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Introduction

Most Jaguar Service Training courses concentrate on the technical details of a specific vehicle system; how the components function and how to determine if the system is functioning correctly. Advanced Diagnostics courses have a different focus; they concentrate on the process used to diagnose faults. They are for professionals who already have practical knowledge and experience in the systems covered by the courses.

We have all developed diagnostic techniques that we use on a regular basis and this course provides the opportunity to examine and further develop these techniques and share them with other technicians.

To get the most from Advanced Diagnostic training, you should practice the structured diagnostic process that will be presented and apply some critical thought to the process that you use. Time spent developing your diagnostic technique here will be paid back as you solve problems more efficiently at the dealership. Combining the structured diagnostic process with your existing experience will result in:

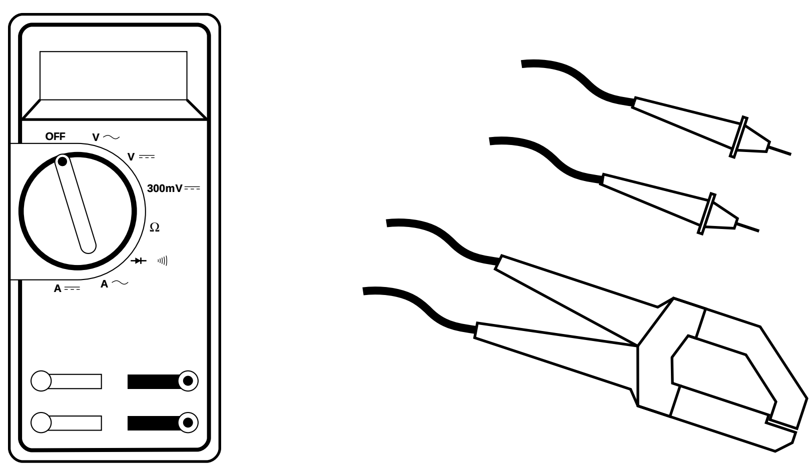
- More effective troubleshooting
- More "fixed right the first time" repair
- More confidence in the repair

Most importantly, the enhancement of your diagnostic skills will increase customer loyalty and promote your professional image.

Testing Equipment

Because sensitive electronic circuits can be damaged by using analog (dial type) meters, test lights and many types of circuit testers, only digital multimeters (DVOM) should be used. Analog meters require too much power to be used in circuits with sensitive digital components. DVOMs require very little power. In addition, DVOMs are more accurate, enabling precise value measurement. By using a DVOM with a combination digital / analog display or a MIN / MAX mode, it can be determined if the measured value is increasing or decreasing during the test.

DIGITAL MULTIMETER (DVOM) WITH LEADS AND CURRENT PROBE



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Jaguar diagnostic equipment – both PDU and JDS – have digital multimeter capabilities and can be used for circuit analysis.

When performing electrical tests, refer to the applicable Electrical Guide to determine the circuit construction, associated circuits, wire colors and connector, splice, component and ground locations.

NOTES

Electrical Units and Quantities

The international engineering and scientific communities have adopted standards for quantities and units in order to do away with the confusion caused by converting between the various measurement systems used by individual countries. The ISO (International Organization for Standardization) published the standards in their documents ISO 31 and ISO 1000. The units used in this standardized measurement system are known as SI (Systéme International) units.

Selected Units

Base unit	Symbol	SI unit	Symbol
Electric current	I	Ampere	A
Electric potential	E	Volt	V
Electric conductance	G	Siemens	S
Electric resistance	R	Ohm	Ω
Quantity of electricity	Q	Ampere hour	A h
Electric capacitance	C	Farad	F
Time	t	second	s
Power	P	Watt	W

Multiples or decimal fractions of SI units are shown by prefixes or prefix symbols before the name of the unit. Refer to the chart below.

Selected Quantities

Quantity	Prefix	Symbol
1,000,000,000 (billion [milliard])	giga	G
1,000,000 (million)	mega	M
1,000 (thousand)	kilo	k
100 (hundred)	hecto	h
10 (ten)	deka	da
0.1 (tenth)	deci	d
0.01 (hundredth)	centi	c
0.001 (thousandth)	milli	m
0.000001 (millionth)	micro	µ

Examples: 2,000,000 Ohms (two million Ohms) is written as 2 MΩ (two mega-Ohms)
6/1,000 Volt (six-thousandths of a Volt) is written as 6 mV (six milli-Volts)

NOTES

Rules Governing Electrical Circuits

Ohm’s Law describes the relationship between voltage and resistance in solid and liquid conductors: Electrical potential *(E)* is equal to the electrical current *(I)* multiplied by the electrical resistance *(R)*. The formula is written as $E = I \times R$ [*E (volts) = I (amperes) x R (ohms)*].

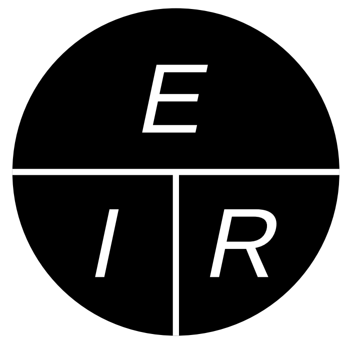
Ohm’s Law can be useful during diagnoses to help determine the effect of voltage, current flow or resistance in a circuit. If two values are known, the third value can easily be calculated.

The diagram at right is designed to simplify the use of Ohm's Law. The horizontal line indicates that two values should be divided; the vertical line indicates that two values should be multiplied. To use the formula, substitute the known or measured values for their symbols, cover the unknown value with your thumb and multiply or divide, as indicated, to find the missing value.

For example, if the electrical potential *(E)* and the current *(I)* are known, but the resistance *(R)* is not, divide the electrical potential *(E)* by the electrical current *(I)* to find the electrical resistance *(R)*:

R (ohms) = E (volts) ÷ I (amperes).

DIAGRAM FOR USING OHM'S LAW



$E = I \times R$ $\quad I = E \div R$ $\quad R = E \div I$

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Electrical resistance depends on the dimensions, material and temperature of the conductor. Resistance in metal conductors generally increases with the length and temperature of the conductor. Conductors with larger cross sectional areas have less resistance than conductors with smaller cross sectional areas.

Electrical Power

Electrical power is expressed in watts: *W (watts) = E (volts) x I (amperes).*

Energy Conversions

1 Watt = 0.0013 HP

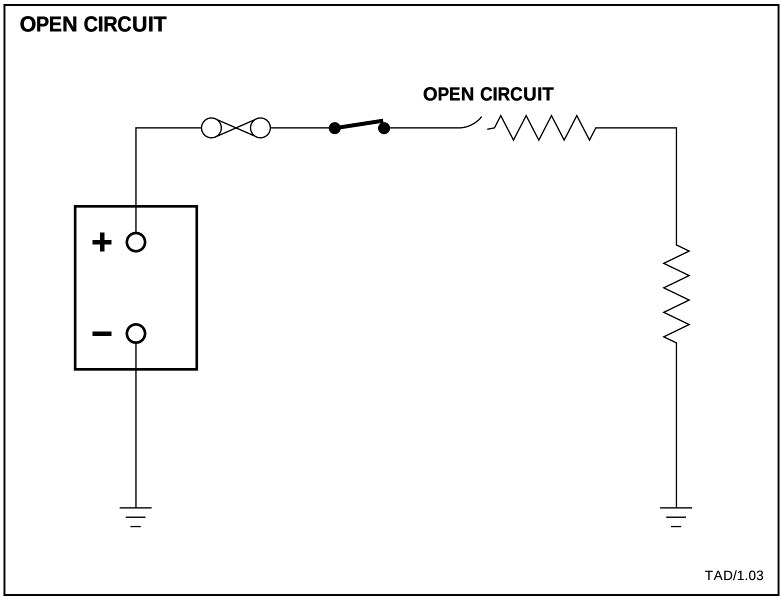
1 Kw = 1.341 HP

1 HP = 745.7 Watts

NOTES

Basic Electrical Circuit Faults

Electrical circuit faults can be categorized as follows:



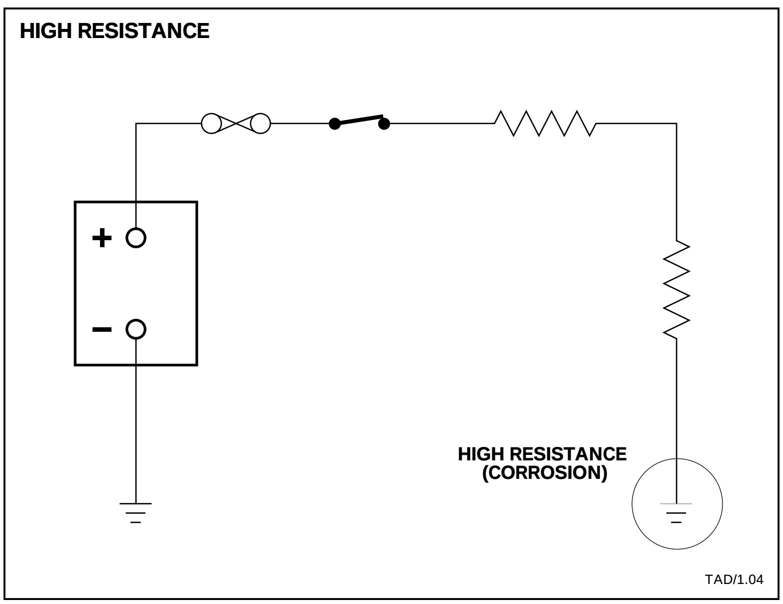
Open circuit

An open circuit is a break in the path of current flow. If the circuit is powered, a voltage potential will be present in the portion of the circuit that is still connected to the power source.

With parallel circuits, an open circuit in one branch will stop operation in that branch, but the other branches will continue to operate.

An ohmmeter test can determine if a circuit is open (infinite resistance [∞ Ω]).

A voltmeter can also be used to determine an open circuit. By measuring the available voltage at various points or the voltage drop between two points, it is possible to determine the location of the open circuit.



High resistance

A high resistance circuit is a circuit with more resistance than specified. High resistance reduces the amount of power (current x voltage) available for components connected to the circuit.

High resistance can be caused by loose, dirty or corroded connections. Broken strands of conductor within a wire's insulation or at a connector will also increase circuit resistance.

When diagnosing a circuit for high resistance, disturb the connections as little as possible until the area of high resistance has been found. Disturbing connections may clean any corrosion or dirt, temporarily correcting the problem and making diagnosis difficult.

An ohmmeter test on an unpowered circuit can determine high resistance.

An available voltage or voltage drop test on a powered circuit can also determine areas of high resistance.

Short circuit to ground

A short circuit to ground occurs when the circuit is grounded or partially grounded where not designed. If the short circuit is located after the load, circuit control may be lost causing operation when it is not wanted.

To diagnose a short circuit to ground in a fused circuit, substitute a voltmeter for the fuse. Systematically disconnecting circuit components until the voltmeter reads 0 V will identify the area of the short circuit.

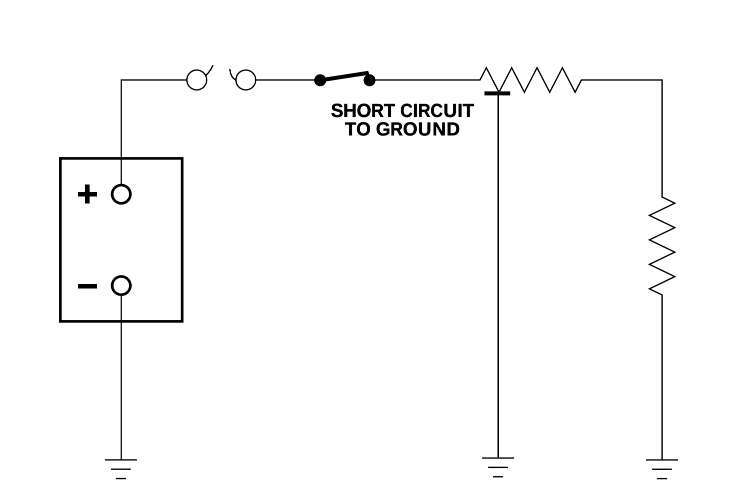
Short circuit to voltage

A short circuit to voltage occurs when insulation failure causes a conductor to contact the voltage of another circuit. The circuit (or circuits) will operate improperly.

Carefully observe the symptoms and related symptoms and refer to the Electrical Guide to understand the circuits involved. Remove fuses until the circuit is isolated, then measure resistance and voltage as appropriate to find the problem area.

NOTES

SHORT CIRCUIT TO GROUND



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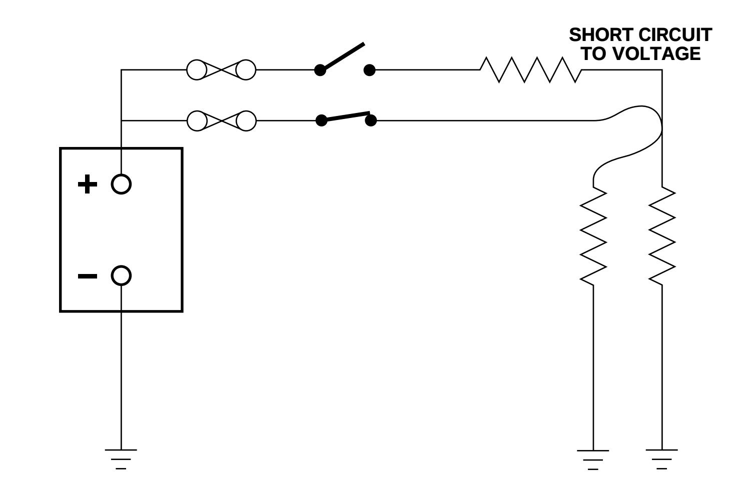
SHORT CIRCUIT TO VOLTAGE



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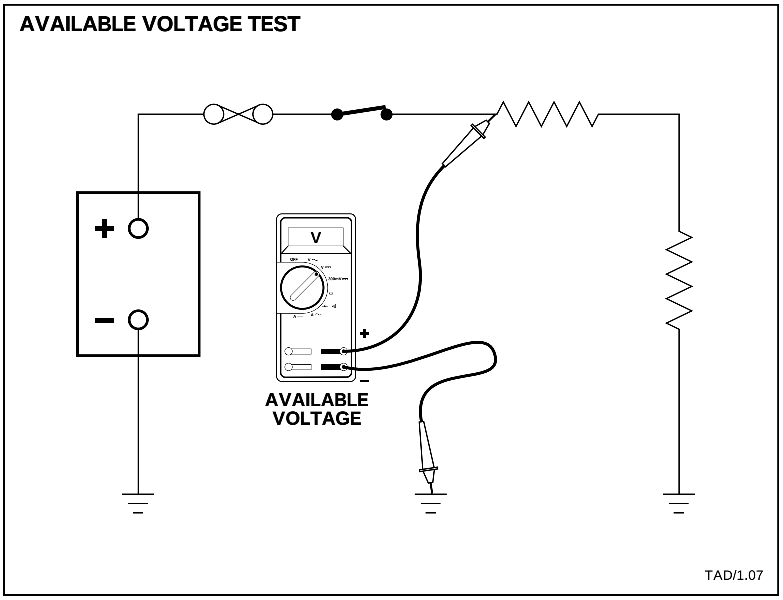
Voltmeter Tests

Voltmeter tests are useful because they measure the voltage potential in the circuit during its operational state.



Available voltage test

Tests for power supply availability, open circuits, short circuits.

Measures the AMOUNT of voltage available at that point of the circuit. The circuit must be powered (active).

Should show circuit operating voltage (usually B+ voltage).

Voltage drop test

Tests for circuit resistance under load.

Measures the DIFFERENCE in voltage between two points in the circuit. The circuit must be powered (active).

Generally, voltage drops should not exceed the following values:

Wire or cable	200 mV	Ground connection	100 mV
Switch	300 mV	Connector	50 mV

NOTE: The voltage reading depends on the portion of the circuit being tested. The lower the voltage reading, the lower the resistance.

High current circuits such as the starter motor circuit have greater voltage drops.

The relationship between voltage, resistance and current flow, as expressed by Ohm's Law, shows that even a small amount of resistance can have a great affect on the electrical power available in the circuit.

Example: A 12 V starting system drawing 200 Amps will develop 2400 Watts of power (Volts x Amps = Watts). The starter motor will develop 3.22 HP (746 Watts = 1 HP).

A resistance of 0.01 Ω in the starter cable will drop the voltage available at the starter by 2 V (Amps x Ohms = Volts). The 2 V drop caused by the resistance results in only 2000 Watts (83%) of starting power. The starter will develop only 2.68 HP.

Small amounts of resistance are difficult to determine without expensive equipment. In addition, battery power must be disconnected from the circuit to measure resistance. Voltage drop measurements indicate circuit resistance without disconnecting power or disturbing the circuit.

Voltage drop test: ground side

Tests for ground circuit high resistance, open circuit.

Measures the DIFFERENCE in voltage between a point in the circuit and ground. The circuit must be powered (active).

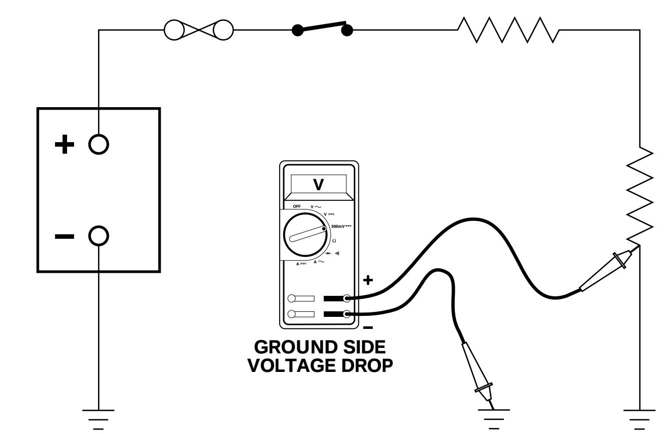
Voltage drop test: switch or connector

Tests for component high resistance, open circuit, switch function.

Measures the DIFFERENCE in voltage across a switch or connector. The circuit must be powered (active).

NOTES

VOLTAGE DROP TEST: GROUND SIDE



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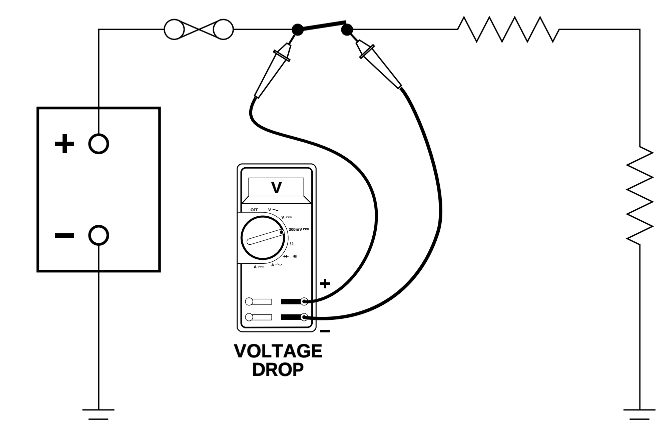
VOLTAGE DROP TEST: SWITCH



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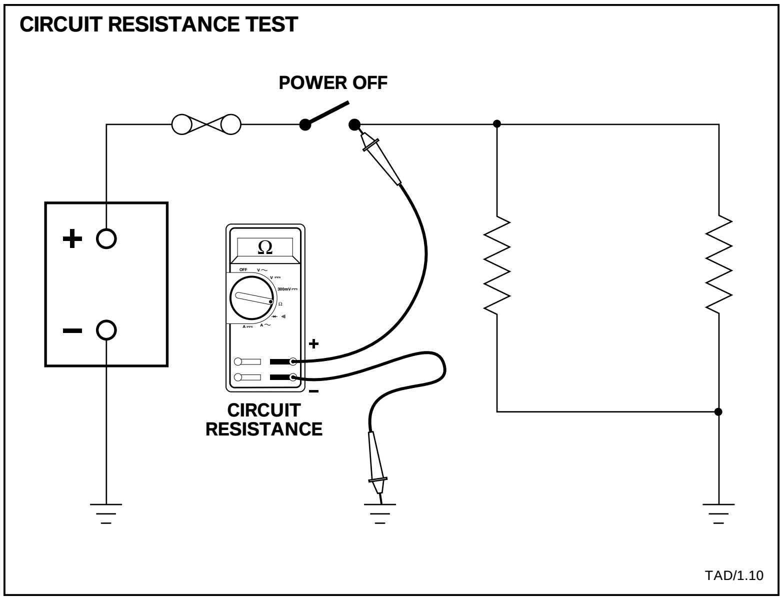
Ohmmeter Tests

NOTE: Battery power MUST be disconnected from circuits when measuring resistance. The meter provides a small amount of power to measure the circuit resistance.



Circuit resistance test

Tests for circuit resistance, open circuit, short circuit.

Measures circuit resistance between the probes. The circuit must be unpowered.

The tested value should equal the specified circuit resistance.

NOTE: When checking a parallel circuit, the total circuit resistance will be less than the value of the lowest resistance load in the circuit.

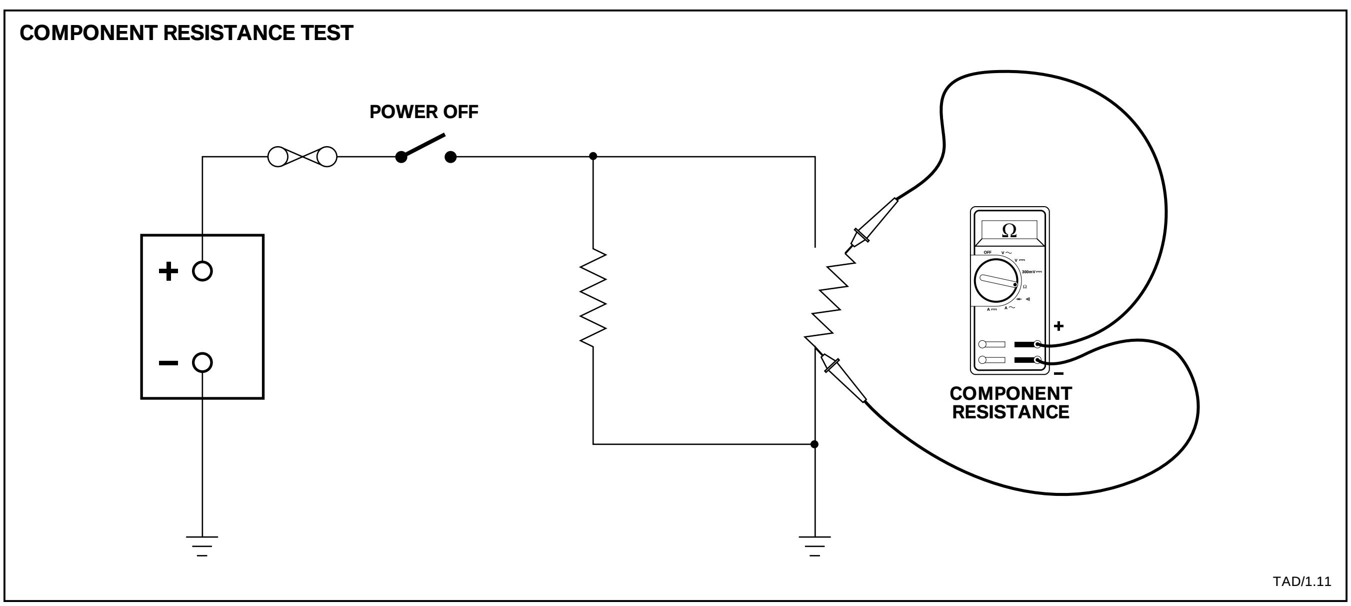
Component resistance test

Tests for component resistance, open circuit, short circuit.

Measures individual component resistance. The circuit must be unpowered.

The tested value should equal the specified component resistance.

NOTE: Disconnect components in parallel circuits when measuring resistance. If connected, the total circuit resistance will be less than the value of the lowest resistance load in the circuit.



General Approach to Circuit Testing

There are a number of ways to test a circuit using a DVOM. The test methods chosen depend on the symptoms shown in the circuit, how the circuit functions electrically and its physical layout (accessibility to test points).

Always verify the symptoms to isolate the exact nature of the failure. Refer to the circuit diagram in the Electrical Guide to determine the power supply and ground side portions of the circuit, the type of circuit control (switching) and the most convenient testing points.

PDU functions as a diagnostic aid and a DVOM. PDU will most often help you to pinpoint the cause of the failure. Because PDU diagnostics are software driven, its efficiency in any diagnostic mode depends on the software designer. Most PDU diagnostic modes are excellent. However, a technician with knowledge of the system being tested, using a DVOM and the Electrical Guide, can often diagnose a problem as efficiently as the PDU diagnostic function. PDU is most useful in accessing DTCs, observing the state of electronic components and measuring CM signals.

A DVOM can measure voltage, resistance and current flow. Selecting what to measure and where to measure depends on the individual circuit construction and failure symptoms

When testing:

Usually, test for available voltage first. Start at the easiest point to determine if the consumer power supply is sufficient.

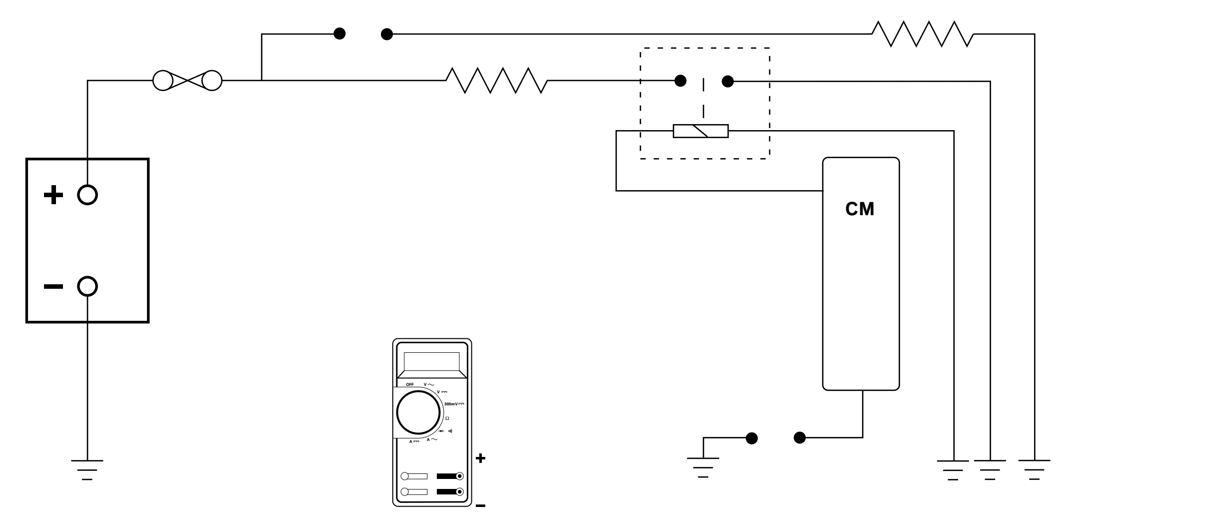
If the power supply is insufficient, the fault is located somewhere in the "front half" of the circuit, between the test point and the battery.

If there is sufficient power available at the consumer, the fault is probably in the consumer itself or in the ground side of the circuit. Remember, consumers can be controlled on the power side or the ground side.

It is generally most efficient to "split-half test" the faulty circuit. Split-half testing means progressively narrowing down the area of the fault by testing half of each faulty section until the fault location is precisely determined.

Refer to the Electrical Guide to determine the most convenient test points.

SPLIT-HALF TESTING



Diagnostic Strategy

Problem diagnosis can be time consuming and sometimes frustrating. However, the job will be easier if you apply a logical approach to the task, called a Diagnostic Strategy.

The following outlines a Diagnostic Strategy that will help ensure that none of the information necessary for accurate diagnosis is overlooked.

1 Verify the complaint

Check the accuracy and detail of information on the repair order.

Confirm that the condition is an actual fault and if it is permanent or intermittent.

Duplicate the condition and note all of the symptoms.

2 Analyze the system(s) and identify probable causes

Research the Service Manual, Technical Introduction Guides and Service Training material to identify the vehicle systems that are related to the complaint.

Check Technical Bulletins for issues with related symptoms.

Use the Electrical Guides to identify circuits or components that could cause the symptoms. Trace the circuits from power to ground to find related circuits that could cause the problem.

Use your previous experience.

Prioritize possible causes from the most likely and easiest to test, to the least likely and most difficult to test.

3 Inspect, test and pinpoint the fault

Visually inspect the vehicle and look for obvious faults first.

Read the Service Manual and check PDU menus for tests that apply to the systems, circuits and components identified in the step 2 analysis.

Test the circuits and components. Start with those that are the most likely cause and the easiest to test.

Be aware that intermittent faults or symptoms may require recreating the fault conditions while testing: hot condition, cold condition, or “wiggle” test. Refer to page 18 for the “wiggle” test.

4 Perform the repair

Follow the recommended service procedures.

To avoid a repeat failure, ensure that wiring, connectors and grounds are in good condition before fitting new components.

Replace defective components.

5 Evaluate the results

Verify that the customer complaint is resolved and that all of the original symptoms have disappeared.

Confirm that no new conditions were created by performing operational tests of any other systems that were disturbed during the repair or that are related to the complaint.

NOTES

Professional Electrical Practices

When testing electrical circuits it is important to access the circuits carefully to avoid damaging insulation, conductors, contacts or components. Measurements should be performed carefully. Ensure that the tester is connected to the correct pins. If measurements are not consistent with the values expected, always double check that the tester is correctly connected.

Back probing sealed electrical connectors will damage the sealing material an allow moisture or other contaminants to enter the connector causing corrosion.

Piercing the insulation of conductors when performing measurements will damage the conductor, increasing the conductor resistance, and allow moisture or other contaminants to enter the connector causing corrosion.

Circuit powered or self-powered test lights or circuit testers may cause damage to sensitive components. Because of the amount of sensitive components in modern vehicles, the best rule is to use only a high impedance digital multimeter when measuring any electrical circuit in the vehicle.

Periodically calibrate test equipment and check the resistance of the test leads and adapters to assure that measurements are accurate.

Use the correct testing adapters when performing measurements. Using incorrect adapters or probing connectors may damage the plating on the contacts, causing corrosion and increased resistance.

NOTES

Circuit Failure Testing

Consumer / function doesn't work; power fuse open circuits

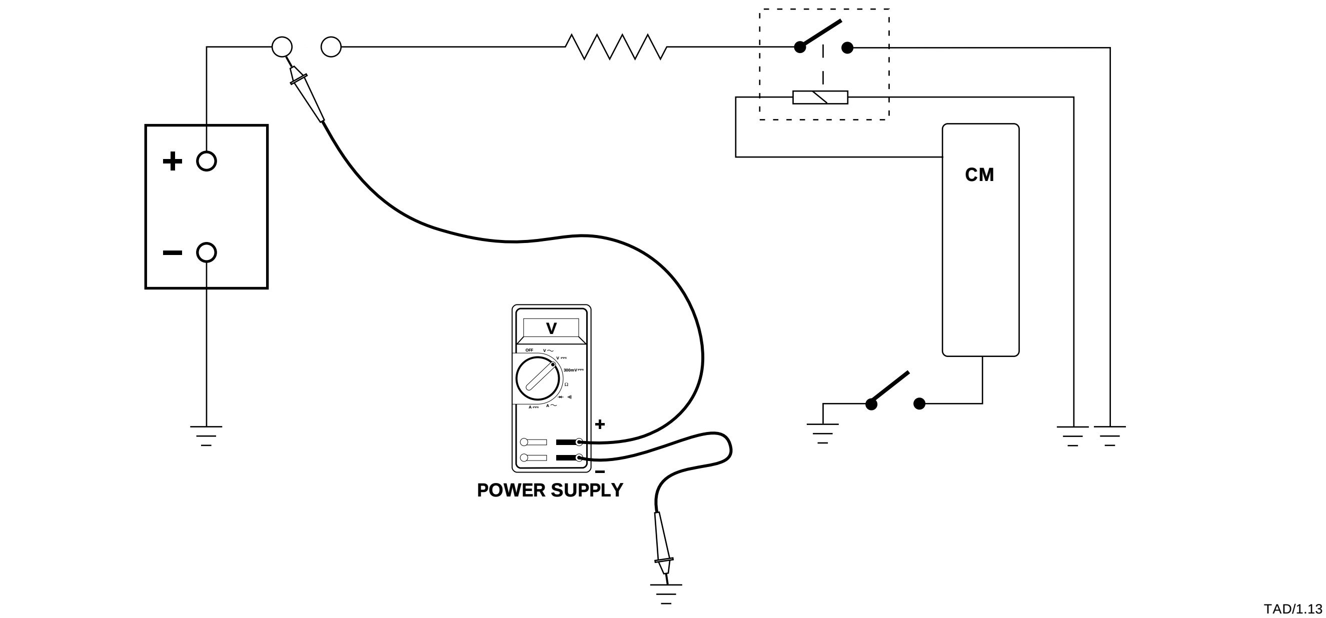
The problem MUST be related to excessive current draw. Excessive current draw is caused by the following:

- A short circuit to ground in the power supply after the fuse or a short circuit in the consumer
- A mechanical problem in the consumer or its drives

Testing strategy depends on the circuit and how easy it is to access its parts. The following example is based on the circuit illustrated.

– Switch everything OFF; check for available voltage at the B+ side of the fuse

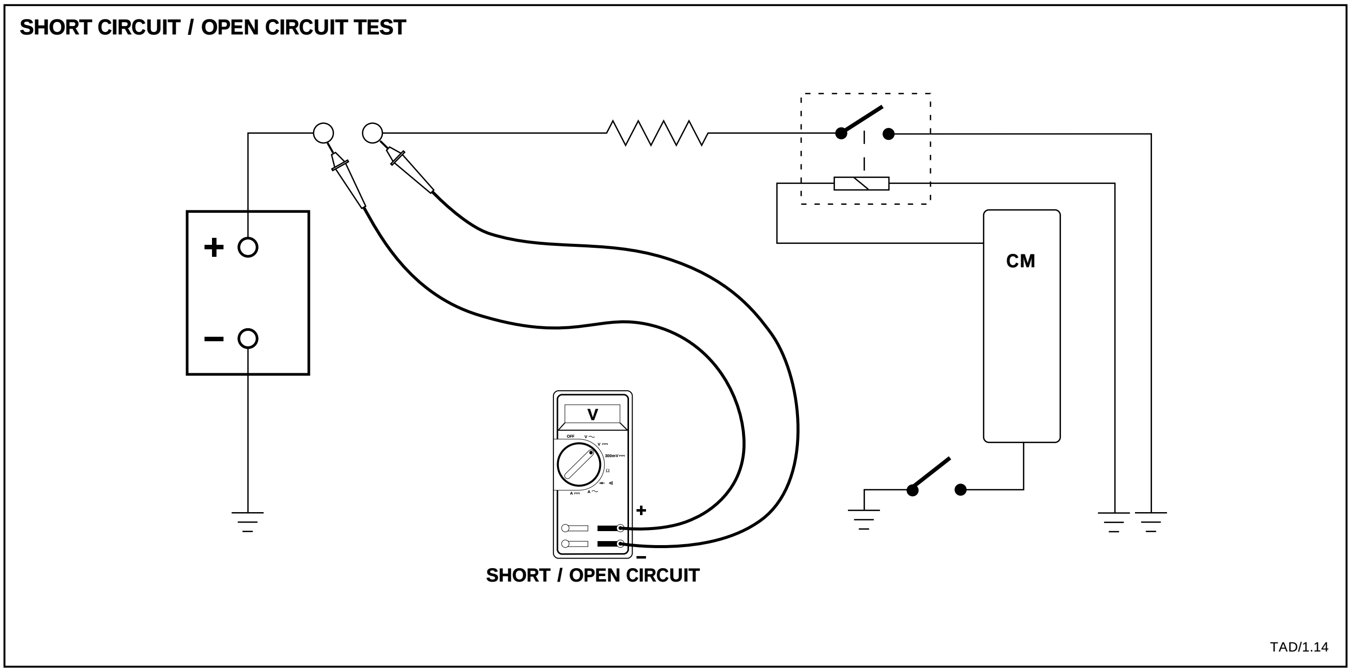
AVAILABLE VOLTAGE TEST



If there is no voltage or low voltage, the power supply is insufficient. (ALWAYS CHECK THE POWER SUPPLY).

NOTES

– **Connect the voltmeter across the fuse**



If there is a voltage reading, there is a short circuit before the control.

If there is no voltage reading…

– **Switch the circuit ON**

If there is no voltage reading, there is an open circuit or no control.

If there is a voltage reading, there is a short circuit after the control.

NOTES

Circuit Failure Testing

Consumer / function doesn't work; power fuse is OK

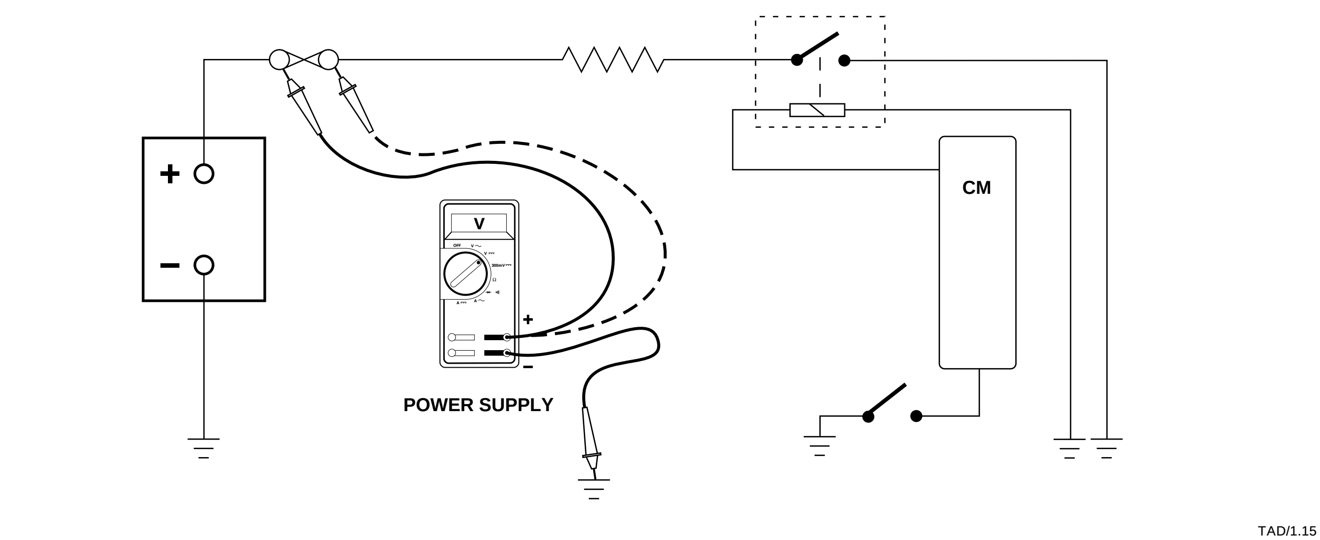
The problem MUST be caused by the following:

- No power supply to the consumer, open circuit in the consumer power supply circuit or in the consumer
- No ground or control circuit

Testing strategy depends on the circuit and how easy it is to access its parts. The following example is based on the circuit illustrated.

– **Switch everything OFF; check for available voltage at the B+ side of the fuse.**

AVAILABLE VOLTAGE TEST



If there is no voltage or low voltage, the power supply is insufficient. (ALWAYS CHECK THE POWER SUPPLY).

– **Check for voltage at the other side of the fuse**

If there is no voltage or insufficient voltage, there is an open circuit in the fuse or fuse box.

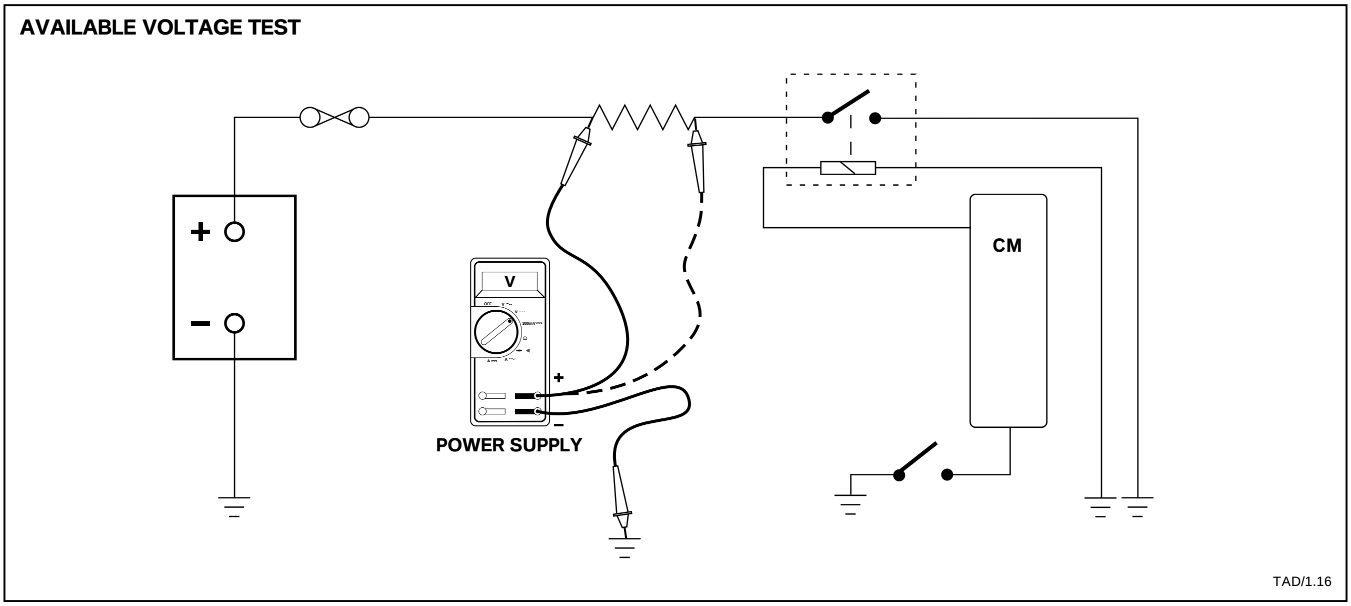
– **Check for voltage at the consumer or at a convenient point close to the consumer**

If the voltage is OK, the circuit is OK to that point.

– **Check the power supply at the consumer**

– **Check the voltage at the ground side of the consumer**

NOTES



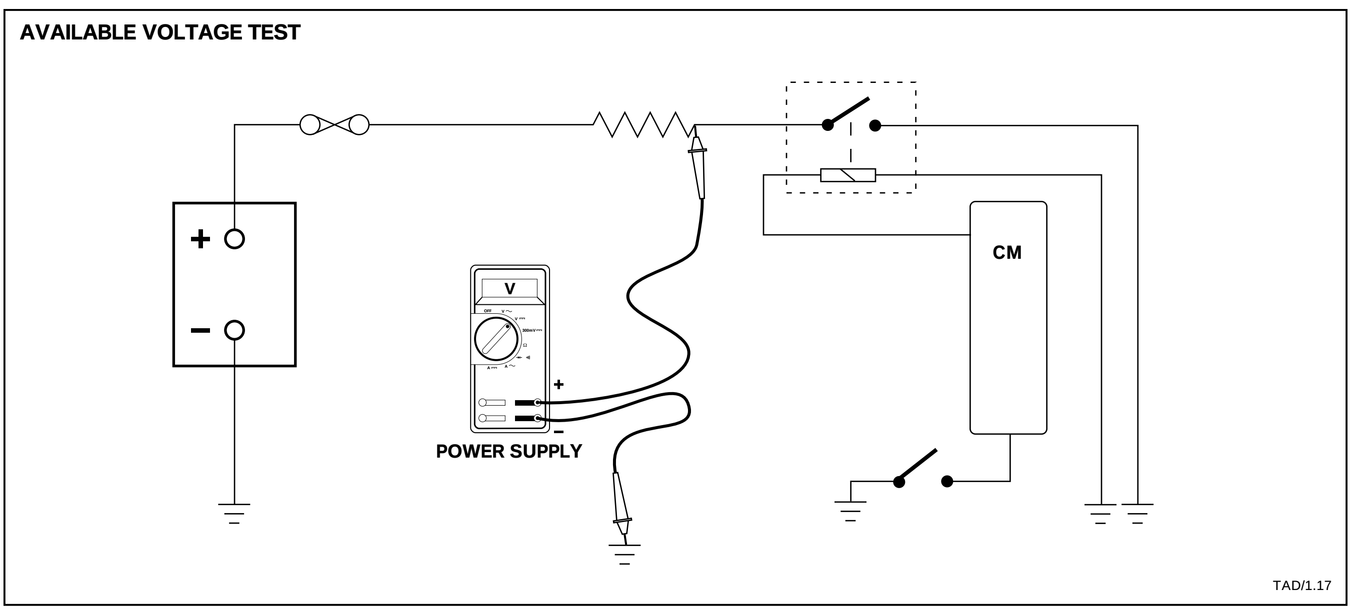
If the voltage is OK, the consumer is probably OK.

– **Switch the circuit ON**

If there is no change in the available voltage reading at the ground side of the consumer, there is a control circuit failure or an open ground circuit.

If the voltage drops to near zero…

– **Test the consumer**



If there is no voltage or insufficient voltage, there is an open circuit between the fuse box and the point tested.

Refer to the Electrical guide and split-half test the suspected section of the circuit, narrowing down to the fault area.

Circuit Failure Testing

Consumer / function operates intermittently

Because the failure is not always present, intermittent failures can be the most difficult to diagnose. If the system is electronically controlled and its control module is capable of storing DTCs, extract any DTCs as a guide to diagnosis.

It is also vital to gather the following information about any intermittent failure:

- When does the function fail?
- Are any other functions affected?
- Were any other functions in operation at the time of failure?
- Is the failure related to a vibration or bump occurrence?
- Does the failure occur at any specific temperature, time of day, engine or transmission operating condition?

Try to recreate the failure by operating the vehicle under the conditions reported. If the failure can be recreated, follow the general diagnostic procedures.

If the failure cannot be recreated, apply the reported failure conditions to the symptoms in order to determine the probable causes of the failure. Then, carefully examine each of the probable causes. Start with the circuit areas or system components that are the most probable causes of the failure and thoroughly test each one. Apply the “wiggle” test while following the general diagnostic procedures.

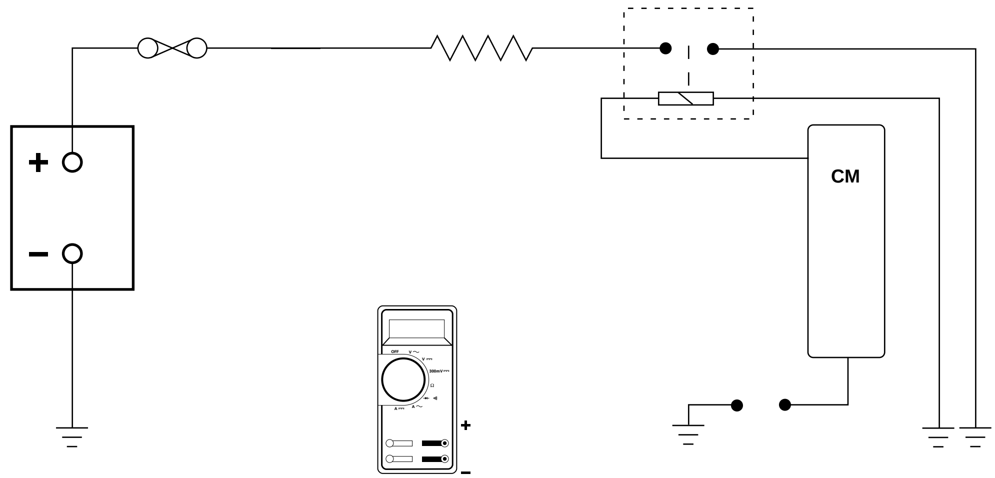
”Wiggle” test

Tests for intermittent circuit faults

The so called “wiggle” test is important to help identify circuit problems caused by intermittent failures in the wiring, connectors or grounds. With the meter connected, “wiggle” the suspect wires or connectors and look for differences in the meter reading indicating changes in resistance or voltage.

NOTES

CIRCUIT DIAGNOSIS



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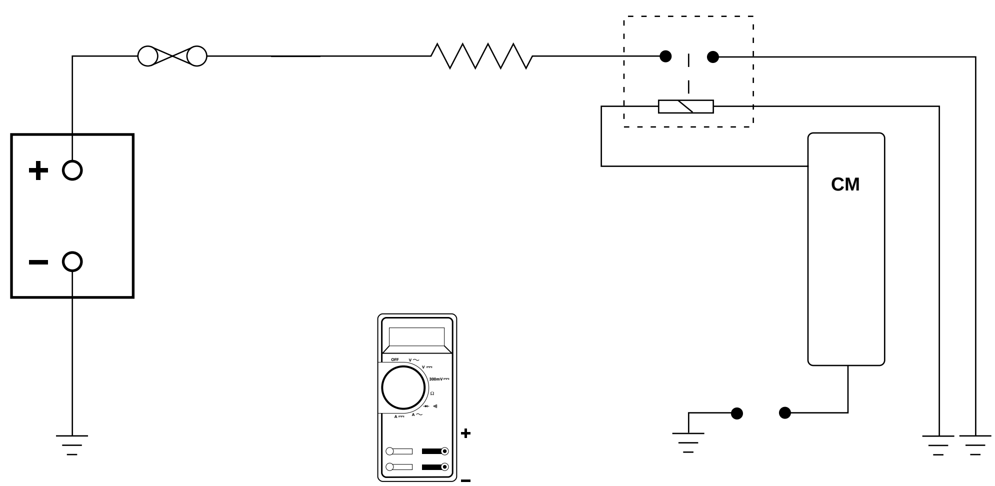
CIRCUIT DIAGNOSIS



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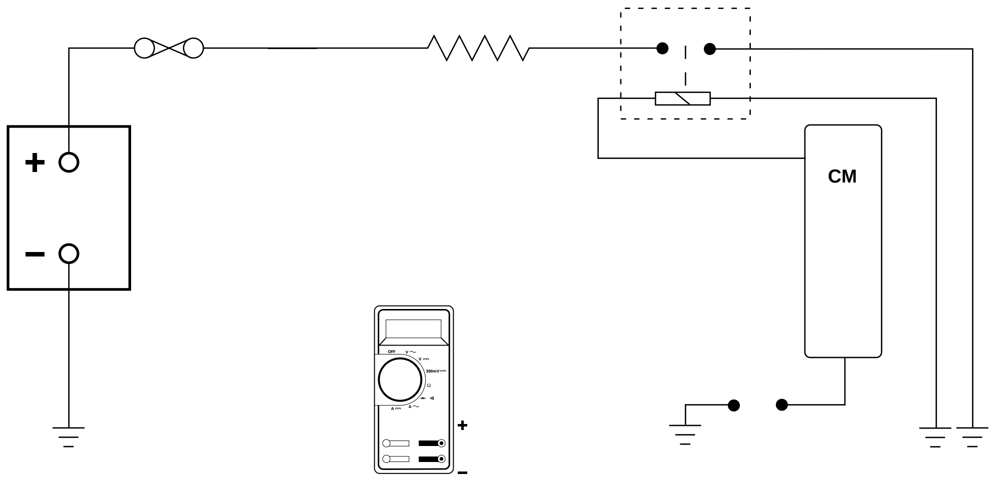
CIRCUIT DIAGNOSIS



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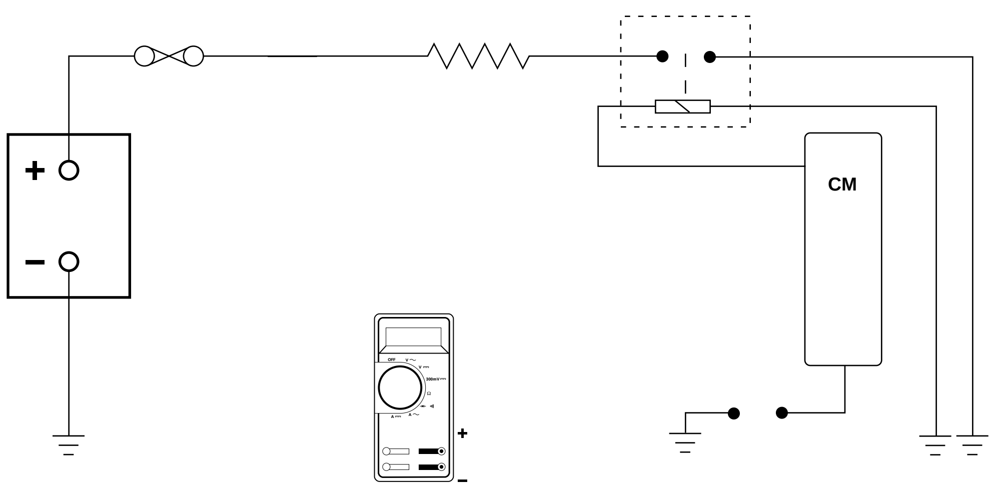

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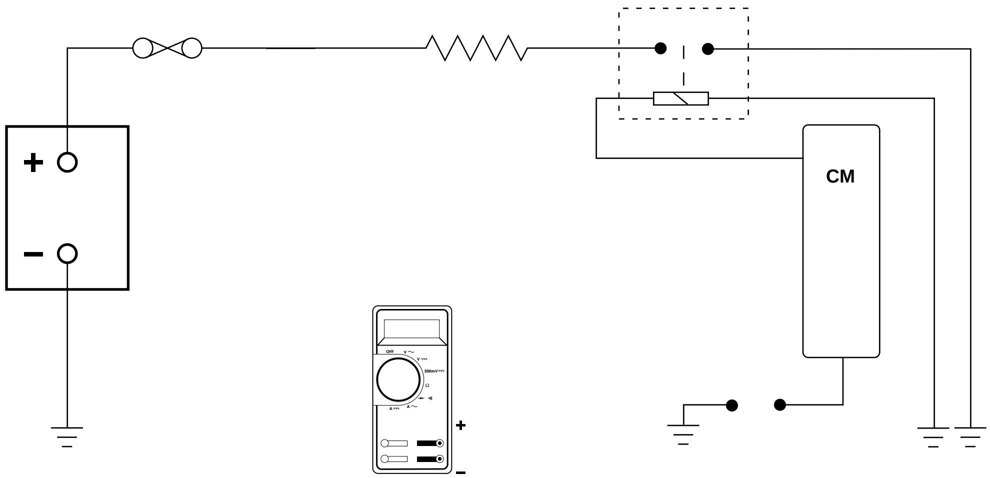
CIRCUIT DIAGNOSIS



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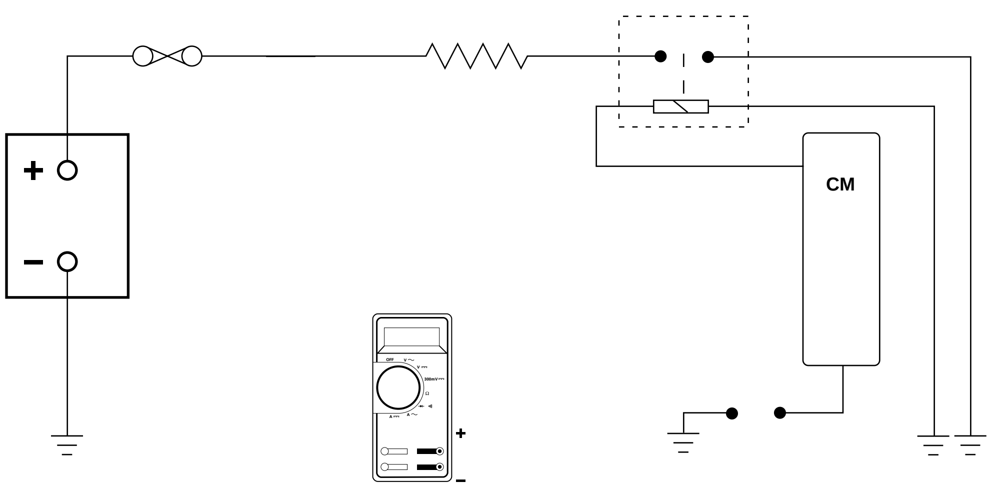

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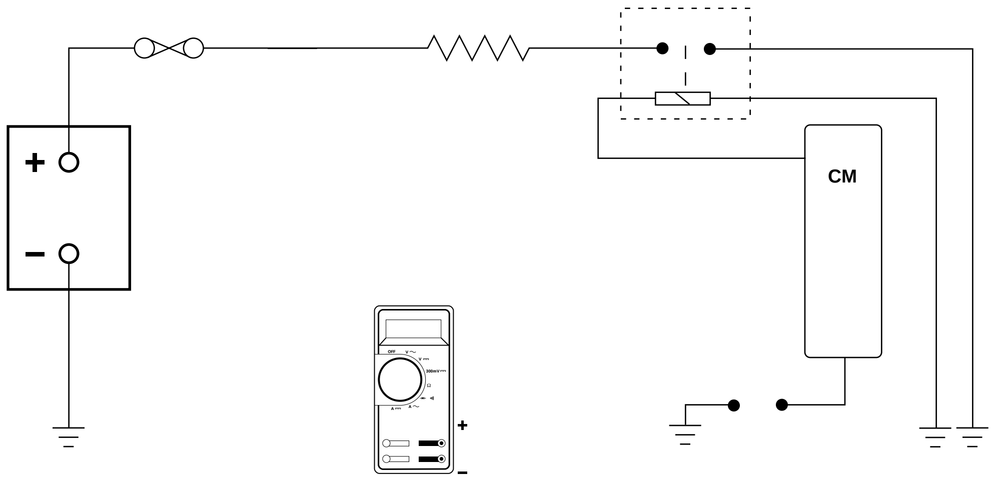

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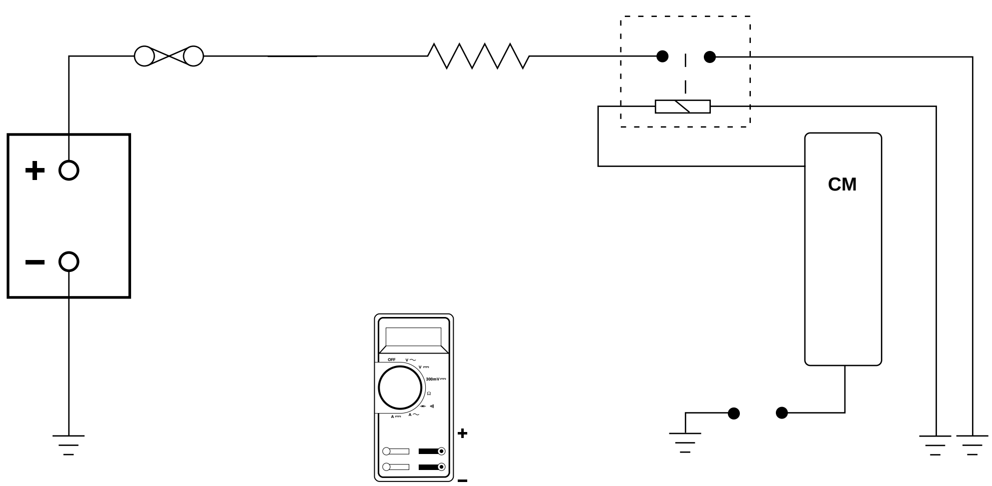

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