

INTRODUCTION

Disclaimer – This document has been prepared solely for information purposes for the use of the recipient (and his son) and without any commitment or responsibility on the part of the author.

This document is not intended to be a comprehensive guide to car electrics but just cover some basic principles and fault finding. To cover all the basics (Dynos, Regulators etc) I would have ended up writing a book which is not the point. This is meant to give a very brief overview and give an idea how to go about basic fault finding.

This document assumes the car is a **Negative Earth** vehicle

Voltages given are typical but do vary from car to car so check with the workshop manual (Haynes, etc) for actual figures.

This is meant as a quick overview. If you want to understand car electrics in depth then get hold of one of the many books available via the internet (Haynes, Rick Astley etc) and read it instead of watching endless cookery/property/quiz shows on the telly

SAFETY FIRST

Before going anywhere near a car battery, it's important to understand the dangers.

Follow these rules to ensure any risks are minimised and keep safety foremost:

When working on car electrics it must be borne in mind that a car battery is a powerful device and must be treated with respect!.

They are really heavy. There's a lot of lead inside, so be careful when lifting.

They contain sulphuric acid. Keep the battery upright to avoid spills. If any is spilt, then flush with plenty of water immediately.

They contain an enormous amount of energy, enough in fact to start fires or burn through metal.

Make sure that you don't short out the terminals with anything metal. Don't store any tools on the battery. When connecting or disconnecting a battery, there's a simple rule. If there's only one side of the battery connected, it **MUST** be the positive (red) one.

They give off hydrogen as part of the charging process. Hydrogen is explosive so don't make any sparks.

When connecting or disconnecting a battery charger, unplug it from the mains supply before going near the battery, and you won't make a spark.

If working near the battery wear protective glasses

It goes without saying- No Smoking near a battery.

Always have a suitable Fire Extinguisher near at hand in your garage.

If working on wiring etc always disconnect the cable on the negative post of the battery. This will isolate the wiring (or use a Battery Isolator).

Always use insulated tools if possible

If using a test meter always ensure the leads are kept well clear of moving objects (Fans etc).

Read the wiring diagrams thoroughly before starting work on car electrics

Lastly – use your common sense

BASIC PRINCIPLES

Before we begin fault finding a good understanding of Ohm's Law is desirable especially when testing circuits under load.

BASIC ELECTRICAL CALCULATIONS

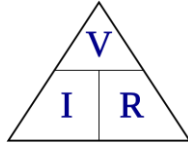
Good old Mr Ohm worked out that the current flowing through a circuit is directly proportional to the voltage and inversely proportional to the circuit's resistance.

Voltage is measured in Volts (V), Current is measured in Amperes (A) and resistance is measured in Ohms (Ω).

The basic formula is:

$$V=IR \text{ or } I=V/R$$

A simple way to remember this is the Ohm triangle



The other important formula is **Power** (measured in Watts) **equals** the **Voltage times** the **Current** flowing through the circuit

$$W = IV \text{ or } I = W/V \quad (\text{luckily } V \text{ is always rounded out at } 12 \text{ in car electrics calculations})$$

EXAMPLES

Note: I have rounded up the wattage figures to make the calculations easier

1. Head/Tail Lights

A circuit provides power to a headlight of 40 watts and a tail light of 20 watts – what is the minimum fuse required per head and tail light combination?

Total power requirement = $40 + 20 = 60$ Watts.

From **Watts = I (Amps) x V (Volts)**, then **$I = W/V$**

i.e. **I (current) = $60/12 = 5$ Amps**

Therefore it needs an **8 Amp Fuse** for adequate protection

2. Direction Indicators

Let's say each indicator bulb is 22 Watts plus a dash light indicator of 4 watts

Total Power requirement when front and rear indicators flash is $22+22+4 = 48$ Watts

I (Current) = $W/V = 48/12 = 4$ amps

Therefore a fuse of **8 amps** is required.

3. Calculating Wattage of a bulb with no markings.

With the meter on its lowest resistance range (typically 200Ω) measure the resistance of the bulb.

For this example the resistance was found to be **8Ω**

We know **$W = IV$** but also **$I = V/R$**

Therefore **$W = IV \times V/R = V^2/R$**

V is always 12 for our calculations, so $V^2 = 144$

Therefore the Bulb Wattage is $144/8 = 18$ Watts

4. Effect of Faulty earth in Headlamp Wiring

Because of the high current used by the headlamps/tail lamps, a fairly low resistance fault in the lighting circuit can have a significant impact.

From example 1 above, we know that the lights take 5 Amps therefore the resistance of the lights is (**$R = V/I$**) $12/5 = 2.2$ ohms. If a resistance of just 1Ω is introduced into the wiring through a bad earth, faulty switch or connector then the total lighting resistance is now 3.2Ω . Therefore the new current that will flow (**$I = V/R$**) = $12/3.2 = 3.75$ A.

The voltage drop across the "bad" resistance of 1Ω (**$V = IR$**), = $3.75 \times 1 = 3.75$ volts

The actual voltage feed to the headlamp is now $12V - 3.75V = 8.25$ volts

Therefore the power output of the lamp is now $IV = 3.75 \times 8.25 = 31$ Watts – A reduction of 25% just through a 1Ω bad connection!

Now work it out for 2Ω bad connection – the answers at the end of this document.

Here endeth the first Lesson.

CAR ELECTRICS FAULT FINDING

1. GENERAL

For this you will need a good digital voltmeter which can measure to at least 1 decimal place – you can buy one for under a tenner these days. Also a test probe with a bulb/LED and a lead with a crocodile clip is also useful for telling if there is voltage present at a connection/terminal.

Always use insulated tools.

When working on car electrics always take extreme care when working near un-fused circuits especially starter and main battery feeds.

Ensure Voltmeter leads are always kept well clear of moving parts.

The key to keepings electrics working is getting good low resistance connections. If I have to make a connection into existing wiring I always use bullet connectors which have been properly soldered. If the bullet connector is close to the front grill or anywhere there is a possibility of water ingress, I fit a shrink wrap sleeve over the bullet approx 4cm longer than the bullet and shrink 2cm either side of the bullet with a heat gun on a lowish setting.

For spade terminals I both crimp using the proper crimping tool and also solder the wire just below the crimp. I always use insulating shrouds over spade terminals. These help to prevent the contact becoming dirty and also importantly help prevent accidental short circuits

If a lamp is earthed to the body through direct physical contact between the lamp body (usually 2 bolt fixings) and the chassis, I always supplement this with a dedicated earth lead fixed to the lamp fixing bolts using a ring terminal with the earth wire crimped and soldered to the ring tag. I then ensure this is earthed to a good earthing point on the body.

Before fault finding I go round the circuit checking for loose/dirty connections and clean with 400 wet/dry where necessary.

2. BATTERY

Power for starting and other devices when the car is stationary is provided by the battery – normally a Lead Acid battery on classics cars. The nominal voltage of a single battery cell fully charged is 2.2V. A 12V battery has 6 cells so the nominal battery voltage is 13.2V but this usually referred to as a 12V system.

The Battery is normally kept in a charged state by the Alternator or on earlier cars a Dynamo.

To ensure the Battery Charges, a high enough voltage is applied to the battery to give it a decent charging rate. This is why the output of an Alternator or Dynamo is set to 14.2V. A lower voltage would not charge the battery sufficiently quickly and a higher voltage could lead to damage to the battery and the cars components. Batteries should not be left in a low charge condition for any length of time as the plates can become sulphated and the battery will lose its capacity.

The only way to test a Battery condition without garage equipment is with a Specific Hydrometer but if the battery is old, if in doubt get a new one.

If the car is to be laid up for any length of time then use a battery charger/conditioner to keep the battery in tip top condition. Battery posts must be kept clean and petroleum jelly smeared on the posts will help prevent corrosion.

Never use force when disconnecting Battery clamps.

Before disconnecting the negative supply make sure all the car electrics are switched OFF especially those that have an inductive component, windscreen wiper, ignition circuit – this will prevent any

sparking near the battery terminals. When reconnecting the negative again make sure you have switched off any electrical circuits to prevent sparking.

When working on car electrics you will come across 4 types of wires/cables:

- a) **HOT/ UNFUSED** – these wires are always live irrespective of the ignition key and importantly are not fused. They feed directly back to the battery. Touch one of these against the body and it will do a good imitation of a MIG Welder and probably weld itself to the body. There is every chance there will be a big bang, the wire will fuse itself to the metal body and start to burn. Before working on these disconnect the negative post of the battery. The best choice is to fit an isolator switch on the negative post to easily isolate the battery. They're not expensive and are easy to fit and save your nerves. Always test to make sure the circuit is dead before you work on it. These usually feed critical parts of the car which need to be live at all times e.g. Starter solenoid feed, Alternator, Fuse box live feed, Ignition switch live feed, Hazard Switch feed.
- b) **HOT/FUSED**- as above but these are protected by a fuse. These are circuits which need power when the car is stationary but are not critical if the fuse blows e.g. Headlight switch, Horn, Boot lamp, interior lamp, etc
- c) **IGNITION ON HOT/UNFUSED** – Live when the ignition key is turned on. These circuits are critical to the car and so cannot be fused e.g. Fuel pump, Ignition coil feed, Ignition ON light, etc
- d) **IGNITION ON HOT/FUSED** – Live only when the ignition key is turned on, and are protected by a fuse. Typical applications are:
Indicator (Flasher) unit, Brake light switch, reverse light switch etc

Fuses: confusingly, there are two fuse rating systems. Older fuses are marked with their maximum rating before blowing – they must only carry half this current in constant use. E.g. if a lighting system carries 16 amps, use a 35 amp fuse.

Newer fuses are marked with a Constant Rating (CR). An 8CR fuse will carry 8 Amps continuously but will blow at 16 amps.

3. STARTER MOTORS

The Starter converts electrical energy into a mechanical turning force to crank the engine over
There are two types

- 1) **Inertia Type** – when the starter is energised as the armature spins, a screwed sleeve or pinion is moved along to engage with a ring gear around the outside of the engine flywheel. When the engine fires and the flywheel turns faster than the starter motor the pinion is ejected back along the shaft, disengaging from the flywheel.
- 2) **Pre-engaged** - by operating a solenoid, the pinion is forced along the starter shaft to engage with the ring gear. As it does, a contact is made with the windings of the starter motor which turns and hence spins the engine over until it starts.

If a Starter Motor spins slowly or not at all carry out the following tests

TEST 3.1 – Battery Voltage under Load

Connect a voltmeter across the battery terminals (on 20V range)

Crank the engine over. The Battery voltage should typically fall to 10.0 V. Any voltage below this the battery should be tested.

TEST 3.2 – Voltage at Starter Motor Terminal under Starting Load

Connect the voltmeter across the starter terminal (normally a thick brown lead) and the earth terminal or starter body. Crank the engine over. The voltage reading should be no more than 0.5 volts less than the above figure measured at the battery post. If it is, then there is too high a resistance between the battery terminal and the starter terminal which could be a bad connection or the starter cable or main earthing strap/cable is failing.

TEST 3.3 Starter Solenoid Contacts

Connect the voltmeter across the Solenoid contacts. When the Starter is energised, there should be a fractional voltage drop across the contacts. The contacts are normally shorted by a heavy gauge brass or copper bar to carry the heavy starting current and hence should have very low resistance and voltage drop when energised. If the reading is high (> 1 volt) then this could indicate faulty contacts in the solenoid.

Test 4 Starter Earth Connection

Connect the negative of the meter to the negative post of the battery. Connect the positive meter lead to the earthed body of the starter motor. Crank the engine. There should be minimal voltage drop across the earth connection. If high check the earthing strap.

4. ALTERNATOR

Because of the sealed nature of the solid state regulator/rectifier there is not much the average person can do with an fixing an alternator apart from checking the connections on the back of the alternator are clean and sound.

Never run an alternator in situ with the battery or Voltage Regulator disconnected!

I have produced a separate document to deal with Alternator operation and basic fault finding
FIAT 500 Ignition Fault Finding - Alternator

For Dynamo equipped cars see

Fiat 500 Ignition Fault Finding – Dynamo

Voltage Stabiliser (Fiat 500 Classic owners look away now)

Note: although the alternator has a regulator, the battery voltage does fluctuate, usually by about a volt under normal running especially as you switch headlamps On/Off. This would affect any electric powered gauges (Fuel, Oil temp, water temp etc) which as well as making the reading inaccurate could also make the needles fluctuate which is annoying. To prevent this, the voltage feed to the dash instruments goes through a voltage stabiliser. This has a bi-metallic element which maintains a steady voltage feed to the gauges usually about 10V so that the largest voltage drop of the Battery will not fall below the Stabilised voltage. The gauge bulbs are fed by a different circuit usually through a dimmer rheostat. If you suspect the stabiliser is faulty (the gauges rise and fall with engine speed) then replace it either with an original unit or a modern solid state replacement.

The stabiliser has three terminals

B – connects to the battery feed via the ignition switch

E – the earth (ground) connection

I – Instrument feed

Don't confuse the Stabiliser with the Regulator

5. IGNITION CIRCUIT

To power the car, the fuel/air mixture from the carbs needs to be ignited at the right point in the combustion chamber – to ensure the complete combustion flame occurs when the piston is almost at **Top Dead Centre (TDC)**. The ignition of the fuel is provided by **the Spark Plug**. There is a small gap (typically 25 thou) between the body of the Spark Plug and a centre electrode. The body is earthed by the engine block. The centre electrode is connected to a **High Tension (HT)** lead which goes between the **Distributor Cap (see pic. below)** and the Spark Plug. When the HT voltage is applied there is a small electrical spark which arcs between the Spark Plug Body and the centre electrode igniting the fuel/air mixture.



To ensure the right Spark Plug gets the spark at the right time, the leads are arranged in the Distributor Cap in the firing order (for the MGB it is 1-3-4-2).

The centre electrode in the Distributor Cap carries the HT from the Ignition Coil. It “carries” the HT to the right Spark Plug lead through a **Rotor Arm (see pic. below)**. The Centre Electrode has a sprung carbon brush which makes contact with a brass plate on the rotor arm. As the rotor arm rotates it passes a stud which has the relevant cylinder Spark plug lead connected to it and the HT voltage jumps across the small gap between Rotor arm and lead stud.



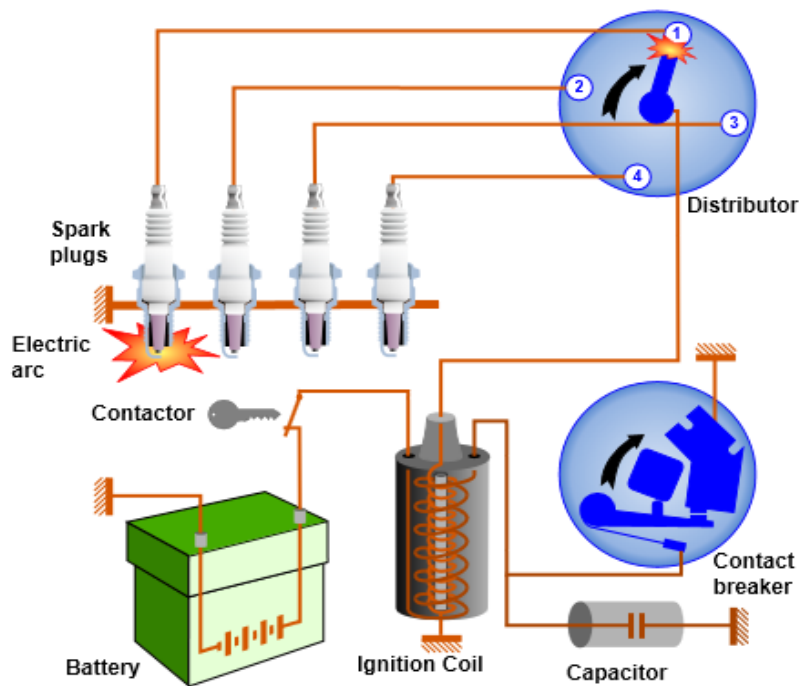
To generate the HT voltage, a kind of “transformer” is used – this is the **Ignition (or Spark) Coil**. The primary has a small number of turns which carry the **Low Tension (LT)** voltage – 12V. The secondary has thousands of turns which generate the HT voltage (typically 15K Volts).

The next bit covers the bog standard Contact Breaker Points installed on earlier cars.

The battery is connected, via the ignition switch, to the primary of the ignition coil. The other side of the primary connects to a set of **contact breaker points** inside the distributor body (ignore the capacitor for the moment).

The contact breaker points are normally closed which completes the circuit for the coil – this allows a magnetic field to build up inside the coil. There is also a cam which is connected via a drive shaft to the main camshaft. As the engine turns the **Distributor (or “Dizzy”)** cam breaks open the contacts. When this happens, the primary magnetic field collapses but as it does, the energy is transferred to the secondary. Because the secondary has a thousand more times windings it produces a very high voltage (but also a very low current) in the secondary.

The capacitor helps to store more energy for the primary and importantly reduce arcing across the contacts due to the back EMF in the primary winding when the contacts open.



The problem with the above system is that the contact breaker points burn out over time and need constant adjustment. Most modern systems use **Electronic Ignition** systems such as **Lumenition**.

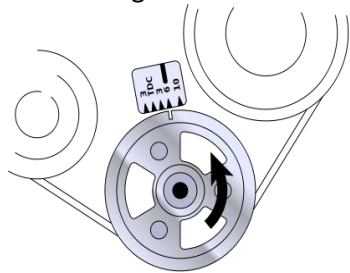
These basically replace the points and provide a “Boost” to the primary. The two main types are:

OPTO – these use a rotor to break an infra red beam to “Fire” the coil

MAGNETO – these use a small magnet on the rotor which passes over a trigger sensor which “fires” the coil.

The time a spark happens is usually referred to a Degrees **Before Top Dead Centre (BTDC)** for Cylinder Number 1. The spark doesn’t happen as the piston is at TDC because it takes time for the flame to spread across the piston once it has been ignited by the spark plug.

To help timing, there is a TDC mark (notch) on the main crankshaft pulley (this is zero degrees BTDC). Next to the TDC timing mark on the pulley there is usually a set of timing marks (teeth) showing various degrees BTDC.



TEST 5.1 Quick Battery Load Test

Switch on headlights at full beam. Crank engine over. If the engine spins at a reasonable speed and lights remain reasonably bright then there should be sufficient voltage to carry out ignition tests

TEST 5.2 HT Spark

Remove the end of the main HT lead that goes from the coil to the distributor (at the dizzy end). Hold end about 6mm away from the exposed engine block. Crank the engine over. There should be a nice blue spark between the HT lead and the block. If there is then the starting problem probably lies with plugs, fuel, timing etc. If no spark occurs then:

TEST 5.3 Coil Primary Circuit

5.3.1 Points Contacts Open

With the cap off the dizzy slowly turn the engine by hand until the contact points fully open. Connect Voltmeter to the “+” on the coil and negative test lead to a good earth. Switch on the ignition – it should register battery voltage. If not then the fault is between the battery and the coil (could be a faulty ignition switch).

Now connect the voltmeter to the “-” terminal on the coil. When the points are open this should register battery voltage – if not then:

- a) The coil is open circuit. To check, switch off the ignition and using the test meter measure the resistance across the coil with the terminal wires removed. Or
- b) there may be a short circuit to earth in the dizzy.

5.3.2 Points Contacts Closed

Slowly turn the engine by hand until the points are fully closed - measure the voltage on the “-” coil terminal when the points are closed - this should register zero volts.

If it reads battery or a high voltage then the fault is between the negative terminal and the points.

This could be due to:

Points not closing properly

Dirty contacts

Broken lead between the dizzy LT terminal and the contact breaker contact post

TEST 5.4 Coil Secondary Circuit

Connect a good HT lead to the HT output of the coil. Turn the engine until the points are closed.

Switch on the ignition. Now hold the other end of the HT lead 6mm from the engine block. With a screwdriver carefully flick the points open. There should be a good blue spark between the exposed end of the HT lead and the engine block. If not then the coil is suspect or the capacitor in the dizzy is faulty. The only way to determine this is to replace the capacitor with a known good one and retest.

TEST 5.5 Rotor Arm

If there is a good spark from the coil secondary then the next suspect is the rotor arm. Because of the high voltages, rotor arm insulation can break down especially where it is mounted on the dizzy. The only way to test is to substitute it with a known good one.

BALLASTED IGNITION SYSTEMS

Ballasted systems are usually found on classic cars. There is a Ballast Resistor which is wired in series with the Coil. The coil itself has a lower primary resistance than a standard 12V coil and is optimised to have a normal operating voltage of approx 6 volts. Under normal battery voltage of 12 Volts, the coil would overheat and probably burn out or short circuit. Therefore a Ballast Resistor is placed in series with the coil to drop the voltage applied to the coil, however, when the engine is being cranked over, the starter motor draws such a high current that the battery voltage could drop down to 9 – 10 volts. When the starter motor is energised, the coil is fed directly from the solenoid. This means that the coil will give maximum output because the power battery voltage at starting is equal or close to the coils normal operating voltage. When the car fires and the starter is released, the coil is now supplied via the ballast resistor. Because the car is cranked for a relatively short period, the coil is not in danger of overheating if the applied voltage is higher than 6V

Therefore in the above tests you also need to test that under starting, battery voltage (9-10 volts at cranking) is applied to the coil and under normal running conditions a lower voltage (because of the voltage drop across the ballast resistor in series with the coil) - typically 6V is applied to the coil.

6. LIGHTING

To locate faults on lighting systems needs a thorough understanding of the Ohms Law since most of the testing is done under load with the ignition on.

Therefore you need to ensure the battery has a good charge before starting fault finding.

Often poor lighting can be down to simply poor earthing arrangements where contact between the body of the light fitment and the car chassis is used for earth return.

To improve earthing, use a dedicated earth loop for lighting. Using a “ring” terminal ensure that this is fixed to a good earthed point on the car either (ensure any paint is removed and the earth tag is touching bare metal). Run the earth lead to the nearest light fixing and using another ring tag secure this to one of the fixing bolts on the lamp body. Then run another earth wire to the next light fitting until you have earthed all the front lights and on the last light run another earth back to the body. Use a decent gauge wire - minimum 28/0.3mm.

Weak Tail/side lights – all tests carried out with side/tail lights on

Test 6.1 – Battery Voltage under load

Measure Battery voltage with side lights on. Connect negative test lead to good earth near bulb. Check voltage at bulb, there should not be more than a 1.5 volt drop.

Test 6.2 Voltage drop on positive feed to lamp.

Connect Voltmeter positive lead to battery positive post. Measure Voltage at Bulb positive connection – note the reading

Test 6.3 Voltage drop on earth feed to lamp

Connect negative test lead to battery negative terminal. Measure voltage at earth feed to lamp. Note the reading

If there is a reading of greater than 10% of the battery voltage under this load, then a high resistance fault exists in either the live feed or the earth feed

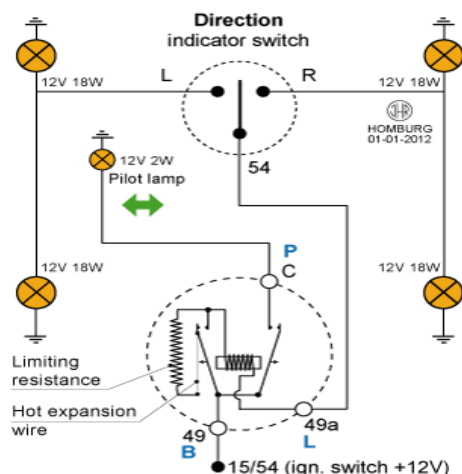
If it is in the live feed then the voltage drop on the live feed (under load conditions) must be checked at every stage of the live feed to the bulbs (ignition switch, Fuse, Light switch) to determine the fault location.

Weak Headlights

Exactly the same procedure is applied as above. With the greater current drawn by the headlights esp. full beam, any high resistance faults will cause the headlights to dim. Good earthing needs to be established in the main lighting circuit

7. FLASHER/INDICATOR LIGHTS

Most classic cars have a “Hot Wire” flasher unit in the indicator circuit. This operates on the principle that when the indicator stalk is moved to the left or right, the indicator lights (front, rear, side and dash light if fitted) complete the circuit from the battery, via the flasher unit and lamps to earth. From Ohms Law Example 2 a current of about 4 amps will flow through the Flasher Unit. Flasher units can be 2 Terminal or three terminal (ignoring earth) where the third terminal is for a dash light. The Battery Feed is the “B” or “+” terminal. The indicator light feed is the “L” terminal



7.1 Simplified description of a Flasher unit (diagram courtesy Hans Homburg)

When the direction indicator switch is moved to the left or right, current flows through the heater wire, the resistor and an armature coil. As the heater wire expands, the main armature moves under spring tension to close the main contacts. During heating the limiting resistance prevents lighting of the indicator lamps, but when the contacts close this resistance is short-circuited and connects the indicator lamps straight on to the 12 volt supply via the coil.

The higher current in the coil then magnetises the iron core and attracts the armature so that the contacts close firmly.

As the short circuited heater wire cools, it contracts and pulls the contacts open and the process repeats itself until the stalk is moved to the neutral position.

The allowed flashing rate is 60 – 120 flashes per minute.

There is a secondary armature which operates the dash lamp via terminal P.

7.2 Neither flashers work

If there is no flashing when either left or right indicators are selected then it is probably a common fault in the live feed to the indicator stalk or the flasher unit has failed. Switch on the ignition and select either left or right turn. Check the voltage at the “B” terminal of the flasher unit. It should be within 10% of the battery voltage.

If it is then check at the “L” Terminal. If it is the same as the “B” terminal then check the wiring to the indicator stalk. If there is no voltage then the flasher unit probably has failed. To check this, remove the flasher unit and connect the “B” and “L” feeds together. Move the indicator stalk and the indicator lights should come on permanently and be the same brightness on both sides.

7.3 Indicators flash at high speed – one side only.

If an indicator lamp fails, the current drawn is lower and the flashing frequency will rise. Additionally it may be that the secondary armature will not close at all, so no dashboard warning light will come on.

7.4 Indicators flash at high speed both sides

This is probably down to a high resistance in the live feed. This should be located using the volt drop procedure above.

7B - LED BULBS

The above describes how a “Flasher” works with standard incandescent bulbs which draw a fair amount of current to operate the unit.

A recent development in vehicle lighting is the use of VLED (visible LED’s – as opposed to the “invisible” infra red LED’s used in remote controls).

Simple Explanation: An LED is basically a diode composed of elements of Gallium Arsenide which give off visible light when a voltage is applied (in the right polarity) across the diode. Unlike the diodes you may have encountered in electronic circuits which are normally encapsulated, when researchers were looking at the properties of elements used in the PN junction of the diode, a Gallium Arsenide composition produced photons of light when a voltage was applied.

Initially these were of a very low light output but recent developments have produced more powerful VLEDs which are now making their way into headlights.

The major advantages of VLEDs are their Long life, robustness, instant illumination and excellent power efficiency when compared to filament lamps/bulbs.

A disadvantage however is that replacing an indicator bulb with a VLED will not draw sufficient current to operate the Flasher unit. Therefore a special electronic flasher unit must be used.

Always check that any VLED replacement has been approved for use on a vehicle. Some are not approved so please check before replacing.

8 WINDSCREEN WIPERS

I have already posted the operation of a Fiat 500 wiper operation previously on the Fiat 500 Forum.

9. EFFECT of 2Ω RESISTANCE IN HEADLAMP CIRCUIT

From example 1 above, we know that the lights take 5 Amps therefore the resistance of the lights is ($R = V/I$) $12/5 = 2.2$ ohms. If a resistance of $2\ \Omega$ is introduced into the wiring through a bad earth or connector then the total lighting resistance is now $4.2\ \Omega$. Therefore the new current that will flow ($I=V/R$) $= 12/4.2 = 2.9A$.

The voltage drop across the “bad” resistance of $2\ \Omega$ ($V=IR$), $= 2.9 \times 2 = 5.8$ volts

The true voltage feed to the headlamp is $12 - 5.8 = 6.2$ volts

Therefore the power output of the lamp is now $IV = 2.9 \times 6.2 =$ **18Watts** – A reduction of 55% power output just through a $2\ \Omega$ bad connection.

And Lastly

REMEMBER- SAFETY IS THE No1 PRIORITY WHEN WORKING ON CAR ELECTRICS – IF IN DOUBT DONT TOUCH, AND ALWAYS READ THE WORKSHOP MANUAL AND IF UNSURE TAKE IT TO AN AUTOELECTRICIAN