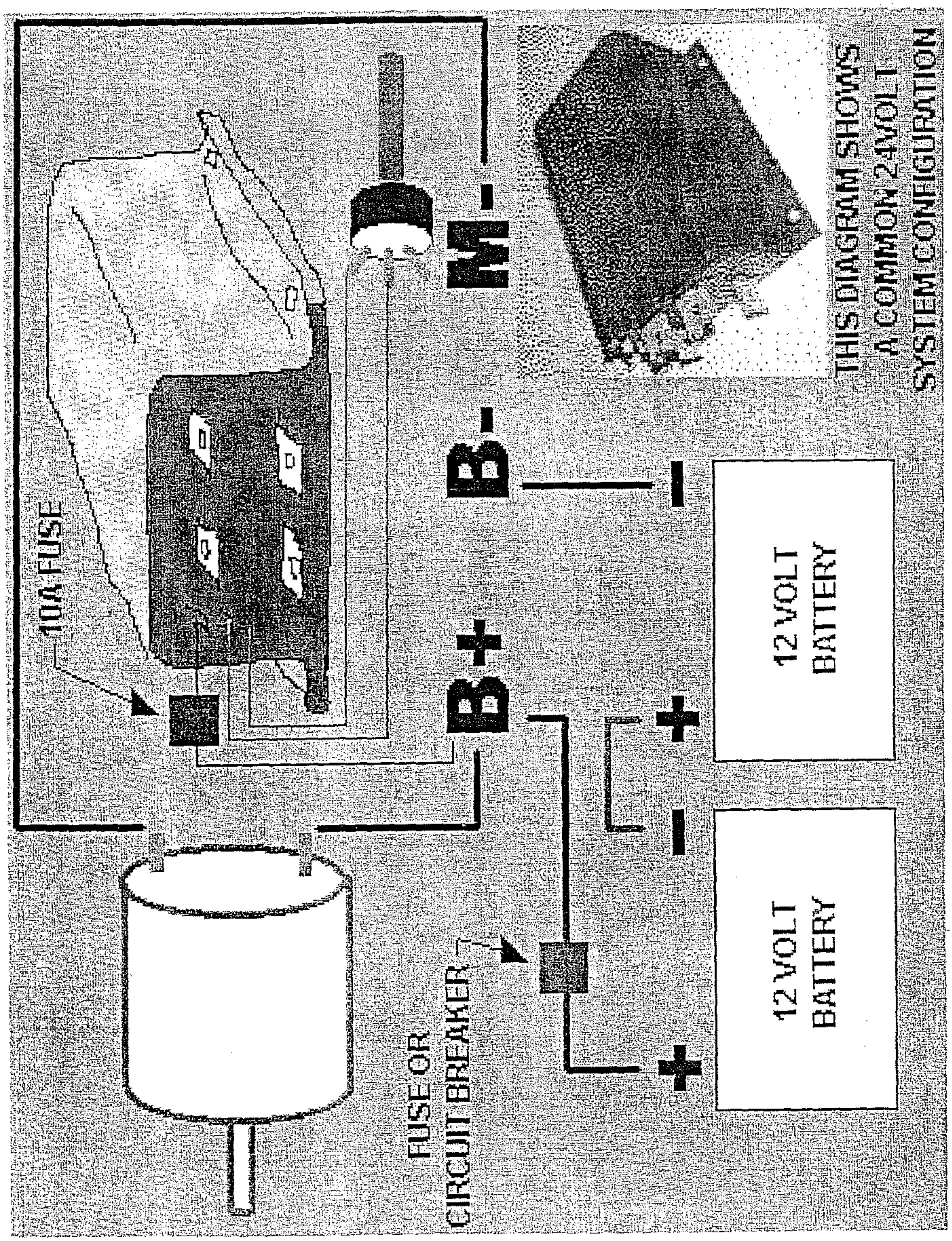
Connecting the Ammeter
Connect one of the leads of the ammeter to one side of the shunt. Then connect the other lead from the ammeter to the other side of the shunt.



Connecting the Voltmeter
Connect the + positive lead of the voltmeter to the B+ terminal on the controller. Then connect the – negative lead of the voltmeter to the B- terminal on the controller.



Wiring Schematic



Assignment

Using the Power Drive Electrical System module, locate, and label each component. Next connect the components together to make the electrical system work properly.

The following must be completed before assignment is done:

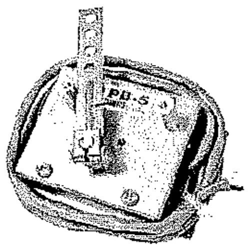
- Each component labeled correctly
- Proper connection of all battery cables
- Proper connection of motor cables
- Proper connection of Potentiometer
- Proper rotational direction of motor
- Functional brake light controlled by a switch
- Functional ammeter
- Functional voltmeter
- Read volts available in system
- Read amps being used in operation of motor

Following completion of this module, you must write a summary of what you learned from this activity, and any problems you encountered with this activity. Also list each component and tell what it does.

Assessment

	Points Available	Points Earned
Lab activity	100 10 points for each part	
Written response	50	
Test	90 6 Points for each question	

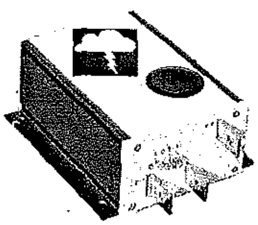
Student Supplement



Curtis PB-5 Style Pot Box, Potentiometer reads 0-5k Ohms

Dimensions: 3-3/4" high, 4" long, 2-1/16" deep

Weight – 0.89 LB **Price - $70.00**

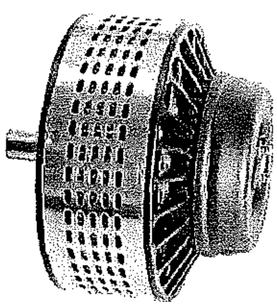


Alltrax, 24-48 volt, 300 amp, Fully Programmable Controller

Capable of changing settings such as voltage, amps, temperature, etc.

Programming functions: Throttle ramp, Throttle response rate, Battery over/under voltage cutback, maximum output current.

Weight – 5.50 LBS **Price - $279.45**

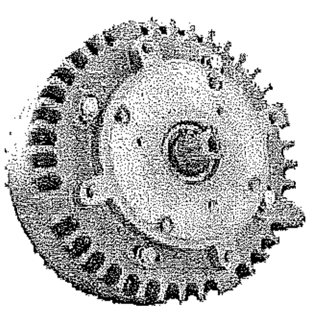


Lemco LEM-170 12 to 48 Volts DC Lynch Motor

This is the latest, second-generation design, which is imported from England.

Motor spins at 75 RPM's per Volt

Weight – 17.20 LBS **Price - $1,650.00**



Briggs and Stratton 24-48 Volt DC Etek Motor

Briggs and Stratton version of the Lynch motor.

Motor spins at 72 RPM's per Volt

Weight – 23 LBS **Price - $375.00**

Wiring Schematic from Curtis model 1204/5 Controller Manual

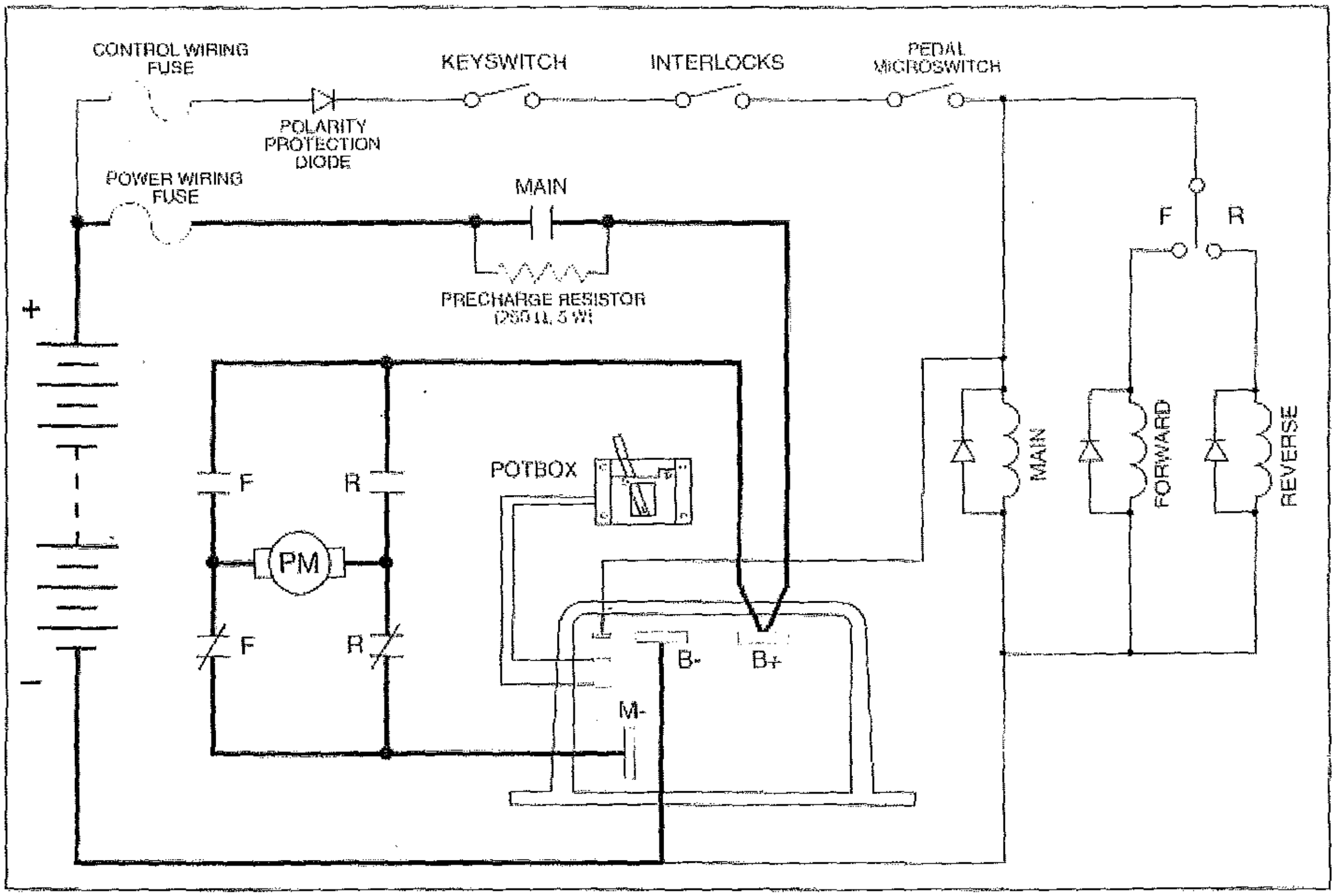


Fig. 15 *Basic wiring for use with PM motors.*

Maintenance Chapter in Curtis Controller Users Manual

4

MAINTENANCE & ADJUSTMENT

Curtis 1204/1205 controllers and potboxes require only minimal maintenance if properly installed. NOTE: The controllers are sealed and thus are not field serviceable.

CONTROLLER

Maintenance

CAUTION

It is recommended that the following two steps be performed occasionally. **First remove power by disconnecting the battery, and discharge the capacitors in the controller** (with a light bulb or a 2–10 Ω, 25 W resistor connected for a few seconds across B+, B-). Follow good safety practices: get the vehicle drive wheels off the ground, wear safety glasses, and use insulated tools *(see page 2)*.

1. Make sure the electrical connections to the controller (and to the motor, contactors, etc.) are tight. When checking the controller bus bar connections for tightness, use two opposing wrenches. This double-wrench technique will help avoid putting stress on the bus bars, which could crack the seals. **Always use insulated wrenches.**

2. Inspect all seals at the front and back of the controller. If necessary, use a moist rag to wipe these areas clean enough so that you can see the seals. Look for cracks and other signs of seal damage.

   If the seals are intact, clean the controller thoroughly either by washing it off or by wiping it clean with a moist rag. **Power must not be reapplied until the controller terminal area is completely dry.**

   If the seals have been damaged, there are several possible causes. Perhaps the double-wrench technique was not used when the cables were installed. Perhaps the vehicle's environment requires that the controller be better protected: either by mounting it in a different location, or by installing a protective cover.

   Damaged seals can lead to faulty operation. We strongly recommend replacing controllers that have faulty seals.

Adjustment

On some models, the plug braking current and acceleration rate settings are adjustable. On these adjustable controllers, the adjustment pots are located as shown in Figure 18.

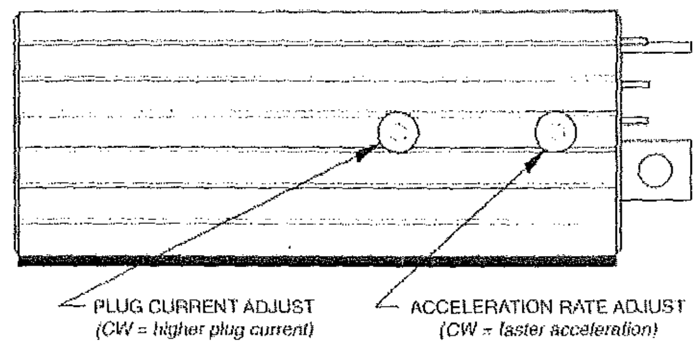


Fig. 18 *Adjustment pots.*

Use the following adjustment procedure. **The keyswitch should be <u>off</u> during adjustment.**

1. Remove the socket head screw (1/8" Allen) for the adjustment you want to make.

2. Adjust the internal potentiometer using a small **insulated** screw-driver *(available from Curtis).*

3. Replace the socket head screw and nylon seal washer. To prevent stripping, do not over-tighten.

POTBOX

Maintenance

Potbox maintenance is similar to controller maintenance: inspect for integrity of connections and mounting, and clean (with a moist rag) as required.

Adjustment

Curtis PMC potboxes are factory set and rarely require user attention. To test and adjust, connect an ohmmeter to the potbox wires and use this procedure:

1. With the spring holding the lever arm against the return stop, the resistance should be less than 50 ohms. Slowly move the lever. If the resistance abruptly starts to increase when the lever is 3 mm (1/8") from the stop (1.5 mm [1/16"] for potboxes without the microswitch), no adjustment is needed.

2. If adjustment is required, loosen the screw holding the lever on the pot shaft. Use a screwdriver to rotate the pot shaft slightly with respect to the lever. Recheck the point at which the resistance starts to increase and continue making adjustments until the increase occurs at 3 mm (1/8") [at 1.5 mm (1/16") for potboxes without the microswitch]. When adjustment is correct, tighten the screw holding the lever on the pot shaft, then recheck to see that this action did not disturb the adjustment. Make sure that the lever is still seated down on the pot shaft below the slight bevel on the end of the shaft.

3. Check the resistance with the lever pushed all the way to the other stop. It should be between 4500 and 5500 ohms. If it is outside this range, the potbox is faulty and should be replaced.

4. For potboxes equipped with a microswitch, check for correct switch operation. Use an ohmmeter, or simply listen for the slight click the switch makes. It should operate when the lever is 1.5 mm (1/16") from the return stop. If it does not, adjust by loosening the two screws holding the slotted microswitch mounting plate to the stop spacers and moving the plate. Recheck the switch operating point after tightening the screws.

5 TROUBLESHOOTING AND BENCH TESTING

Some behaviors that may seem to suggest controller malfunction do not, in fact, indicate a problem but rather are typical of normal operation. Before undertaking the diagnostic tests, check to see whether your problem is addressed in the first section, "Operational Notes." The diagnostic tests are designed to enable you to determine whether the trouble is in the controller or in some other part of the motor control circuitry. ***The controllers themselves are sealed and not field serviceable; contact your local Curtis PMC service center if the problem is in the controller.*** *The diagnostic section provides enough detail to enable you to track circuitry problems to their source and repair them. Finally, the bench tests will allow you to confirm controller operation in a simple, low-power test configuration. Bench testing is primarily intended for checking out a number of controllers on a regular basis.*

OPERATIONAL NOTES

Noise

Controller operation is normally silent. An exception is that a 1 kHz tone may be heard during plug braking. This noise is normal and indicates that plugging is taking place. The noise will stop when plug braking stops.

Inability of Vehicle to Plug Brake to a Stop on a Steep Ramp

If the vehicle is rolling backwards down a steep ramp in reverse and the throttle is applied demanding forward drive, the controller will attempt to plug the vehicle to a stop. If the ramp is so steep that the plugging current setpoint is insufficient to stop the vehicle, it will continue to be braked but will nevertheless roll down the ramp. If the mechanical brakes are applied, and the vehicle is stopped, the full drive current will be available when the throttle is applied and the vehicle will proceed up the ramp.

Sluggish Vehicle Behavior

Loss of power will be noticeable when the batteries become overly discharged. This is a normal response to low battery voltage. Curtis PMC 1204/1205 controllers are designed to protect against damage caused by low batteries. On 24–36 volt controllers, for example, power to the motor is cut back when the voltage goes below 16 volts. Refer to the specifications (Appendix C) for other models.

Hot Controller

If the controller gets hot, it does not necessarily indicate a serious problem. Curtis PMC 1204/1205 controllers protect themselves by reducing power to the motor if their internal temperature exceeds 75°C (167°F). Power output will be reduced for as long as the overheat condition remains, and full power will return when the unit cools.

In typical applications, overheating will rarely be a problem. However, operation with oversized motors and vehicle overloading may cause overheating, particularly if the controller is mounted so that heat cannot be conducted away from its case or if other heat-generating devices are nearby. If thermal cutback occurs often during normal operation, the controller is probably undersized and should be replaced with a higher current model.

Unintended Activation of HPD

Sudden applications of full throttle may activate the HPD feature, in applications where the pedal microswitch is wired in line with KSI. This happens if the pot is rotated well into its active stroke before the microswitch can cause the controller to power up. Normal nonabusive application of the throttle should not cause this action.

IN-VEHICLE DIAGNOSTIC TESTS

These tests require a general purpose volt ohmmeter; you can use either a conventional "V-O-M" or an inexpensive digital voltmeter.

The troubleshooting chart *(opposite)* serves as a guide to the procedures that follow. Before starting these tests, refer to the appropriate wiring diagrams and make sure your controller is hooked up properly.

CAUTION

Working on electric vehicles is potentially dangerous. You should protect yourself while performing the diagnostic tests by jacking up the vehicle to get the drive wheels off the ground, opening the battery circuit before working on the motor control circuit, wearing safety glasses, and using properly insulated tools *(see page 2)*.

Fig. 19 *Guide to troubleshooting procedures.* [To use this guide, refer to the specified PROCEDURES.]

TEST 1 Check for power to the controller

Check voltage at CONTROLLER B- and BATTERY B+ terminals. 1-A, B, C
It should read full voltage for system.

- *if NO* → Bad, discharged, or miswired batteries, or corroded connections. 1-C
- *if YES* ↓

Check voltage at CONTROLLER B- and CONTROLLER B+ terminals. 1-D
It should read 1 to 5 volts less than full battery voltage.

- *if NO* → TOO HIGH: contactor is welded. TOO LOW: 250 Ω resistor or controller is defective. 1-D

TEST 2 Check for main contactor operation and KSI

Check voltage at contactor and at KSI terminal. 2-A, B, C
Contactor should read full rated voltage, and KSI must be above 8V.

- *if NO* → Trace flow to locate problem. 2-D
- *if YES* ↓

Check voltage across contactor power terminals. 2-D
There should be no measurable voltage drop.

- *if YES* → If voltage drop occurs, contactor is defective. 2-E

TEST 3 Check potbox circuitry (0-5kΩ throttles)

Check resistance at potbox wires while depressing pedal. 3-A
Resistance should be between 0–50 ohms with pedal UP, and 4500–5500 ohms with pedal DOWN.

- *if NO* → Defective potbox, broken wires to potbox, or improper mechanical operation. 3-B
- *if YES* ↓

Check for shorts between potbox wires and vehicle frame. 3-C
Resistance should be at least 1 megohm.

- *if NO* → If lower than 1 MΩ, wiring or potbox is defective. 3-C
- *if YES* ↓

Check voltage at upper throttle input terminal on controller. 3-E
Voltage should be 3.6 to 4.2 volts with pedal UP, and 9.1 to 10.3 volts with pedal DOWN.

- *if NO* → Terminal area is probably contaminated with acid or dirt. 3-E, F

TEST 4 Check for controller output

Check voltage output while depressing pedal (B+ to M-). 4-A, B, C
Voltage should be zero with pedal UP, and full battery voltage with pedal DOWN.

- *if NO* → Controller is defective. 4-C
- *if YES* ↓

Check current in controller's M- (motor field) lead while depressing pedal. 4-D, E
Current should be high, and motor should turn.

- *if NO* → If no current, look for open circuit. If current is high but motor won't turn, check motor, wiring & plug diode. 4-F, G, H, I

TEST 1 Check for power to the controller

1-A Leave the keyswitch off for these tests.

1-B Verify that battery (-) connects to the B- terminal of the controller. Connect voltmeter (-) lead to this point.

1-C Connect voltmeter (+) to the battery side of the main contactor. Check for full battery voltage. If it is not there, the trouble is in the battery pack, the cables to it, or the power fuse.

1-D Connect the voltmeter (+) lead to the controller B+ terminal. You should read a voltage 1 to 5 volts less than the full battery voltage. If this voltage is zero or close to zero, the trouble is either a bad controller, a bad 250 Ω resistor across the contactor, or an incorrectly connected cable between the contactor and the controller. Trace the cable to make sure it is hooked up right. Remove and test the 250 Ω resistor with an ohmmeter. If these check out, the controller is malfunctioning. If you see full battery voltage at this point, then the contactor has welded and must be replaced.

TEST 2 Check for main contactor operation and KSI

2-A Turn the key on, place the forward/reverse switch in forward or reverse, and depress the footpedal until its microswitch operates. (In these procedures, we assume the footpedal is equipped with the recommended microswitch.)

2-B This should cause the main contactor to operate with an audible click. Connect the voltmeter across the contactor <u>coil</u> terminals. You should see full battery voltage (minus the polarity diode drop).

2-C The controller KSI terminal should also be getting full battery voltage. Verify this by connecting the voltmeter (-) to the controller's B- terminal, and the voltmeter (+) to the controller's KSI terminal.

2-D If the contactor and KSI terminal are not getting voltage, that's the problem. Use the voltmeter to find out where it is not getting through. Connect the voltmeter (-) to the controller's B- terminal and check the following points with the voltmeter (+) lead to trace

the flow:
1. First, check both sides of the control wiring fuse.
2. Check both sides of the polarity protection diode to make sure its polarity is correct.
3. Check both sides of the keyswitch.
3. Check both sides of the pedal microswitch.
4. Finally, check the contactor coil and controller KSI.

2-E If the contactor coil and KSI are getting voltage, make sure the contactor is really working by connecting the voltmeter across its contacts (the big terminals). There should be no measurable voltage drop. If you see a drop, the contactor is defective. (We assume the recommended precharge resistor is in place.)

TEST 3 Check the potbox circuitry

The following procedure applies to the standard throttle input configuration for these controllers, which is a nominal 5kΩ pot connected as a two-wire rheostat (0 = full off, 5 kΩ = full on), and also to 5kΩ–0 configurations. Some 1204/1205 controllers are sold with other input characteristics. If your installation uses a controller with a throttle input other than 0–5kΩ or 5kΩ–0, find out what its range is and use a procedure comparable to the one below to make sure your pedal/potbox is working correctly.

3-A With the keyswitch off, pull off the connectors going to the throttle input of the controller. Connect an ohmmeter to the two wires going to the potbox and measure the resistance as you move the pedal up and down. The resistance at the limits should be within these ranges:

	RESISTANCE (in ohms)	
	STANDARD 0–5kΩ POT	5kΩ–0 POT
Pedal up:	0 – 50	4500 – 5500
Pedal down:	4500 – 5500	0 – 50

3-B If these resistances are wrong, it is because the pot itself is faulty, the wires to the pot are broken, or the pedal and its linkage are not moving the potbox lever through its proper travel. Actuate the pedal and verify that the potbox lever moves from contacting the pedal-up stop to nearly contacting the pedal-down stop. If the mechanical operation looks okay, replace the potbox.

3-C While you have the potbox wires off the controller, use an ohmmeter to check for shorts between these wires and the vehicle frame. You should see a resistance of at least 1 megohm. If it is lower than that, inspect the wiring for damaged insulation or contact with acid. If necessary, replace the potbox.

3-D Push the wires back on the controller terminals. It doesn't matter which wire goes on which terminal.

3-E Inspect the terminal area of the controller closely. Occasionally a buildup of dirt or acid residue of a conductive nature causes electrical leakage between the throttle input terminals and the B- or M- terminals, leading to faulty controller operation. To check for this problem, measure the voltage at the appropriate throttle input terminal (upper for 0–5kΩ pots, lower for 5kΩ–0 pots), by connecting the voltmeter (-) lead to the controller's B- terminal. The keyswitch must be on and a direction selected for this test.

	ACCELERATOR INPUT VOLTAGE (in volts)	
	STANDARD 0–5kΩ POT UPPER TERMINAL	5kΩ–0 POT LOWER TERMINAL
Pedal up:	3.8	4.3
Pedal down:	9.5	10.2

Compare your readings with these: if they are different by more than a few tenths of a volt, contamination is probably the cause.

3-F Carefully clean off the terminal area of the controller with a cotton swab or clean rag moistened with water, and dry thoroughly.

CAUTION **Be sure to turn everything off before cleaning.**

Now test the controller to see if proper operation is restored. If so, take steps to prevent this from happening again: dirt and water **must** be kept from reaching the terminal area of the controller. If the voltages are still out of range, the controller is at fault and should be replaced.

TEST 4 Check for controller output

4-A The first step is to measure the output drive voltage to the motor at the controller's M- terminal.

4-B Connect the voltmeter (+) lead to the controller's B+ terminal. Connect the voltmeter (-) lead to the controller's M- terminal.

4-C Turn on the keyswitch with the forward/reverse switch in neutral, and then select a direction and watch the voltmeter as you depress the pedal. The voltmeter should read zero (or close to zero) before you apply the pedal, and should read full battery voltage with the pedal fully depressed. If it does not, the controller is defective and must be replaced.

4-D The next step is to measure the current in the controller's M- lead. If you have a means of measuring this high dc current, such as a shunt/meter setup or a clamp-on dc ammeter, use it. If not, we recommend that you buy an inexpensive ammeter of the type that is simply held against the wire being tested. These are readily available at auto parts stores, and their accuracy is adequate for this test.

4-E Turn on the keyswitch with the forward/reverse switch in neutral, and then select a direction and watch the ammeter while depressing the pedal.

4-F If you see no current flowing in the M- lead, the problem is an open circuit in the motor or the wiring between the motor and the controller. Check the forward/reverse switch. If your vehicle uses contactors for reversing, check to see that they are operating and that their contacts are closing. If these are okay, check the motor armature and field for opens.

4-G If you do see a high current flowing in the M- lead, but the motor does not turn, the problem is a short in the motor circuit, a miswired motor, or a short in the controller's internal plug diode. Test the plug diode as follows:

1. Remove power by opening the battery circuit. Take the cable off the controller's A2 terminal.

2. Use an ohmmeter to check the resistance between the controller's A2 and B+ terminals. You are testing for the presence of a diode inside the controller, so swap the two leads of the ohmmeter and look for a low resistance one way and a much higher one the other way. If your meter has a diode test function, use it.

3. If you find the diode to be shorted, the controller is defective.

4-H Put the A2 cable back on the controller and reconnect the battery.

4-I If the plug diode is okay, there is a short in the motor circuit. The short could be in the forward/reverse switch, so look there first. Because the resistance of the motor is so low, the motor must be tested separately if it is suspected of having a shorted winding.

BENCH TESTING

First, before starting any bench testing, pick up the controller and shake it. If anything rattles around inside, the unit should be returned.

CAUTION

Protect yourself during bench testing. Wear safety glasses and use insulated tools.

Equipment Needed

The simple setup shown in Figure 20 is required for testing these controllers on the bench. You will need:

1. a POWER SUPPLY with a voltage equal to the rating of the controller you want to test. You can use either a string of batteries or a regulated line-operated power supply. Because only low power tests will be described, a 10 amp fuse should be wired in series with the batteries to protect both operator and controller against accidental shorts. A battery charger alone should not be used as a power supply, because without a battery load its output voltage may exceed the rating of the controller.

2. an ACCELERATOR POTBOX. For controllers with the standard input configuration (a 5 kΩ pot wired as a two-terminal rheostat), a Curtis PMC potbox or any 5 kΩ pot will work fine.

For controllers with other input options, use whatever kind of potbox is used on the vehicle.

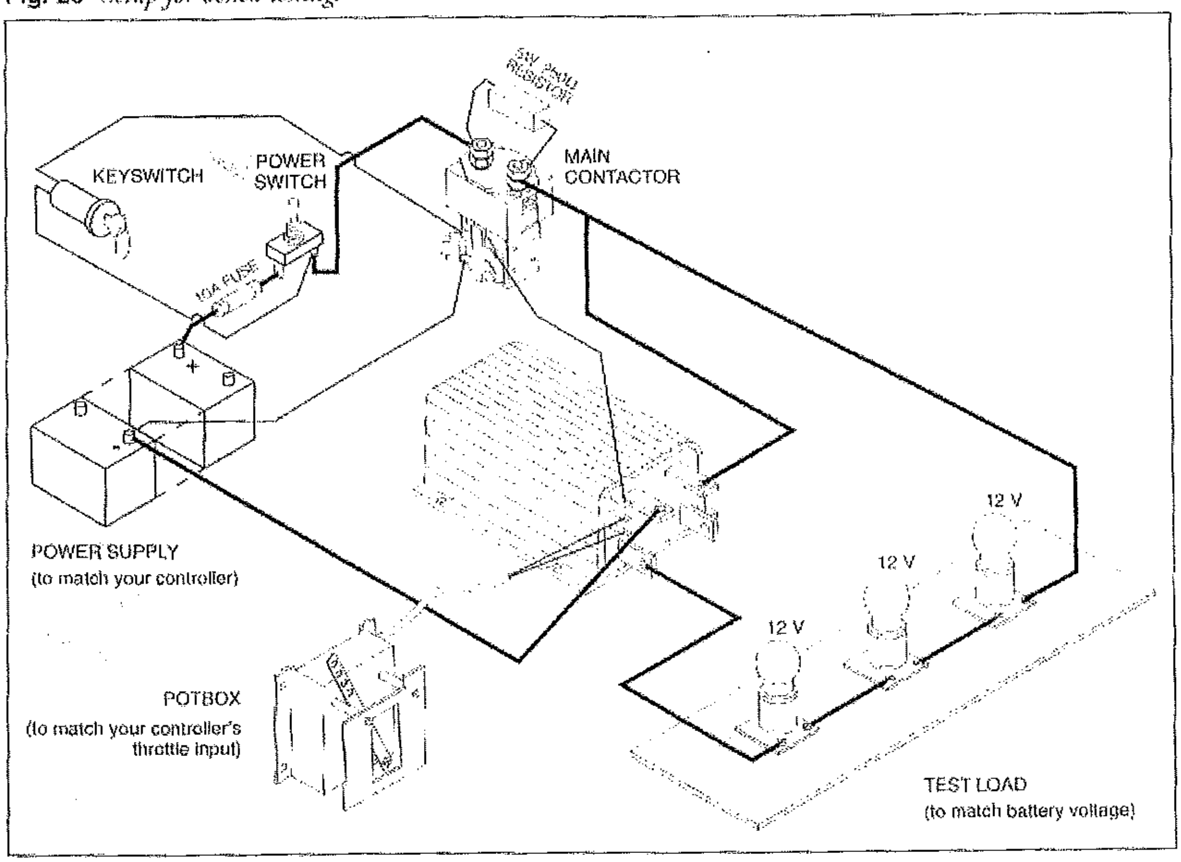
3. a POWER SWITCH to disconnect all power from the test setup.

4. a MAIN CONTACTOR with a 250 ohm, 5 watt resistor across its high-power contacts and a KEYSWITCH to turn it on and off.

5. a TEST LOAD consisting of incandescent light bulbs wired in series to get the same voltage as your power supply. (For example, with a 36 volt battery, use three 12 volt bulbs.)

6. a general purpose VOLT OHMMETER or DIGITAL VOLTMETER.

Fig. 20 *Setup for bench testing.*



Bench Test Procedure

A. Hook up the controller as shown. Connect the voltmeter leads to the controller's B+ and B- terminals.

B. Turn on the power switch (not the keyswitch) and watch the voltmeter. Its reading should build up slowly over several seconds to within a couple of volts of full battery voltage. If this voltage does not come up, the controller is bad.

C. Now turn on the keyswitch. The main contactor should turn on and the voltage at the controller's B+ and B- terminals should now equal the full battery voltage. Move the potbox lever through its range. The lamps should go smoothly from full off to full on with the pot.

D. If the controller has HPD, test this feature as follows:

   1. Turn off the keyswitch.

   2. Move the potbox lever about halfway.

   3. Turn the keyswitch switch on. Verify that the lamps do not come on until the potbox lever is moved most of the way toward OFF and then moved back up.

E. Test the controller's potbox fault protection feature by pulling off one of the potbox's two connections to the controller's throttle input terminals while the lamps are on (potbox lever in the ON position). The lamps should turn off. With the potbox lever still in the ON position, reconnect the wire. The lamps should smoothly increase in brightness to their previous level.

F. Finally, remove the controller from the test setup and check its internal plug diode, as described in Troubleshooting Procedure 4-G.