Charging Around the Circuit

Elek-trickery & Old Geese

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McMillan's V7 demonstrates the "Path of Least Resistance" around Cadwell

I wrote this with the intention of de-mystifying the electrical systems on older (Tonti) Guzzis and to help with the troubleshooting and eradication of electrical gremlins. If I've managed that I'll leave you to decide.

Roy Matson (aka Kiwi_Roy) reviewed it, corrected errors and made many useful suggestions and amendments, which have been incorporated. It would have been a poorer document without his assistance. Roy further gave me kind permission to reproduce his excellent electrical notes, for which I am grateful.

The systems are not difficult and can be broken down into subsystems making it straightforward. There is a downside though, breaking down the systems and simplifying the wiring means interaction between systems is not shown and this can be a factor in the source of a fault. That stated; an understanding gained on how a system's intended to function, should give assistance as to why it's not and be a good place to start. This is a pre-reader before diving into one of Carl Allison's wonderfully clear and colourful wiring diagrams to see how it's wired in the real world.

There are modifications that can be made to improve the reliability of the systems. Possible improvements I'm aware of are described after the circuit explanations.

Formula and theory are avoided as much as possible. This article is based around an LM 1000 but a lot of the Tonti Guzzis are pretty similar. Some of the symbols used are not the standard shapes used to denote these devices within schematics or diagrams. I used Excel and it's a bit limited in the shape selection department. All of the components should be clearly labelled though. The usual caveats apply; any work done is at your own risk. I'm not responsible for damage or injury that results from this guide, it is just that.

Electricity is on the bike to

1) Provide power to start it, via the battery, and distribute power to the other circuits as required (I call this the CORE circuit)

2) Make it go by igniting the mixture, via the spark plugs (The IGNITION system)

3) Power all the stuff on a modern(ish) bike; lights, indicators, starter etc: (The ACCESSORIES system, this system is then further broken down into subsystems, more of that later)

4) As all this stuff uses up electricity, some way of topping the electricity back up is required (The CHARGING system)

General Notes

I won't cover the weird and wonderful world that is electrical DC theory there are many articles on the web covering the basics better than I ever could. If you already understand Ohm's Law (V=IR), the formula for DC power (P=VI) and the difference between series and parallel circuits, your onto a flyer. If not you should still be able to understand everything here.

There are a couple of basics that seem to be the cause of recurring confusion and these are the use of the frame and engine as a return lead and how a relay functions.

<u>Use of the Frame & Engine as a "Return"</u>

As most metals are good conductors the motorcycle frame (chassis if you use the President's English) and engine are used in place of a wire going back to the battery to complete a circuit. The battery negative terminal is clamped to the frame and the wire which would have had to go back to the battery is attached to the frame locally to the device, this could be a bulb, switch etc: This reduces the amount of wire required and simplifies the system. It can be thought of as a big terminal block. You'll hear this wire called negative, return, ground and earth, it's all the same thing. Occasionally it is also very confusingly referred to as common, the term common can also be used to describe the paralleling of circuits, so if you see it be aware it's an ambiguous term. I dislike the terms ground and earth; frame or chassis would surely have been much clearer. Historically some industrial applications used the earth as a return, with stakes literally been driven into the ground. This terminology has been confusingly carried over to automotive applications.

<u>The Relay</u>

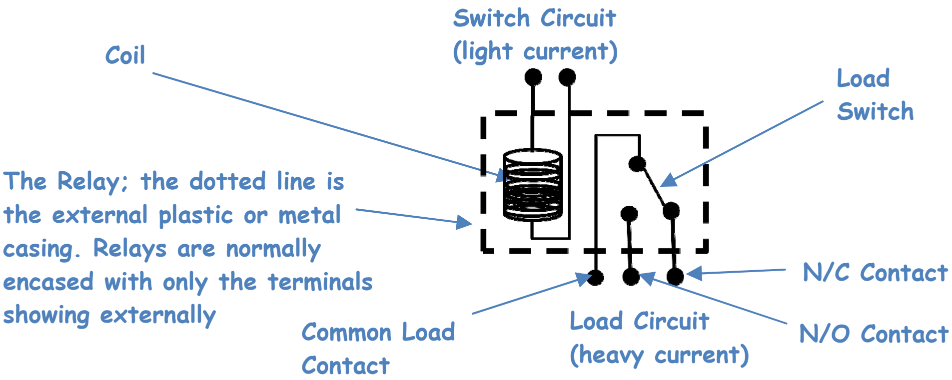
A relay is an electrically operated switch. Its most commonly used to do 2 things on a bike; to reduce the voltage drop in a circuit or/and to operate a heavy current device with a device only capable of supporting a lighter current.

Reducing voltage drop can make devices work a lot better, headlights are a good example, if wired direct from the battery they become a lot brighter, than if the supply has to battle its way through umpteen switches and connectors, each of which will individually reduce the voltage a little bit.

The reason for operating a heavy current device using one only capable of supporting a small current is size and ease of use, a good example is the starter button on the switchgear on the bars. Without relays it would need to be a lot bigger making it heavier and more awkward to use (and look shit too).

Relays are used to also provide a myriad of other functions; two that may be of passing interest are circuit isolation (want to switch something at 12V from 5V electronics?)

and basic logic functions (want something to switch on automatically when some other conditions are satisfied?). These are rarely used on bikes but can be useful.



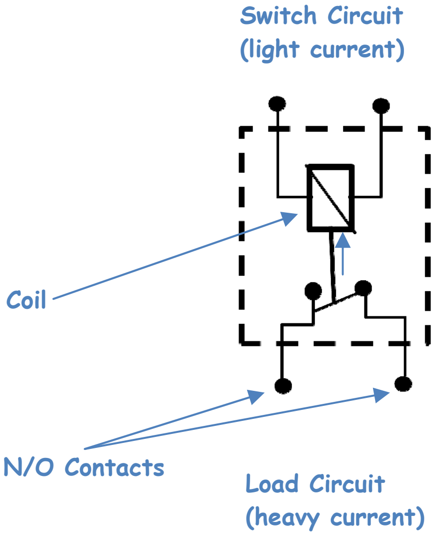
The top 2 connections are wired to a coil. When a small current is applied to the coil it becomes a magnet and the load switch is pulled towards it. The load switch then flips over from being closed on the N/C side to closed on the N/O side (read on and it's explained).

Relays only have one coil but can have one or multiple switches on the load side. You'll often see the contacts of relays referred to as N/O (normally open) or N/C (normally closed) or a combination of both. This refers to the bottom (load) contact(s) and determines the contact state when no power is applied to the relay. For example the relay above has a common contact used for either N/O or N/C (on the bottom left), a N/O (on the bottom middle) and an N/C contact (on the bottom right). When power is applied the N/O contact closes and the N/C contact opens.

After correcting me on some misconceptions and putting me on the path to enlightenment; Roy also drew my attention to a numbering convention used on automotive relays. You may come across these stamped on the bottom of the relay, in the instructions or in the circuit diagram.

30 = Positive "Common" side of "Load circuit"
85 = Negative side of "Switch circuit"
86 = Positive side of "Switch circuit"
87 = Switched (or negative) side of N/O "Load Circuit"
87a = Switched (or negative) side of N/C "Load Circuit"

Relays are also often shown schematically in wiring diagrams like this



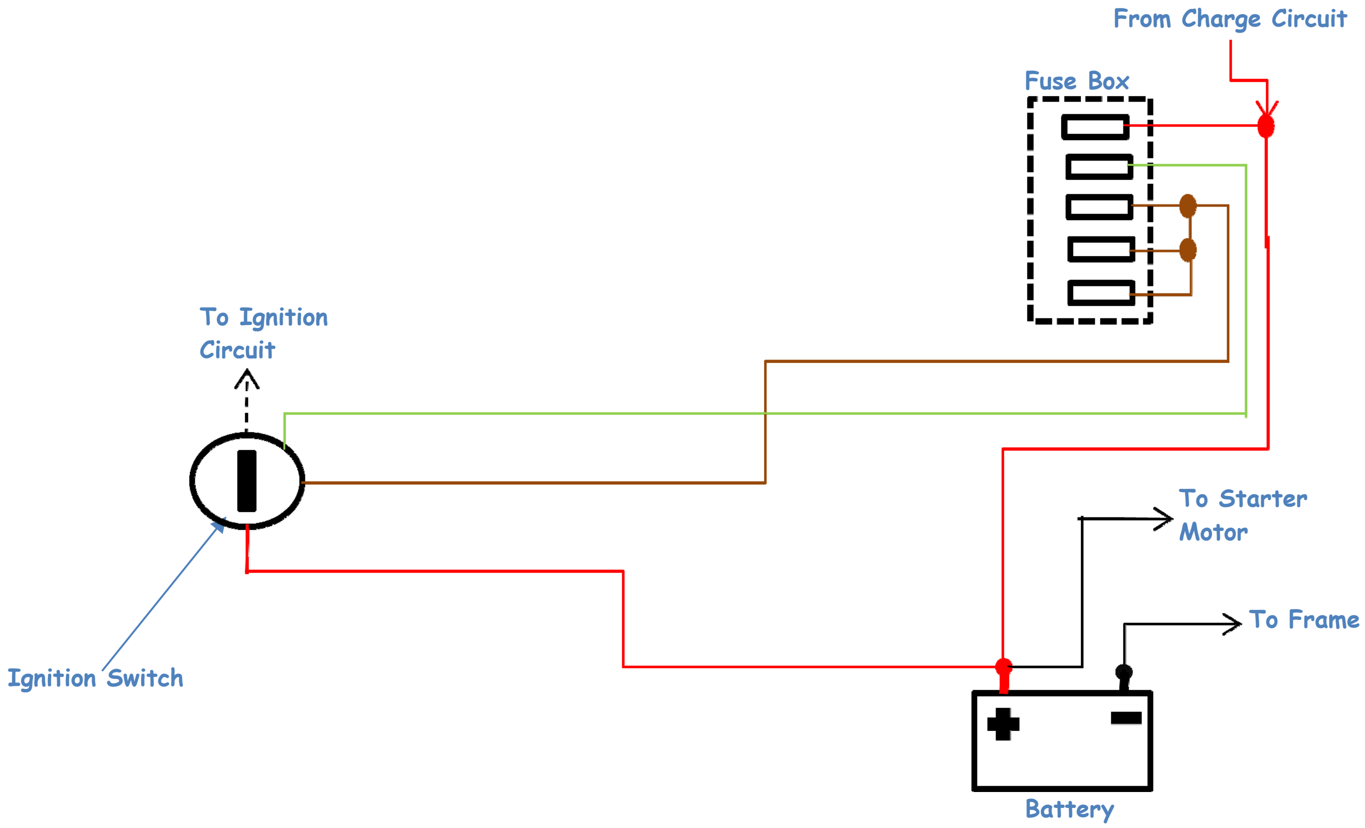
This symbol although commonly used for a relay in automotive diagrams is a diagram of a solenoid. Why does my relay look like a solenoid? Electrical Luigi either couldn't be bothered to draw the coils in the relay schematic "ma handa getta tire-ed" or only had a solenoid shape on his stencil. Fortunately it's not so bad, there is only one solenoid on the bike so when you see this symbol you know it's a relay (except internally in the starter motor where it really is a solenoid, confusingly operated by a relay, but more of that later). A solenoid although internally different from a relay performs a similar function. It's used when heavier currents ("men's current" none of yer "girlie milliamps" here) that would fry a relay, require to be switched. It consists of a coil which has a rod or armature up the centre. When a current is applied to the coil it becomes a magnet and the armature is pulled into the coil. The armature then pulls the heavy contacts closed. Solenoids can have one or multiple coils depending on the load they have to switch. A particularly clever example is used internally in the starter motor, of which we shall see more later.

I'll use this symbol from now on as that's what's used in the wiring diagrams.

The Circuits

The Core, Ignition, Charge and Accessories Circuits

The Core Circuit



The basis of the system; the core circuit is just what I call it in lieu of any other name being commonly used.

When I first traced this out I found it difficult to believe that nearly all of the bike's electrical consumption went through the ignition switch but it does. Depending on the key position electricity is fed from the battery to; none, the park light, or all the circuits (ignition on). This version was taken from the original wiring diagram which utilized a hazard warning circuit which my bike didn't have. Its fuse #1 and is always live being fed directly from the battery, fuse #2 supplies the park lights, fuses #3, 4 & 5 supply everything else.

The incoming feed from the Charge circuit charges the battery and supplies power to the rest of the electrical system. The positive cable to the starter and the negative connection to the frame are heavy cables approximately 12mm^2. The starter needs this directly connected heavy cable because of the extremely high current (in the region of 150A or more) the starter requires. The negative connection needs it because it has to carry all the current from all the circuits on the bike (including that heavy current when starting).

Note that the ignition circuit does not incorporate any form of electrical protection. Electrical Luigi must have finished off the Grappa the night before he dreamed up that configuration.

Modifications to the Core Circuit

Battery

The OEM battery is approx 30 Ah on these old bikes and is a wet cell type. A Lithium Iron (Li Fe) battery is available from Shorai and seems to get favourable reviews; if weight and/or size reduction are the primary goals this is the ultimate, if costly, solution. Some aftermarket regulators and charge systems are not compatible with it, so do some homework. If that's a step too far, AGM batteries, absorbed glass matt are extremely popular, with Odyssey topping the list; I have a PC 680, 16 Ah which works well. When replacing the battery apart from the obvious Voltage and physical dimensions (it has to fit and the leads have to reach the battery terminals), ensure the battery has sufficient cold crank amps (CCA) to turn the engine over. For peace of mind and battery life I wouldn't drop any lower than 16 Ah, but 13Ah capacity has been successfully used by others. A further advantage of both Li Fe and AGM batteries is both are sealed units and don't need a breather. Liquid lead acid batteries can and do discharge acid gas. Over time, battery boxes, seat pans and even the gearbox casing can suffer.

Integrated Fuse & Relay Panels

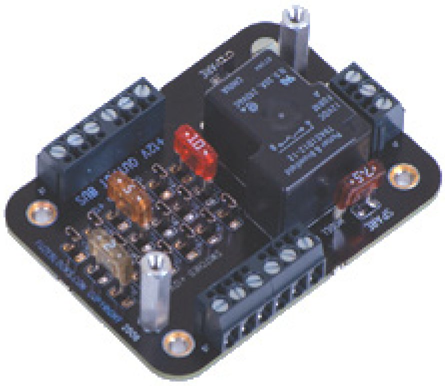
The neatest, easiest way to go if upgrading the whole system is to purchase, or assemble from available components, an integrated fuse and relay panel/box. It is definitely not a cheap route; these items can seriously damage your wealth.

The units take a heavy lead from the battery and feed to the outputs using that lead. The ignition switch wire is only used as a switch circuit. This reduces voltage drops to all the circuits and gives the ignition switch an easier time.

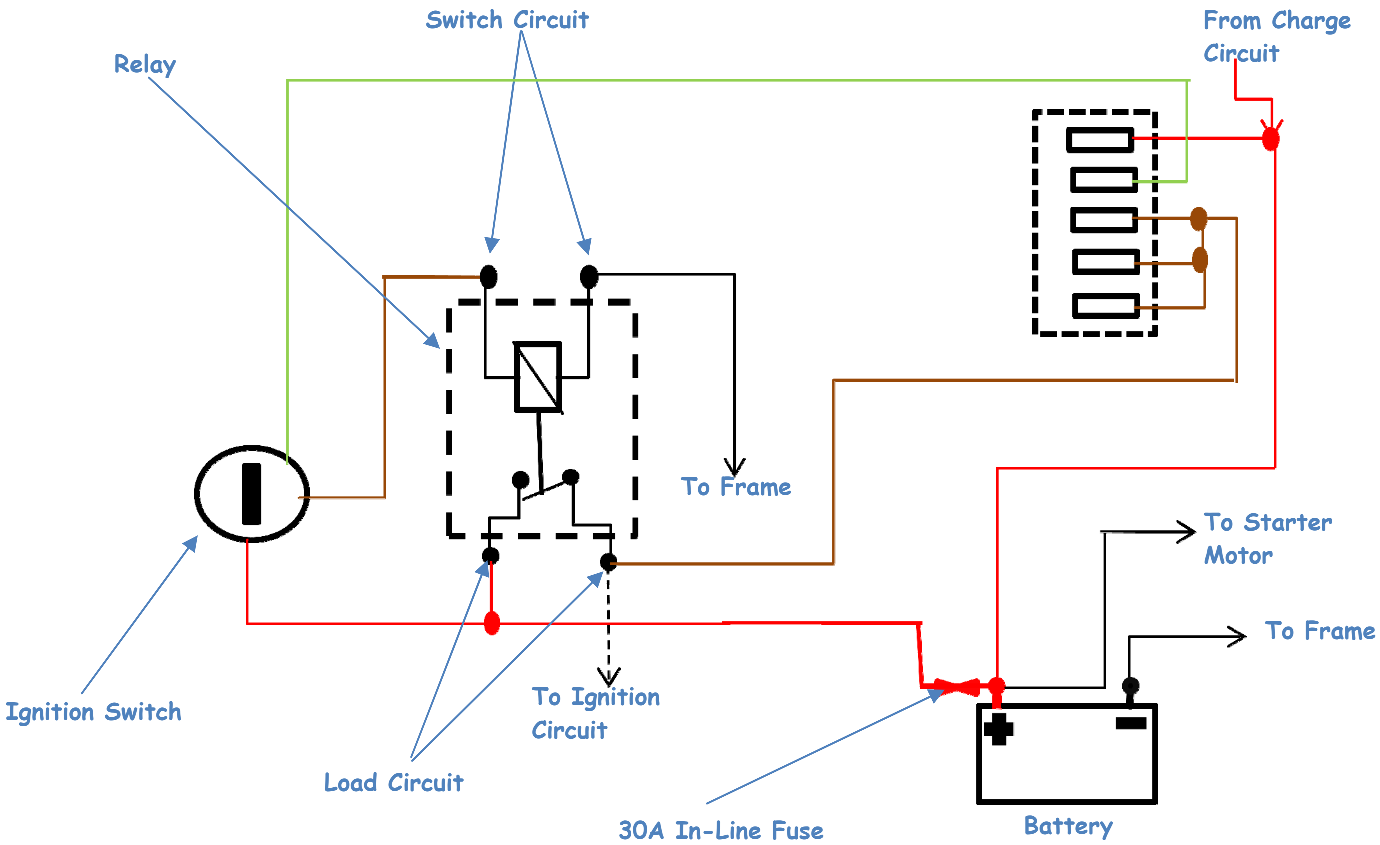
The M-Unit from Motogadget, is an electronic combined circuit breaker/relay unit, which is a very neat solution.

The inputs, on the left, only switch the outputs, on the right, On/Off. The outputs are supplied via the heavy lead going directly to the battery; it's the red cable in the photo. It also incorporates protection on all the circuits.

There are other cheaper integrated units available which don't have as much functionality but are still worthwhile considering. Below, is the Fuzeblock, this uses a mechanical relay for the ignition and fuses for protection. No doubt there are others.



The cheapest way of reducing the current passing through the ignition switch is to purchase a 30A, or greater, relay and wire it in yourself.

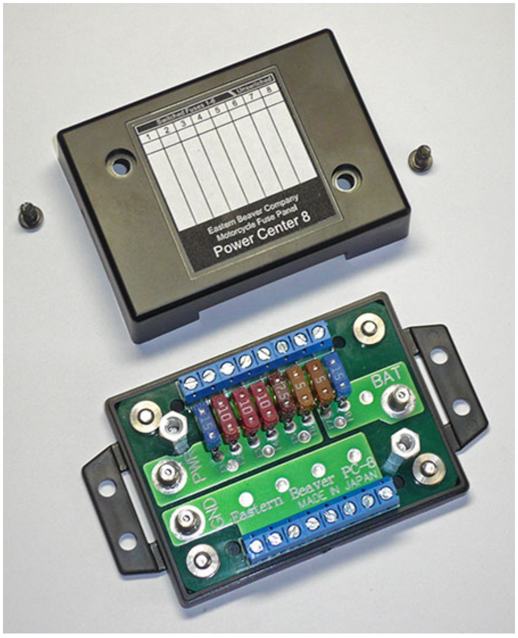


In the above diagram the core circuit has been modified by the addition of a relay and an in-line fuse. The fuse provides protection for the switch, load and ignition circuits.

The red wire after connection to the load circuit of the relay can be a smaller area cable. The ignition switch gets an easier time and there will be minimum Volts drop across the relay.

Fuse Box

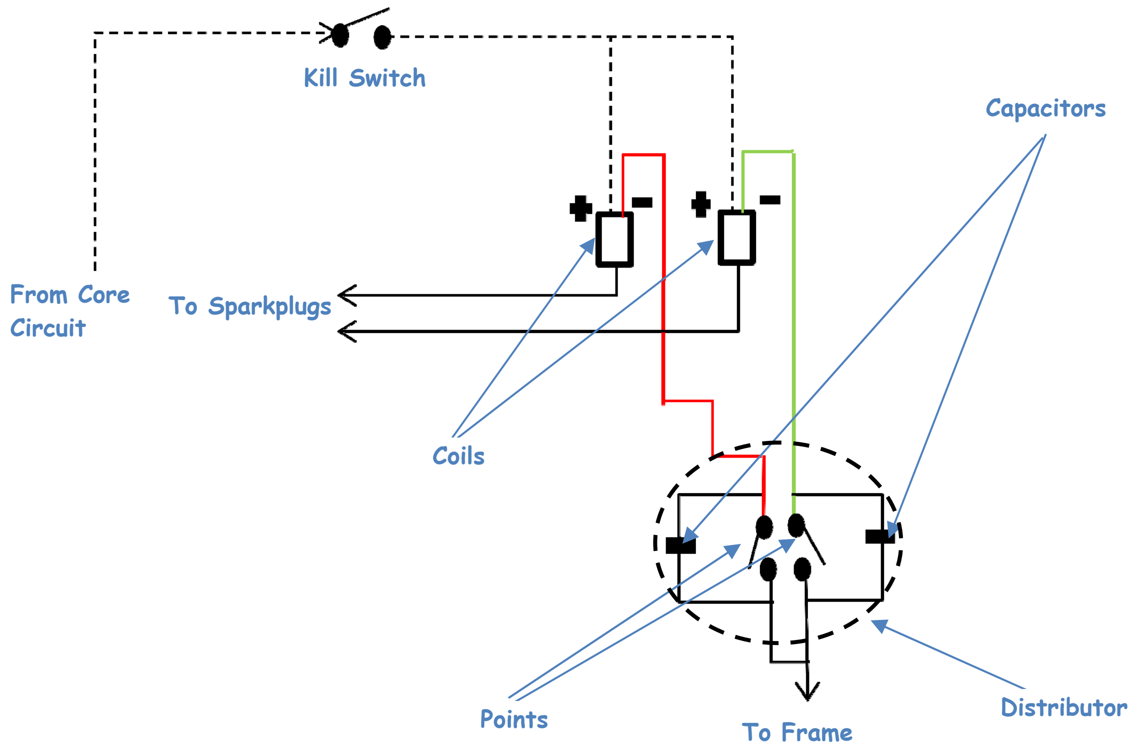
The standard item is plastic of poor quality and often cracks. There are many options, 2 of my favourites are the Power Center 8 from Eastern Beaver and the AP-2 from Centech. Both are not plastic, have split inputs so they can accommodate switched (only live when the ignition switch in "On") and unswitched (always live) inputs. They also have grouped "return" terminal blocks so "frame return" wires can be grouped at the box. Whatever you decide I would recommend a box that uses blade fuses either standard or micro and stay clear of the older Euro or cartridge type.



The more separate fused circuits the better, there is no downside, providing it will physically fit. Each fuse has to supervise fewer circuits, should a fuse blow fewer functions are lost and it simplifies troubleshooting.

I'd also introduce a 30A in line fuse at the battery; this gives extra protection and costs virtually nothing.

The Ignition Circuit



A source of much mumbo jumbo. It's actually not that complicated & the trick of the system is due to the way electricity behaves when it's forced through a coil. The system consists of the kill switch, which can isolate the supply to the system, the coils which generate the high voltage spark and the points which are nothing more than high speed switches.

With the ignition on and the kill switch closed the coils are fed 12V from the battery, the points are closed and a current passes through the coils and they charge up. This is called the "Dwell Time" or "Dwell Angle" (expressing it as an angle is technically more precise as the time the coils get to charge will vary with the revs). The appropriate set of points start to open just before ignition of the fuel mixture is required. This is done via a cam in the distributor, which is driven off the end of the camshaft and is travelling at half crankshaft speed. There are also mechanical bob weights to alter the ignition advance.

When the points move the magic commences. As the points start to open, the resistance in the circuit increases; it gets more difficult for the current to pass along the circuit as the air gap, between the points' contacts gets bigger. The coil tries to maintain the circuit by discharging and the voltage inside it starts to rise (it's a fundamental of the way electricity behaves in a coil). Inside the coil there are actually two wound coils of wire, a primary connected to the low voltage side (the circuit that gets charged) and a secondary (connected to the HT cable and sparkplug). The secondary has many more turns of wire than the primary. As the voltage in the primary rises it also rises in the secondary but at a much higher voltage, the more turns in the coil the higher the voltage will be generated. The relationship between the primary and secondary windings at this point is akin to a transformer. Eventually the secondary has a voltage so high it's able to jump the air gap across the sparkplug to the frame resulting in a spark that ignites the mixture. The points close as the cam turns and the whole cycle starts again.

The capacitors (aka condensers) damp the higher voltage produced on the low voltage side to reduce arcing across the points and prolong their life. On several ignition systems, the capacitors can play a part in spark generation with the capacitors and coil forming a resonant circuit. The details of its workings are beyond the scope of this article and the consensus is that this is not the case in the Guzzi ignition circuit. If, however, fault finding a weak spark on a mechanical system and no other defect can be traced, it may just be worth replacing the capacitors to check.

Don't leave the ignition switched on with the engine stationary for long periods.
If you do need it on to troubleshoot something, switch off the kill switch to open the feed to the coils. As can be seen the coils are "switched on" that is, have a current passing through them, most of the time and are only "switched off" when a spark is required. During the time they are switched on they can draw a relatively high current. Depending on the coil primary resistance, current draw can be up to 6A, per coil. If the coil is left "switched on" for a long period it will overheat and burn out, they are designed for intermittent, not continuous current flow. Having them powered without the engine turning causes them to heat up and does them no favours whatsoever.

Coil resistance generally refers to the primary circuit and is a very low value, usually between 2-6 Ohms. The lower the resistance the faster the coil will charge, but the more current it will draw. There are other considerations but as a rough guide this why coils are made with different resistances. This is also why some ignition systems recommend a specific coil resistance or a range of resistance. Too low and the coil may draw more current than the system can handle and burn out, too high and the system may not give the coil sufficient time to charge up.

A part of the system not discussed so far; Advance (and Retard). As I don't have a mechanical points system my understanding of the bob weights are limited. I do know they are held by springs which control the amount of advance and as the engine revs increase the bob weights fly out (like a Watt fly ball governor seen on steam engines)

Advance is required because in the real world the spark does not occur at TDC but a short time before TDC to allow time for the mixture to start to burn and the flame front in the cylinder to build and spread. The time taken for this is expressed in degrees of crankshaft rotation. Referring to this fixed time; applicable at idle and just beyond, this is Static Advance, the spark is being advanced in the cycle (earlier than in the “ideal” case).

As this process is a function of fixed time the faster the engine is turning the earlier it has to start, think about it. This is Dynamic Advance and progressively increases the faster the engine turns, until at high RPM (circa 6k or so on the Guzzi), when altering it further has negligible effect. This is Dynamic Advance.

Static Advance + Dynamic Advance = Total Advance

Depending on the state of tune and engine type the advance curve can alter quite a bit and has a dramatic effect on engine performance. Take this from one who ran a Lemon on a T3 curve (it was stupidity not an experiment) for a short while. The engine ran rather poorly is the politest way I can think of to express the performance.

Modifications to the Ignition Circuit

Electronic Ignition

This can generate heated debate. Many insist the mechanical system is superior and electronics should be avoided at all costs. Others prefer an electronic unit believing just the opposite. I have an electronic system on mine but it all comes down to your personal belief system.

Ignition systems are, generally inductive type, capacitor discharge is very rare and usually reserved for racing. There are many systems available from the ubiquitous Dyna to the lesser known like Sachse, Myign and many others.

<u>Trigger & Spark; Where & Where?</u>

Most systems can be grouped by 2 distinct functions.

1) Trigger(s) and Sensor(s) Mounting Where? – Distributor or Crank

    a. Distributor type installs into the space occupied by the OEM points system. This means the rotor completes 1 rev for every 2 crankshaft revs (One rev per engine cycle).
    b. Crank type installs onto the end of the alternator rotor and turns at crankshaft speed (Two revs per engine cycle).

    In theory the crank type should be the more accurate as there will be no backlash from the timing chain and distributor drive system. The downside is crank systems will be wasted spark.

2) Spark Type – Normal or Wasted.

    a. Normal; The plug only sparks once per engine cycle
    b. Wasted; The plug sparks twice (or more) per engine cycle

    Normal is the preferred solution, there is no advantage in a wasted spark (some claim there are, but the arguments are specious) and there can be serious downsides. Depending on which camp you fall into this is the "Seed of Satan" or "full of sound and fury signifying nothing". There are wasted systems that are perfectly acceptable. It all depends where and how often the wasted spark is occurring.

3) Wasted Spark – Where?

Cutting to the chase, when does the wasted spark(s) occur in the cycle?

a. Wasted spark occurs when the opposite cylinder requires a spark for ignition. The LH cylinder's wasted spark occurs on the exhaust stroke, the RH cylinder's wasted spark occurs on the induction stroke. The latter can lead to the mixture igniting during induction, the burning mixture flows through the open inlet valve and back into the carb; aka blowback. During normal running it's generally not a problem as the burning mixture will just be drawn back into the cylinder, although it will spit and miss a beat. If however it occurs during starting, the engine will not be turning quickly. The burning mixture can ignite the fuel in the float bowl and your goose can be well and truly cooked or even roasted. Usually seen on a double trigger, single sensor system.
b. Wasted spark generated 360 degrees from when it's required. This means the wasted spark is generated near the top of the exhaust stroke. Although the inlet valve will actually be open there will be negligible mixture in the cylinder and the spark has no effect. Usually seen on a single trigger, double sensor system. This is the system I have on my bike.

I don't draw any conclusions; these are just the facts as I know them.

<u>Coil Compatibility</u>

When replacing the system, are coils being purchased with the system, separately from a different vendor or are the existing pair being kept?

It's probably no longer a consideration, but check the coil voltage required for the system. Lucas Rita used 2x6V coils in series, this was an exception, but there is no harm in checking.

Ensure the system is compatible with the coil resistance, most will state a compatible range, although some will just state a fixed coil resistance. Usually this will be the primary resistance. If it's not stamped on the coil, the primary resistance is measured across the 12V terminals (not the terminal for the HT lead) and will be a low value somewhere between 2 and 6 Ohms. I touched on coil resistance earlier in the system description. Although only available with Cliff Jefferies "MyIgn" (that I know of) this system is capable of altering the dwell time via DIP switches this allows the system to work optimally with different primary coil resistances.

Advance Curves

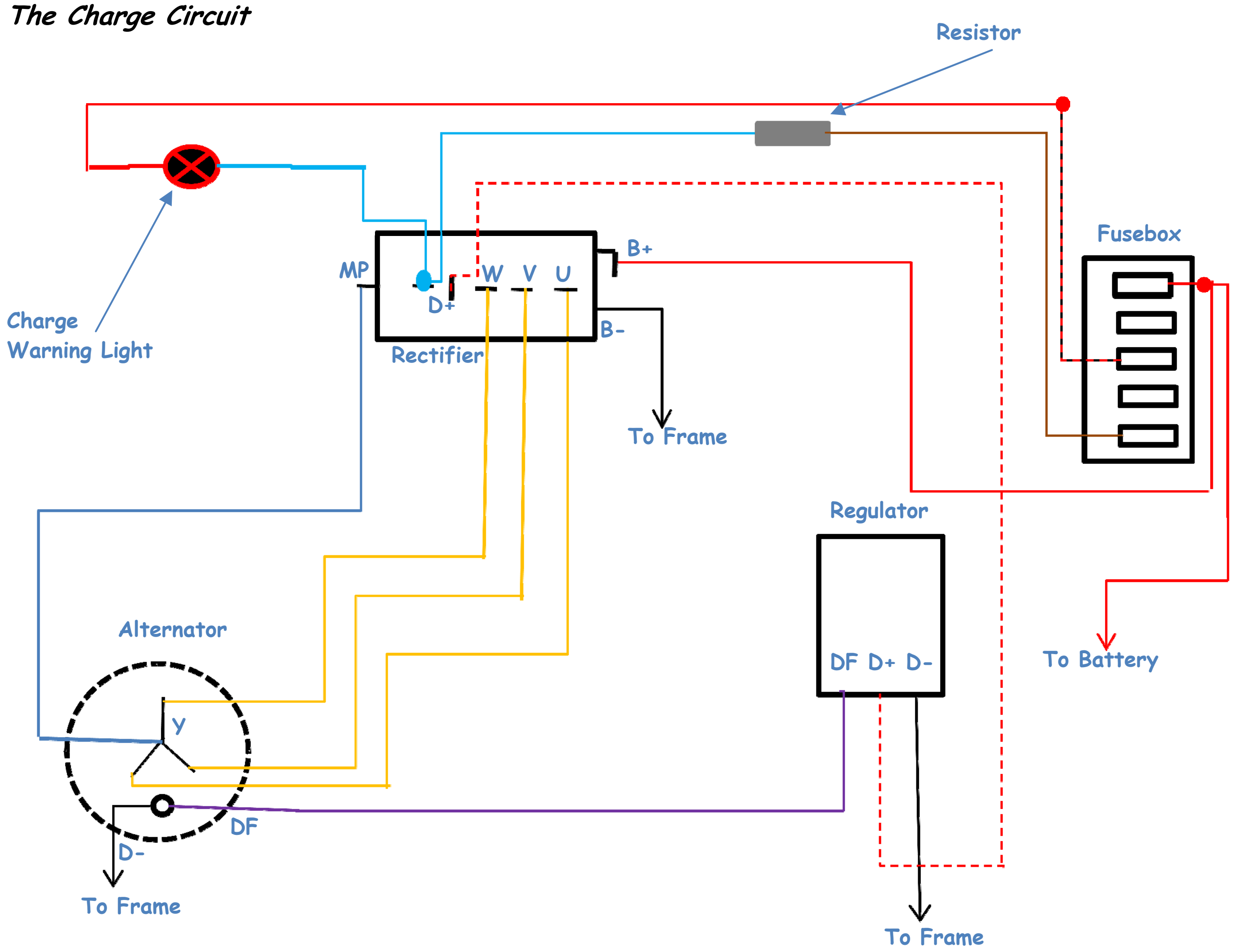
Review how the system handles advance curves. Some come with only 1 curve, which is programmed for the model of bike. Others have multiple curves varying from 3 to dozens which are selectable through either a switch on the electronics unit or via software. Ensure you choose a unit which has a suitable curve, for now and also for future if any tuning or dual plugging is on the horizon. The static and dynamic advance the engine requires should be in the manual.

Coil Replacement

This can generate a lot of grief. I've already touched on compatibility and primary resistance. If the bike is in a high state of tune it may benefit from a performance coil otherwise a normal coil should be fine. On Guzzi's low primary resistance isn't really a requirement.

I've seen enquiries about replacing the 2 coils with a single unit. This would only work on a wasted spark system, where the wasted spark occurs when the other cylinder requires a spark; not a particularly bright idea in the first place. A single coil can only make the system even more unreliable as there is little dwell time between the LH & RH cylinders firing, so the coil may not have sufficient time to fully charge for the RH cylinder. A second coil also has the added bonus of allowing you to limp home on a single cylinder should a coil failure occur.

The Charge Circuit



The charge circuit consists of 3 major components, the Alternator (aka Generator), the Rectifier and the Regulator. This is for the Bosch 3 phase alternator, Guzzi later moved to a Saprisa alternator which is a bit different.

Unfortunately it's not practically possible to produce DC (direct current) which is what the bike runs on. The Alternator produces AC (alternating current). The electrical energy it produces is made by converting shaft power from the crankshaft into AC electricity. AC is not compatible with the rest of the systems on the bike and has to be converted to DC via a rectifier. The regulator's job is to control the quantity of electricity produced, if it wasn't there the unregulated Voltage would fry all the other components including the battery (if you've ever sampled Scottish cuisine you'll know frying comes as second nature). There are descriptions of how the system works on the web if it's necessary to understand it in detail.

The alternator consists of 2 parts

1. The rotor; the bit in the middle that rotates, has a coil wound around it and is attached to the crank.

2. The stator; a set of 3 stationary coils, set around the outside of the rotor, where the electricity is produced.

The output of the alternator can be controlled by the current fed to the rotor coil. The more current it's fed the more electricity will be produced, also remember it's not for nothing. When producing more electricity it's taking power from the crank which would otherwise go to the rear wheel, although it's generally considered negligible. The system can't support loads that would dramatically impact on the bike's performance. Switching the headlamp on at idle will sometimes result in the revs dipping a little, this is a direct manifestation of the phenomena.

The current fed to the rotor coil creates a magnetic field, that's why it is sometimes referred to as the field winding. The positive input to it is fed from D+ on the alternator casing via carbon brushes to the rotor. The second carbon brush on the rotor is for the negative side of the field winding. On the casing the negative field terminal D- has a lug on it for a wire, but is not connected to anything as it has a path to the frame via the stator casing.

The output of the alternator is fed to the rectifier via the 3 heavy yellow (shown as Orange) wires, W,V, U referred to as phases. These can be connected in any order at the generator and the rectifier, it doesn't matter. The negative side of the stator windings is the centre of the Y in the schematic and the 3 coils are joined together at that end. This is called the Y connection or star point. Due to AC being produced and to maximise the alternator output this is not connected to the frame but instead is used inside the rectifier as part of the AC to DC rectification process, it's connected to the MP connection on the rectifier.

The output from the rectifier is fed to the battery and the actual physical connection is at the fuse box. Although shown on the diagram in reality the negative connection B- is not required on the rectifier as it's fed to the frame via the rectifier casing.

The rectifier also provides the feedback line to the regulator. The regulator governs the current fed to the alternator rotor's coil to control the field, in turn, keeping the DC output voltage, from the stator and rectifier, within acceptable limits, usually somewhere around a maximum of 14.2 volts. Output will vary with engine speed, the higher the revs the more electricity can be produced. The regulator negative connection does require a wire from it to the frame at D-.

A peculiarity of this system is the use of an electro, as opposed to a permanent, magnet on the rotor. By using an electromagnet (the hint's in the "electro" bit), the magnet can be made very magnety or less magnety depending on how much DC electricity is sent to the coil on the turny bit. This controls the quantity of electricity made in the non-turny bit. That's fine when it's all spinning and humming. The Alternator makes squiggly electricity, the rectifier irons it straight and a smidgen of straight electricity can be fed back via the regulator to keep the electromagnet, magneting. But what about when it's stopped? If the electromagnet doesn't get DC electricity it's just a lump of copper; no magnet, no electricity and the system can never start. This is where the charge warn light and resistor comes in.

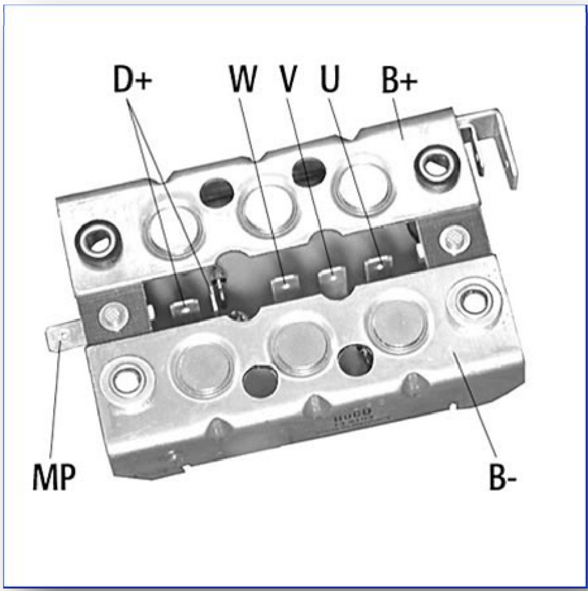
When the ignition is switched on the charge light illuminates as it has a path to the frame via the regulator and the coil in the rotor. The bulb and/or resistor allow a small current to be fed to the rotor coil to magnetize it (both the bulb and resistor limit the flow of current to a low value). When the engine is turning the whole system becomes self sustaining, as previously explained. The rectifier feeds DC electricity to the regulator and in turn the electromagnet on the rotor. The voltage at D+ balances the voltage being fed from the battery and the bulb has the same voltage on either side of it. As the voltage is equal on both sides of the bulb no current can flow and the light goes out.

Some words about that resistor. It's shown on the wiring diagram, however when rewiring my bike I never found it. It certainly makes sense; if the charge light failed it would allow the charge system to start.

It would be a good idea to check if you have that elusive resistor. With the ignition off, remove all the fuses and check the resistances individually between the fuse output and D+ on the rectifier. There should be one fuse that will return approx 120 Ohm, that's the bulb. Only one other should return a value, approx 80 Ohm, if it does then you have the resistor. If all the others are open then you don't.

From all of the above it should be pretty obvious how important this little bulb is, without it the charge system might never start (let's look on the black side and assume the bike doesn't have that resistor). Sometimes the system will work without the light due to residual magnetism in the field being enough to get the system running, but if the bulb is burnt out and not replaced your playing electrical roulette. If the charge system does not start and the bulb is burnt out; you'll get no warning, the battery will run the bike for a while but then it will probably start to misfire, followed, in short order, by stopping altogether, at the most inconvenient place possible, and you are royally stuffed.

Below is a picture of a rectifier with the connections labelled (although B+ is the top half of the casing it's insulated from the frame and the actual connections utilize the double lugs on the RHS side of the picture)



Similar to the ignition system and probably on a par with it as a source of mysticism. The charge circuit generates a lot of enquiries on the fault finding side. Usually kicked off by the dimly glowing charge light. If it has always glowed dimly at idle especially if the idle is low, I wouldn't worry about it, as long as it goes out when the revs start to rise above 1500 rpm. If it suddenly starts to glow dimly, or does it at higher rpm or worse still, starts to glow brightly, it's time to troubleshoot.

There are quite a few guides available including a nice little flowchart produced by Electrosport. However as a starter the first things to check are the obvious, are all the connections in place, tight and clean. Are all the connections to the frame, including the battery negative, clean, tight and free of corrosion? Remove them all clean them and the mating surface underneath. Next thing to check is the brushes on the alternator, ensure they are not worn, the springs are good and when the brushes are lifted off the slip ring they bounce back onto it freely with no sticking. Check the slip rings (the copper rings the brushes sit on) are clean and not covered in dirt and/or muck. After that it's time to get out the multimeter for more involved fault finding. If you need to do this before starting more advanced troubleshooting ensure the battery is in good condition, will hold a charge and has been fully charged with a battery charger. If you don't then you will obtain misleading information from the tests and run around in endless circles until exhausted and put on suicide watch by your loved ones.

Modifications to the Charge Circuit

Alternator

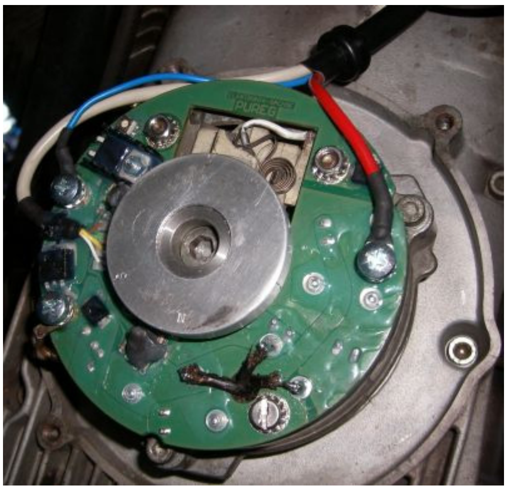
Unless there is a particular reason for requiring more grunt from the system; frequent short journeys; to the shop for tabs and a paper or heavy draw accessories; aircraft landing lights, heated underpants etc: I'd be tempted to just keep the standard system. Granted it's not in the same league as a modern bike but in its time it was considered more than adequate. Providing the bike is used for reasonable distances and the revs are kept above 3k it should be up to the task. An alternative I'll touch on later is lightening the electrical load mainly by installation of more efficient lighting. If less is going to power the consumers on the bike more is available for charging the battery.

There is a complete upgrade kit which includes rotor, stator and regulator/rectifier from Enduralast and very nice it looks to. It is eye wateringly expensive. I have no experience of it, but don't doubt its effectiveness, rotor and stator construction are not exactly rocket science.

Regulator/Rectifier

There are many products available to replace the existing components. Some with superior performance at lower revs which is where the standard system is a bit weak. Enduralast, Electrosport, Newtronic, Sachse and others all offer electronic regulator rectifier boxes which are pretty much plug and play. If strapped for cash off the shelf components can be used to replace the OEM parts and there is an article on Guzzitech DK by Pete Roper about this very topic.

Sachse also offer a combined sealed board assembly which installs onto the end of the stator. I have this unit on my bike, it has Schottky diodes which are apparently more efficient at lower revs. I have never bothered to measure the voltage Vs rpm, but I've never had any problems. The only downside is it requires soldering the stator connections to the board and installing new brushes with the board in place may be a bit tricky.



Considerations at time of purchase

1) The performance of the unit both at low and high revs, get a graph of voltage and current Vs rpm if possible.
2) Unit regulation, this is bit obscure but I am aware of one of these replacements which, due to design, placed a higher load on the alternator which could lead to premature alternator failure.
3) Does the unit keep the charge light? A lot of these units dispense with the charge light. If there is no other monitor of the electrical system on the bike you lose the final warning, of something going awry. Installing a Voltmeter is ludicrously simple and will give more information than the charge warn bulb, but the final choice is yours.

Charge Warn Light

If the system is being kept standard and it's not already installed; an 80 Ohm 2 Watt (or larger power rated) resistor in parallel with the charge lamp will allow the charge system to be "flashed", or started, in the event of a bulb failure. Refer to the charge system circuit diagram.

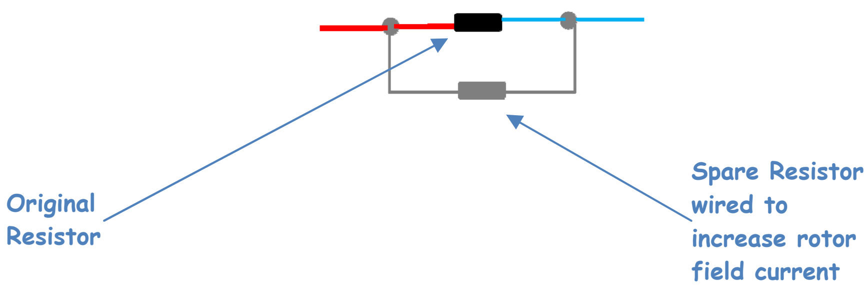
The charge warn bulb can also be replaced with an LED, with either the standard system or replacement aftermarket rectifier/regulator, that retains the charge warn light, refer to Modifications to the Warning Lights Circuit.

Although not applicable to most, I replaced the bulb with a 100 Ohm resistor as I don't have a suitable location for the bulb on the dash. I substituted a simple 3 LED Voltmeter instead. I plan to install a second resistor alongside the existing to increase my options.

1. Provision of a spare resistor ready to wire.

2. To increase current to the rotor field if experiencing starting problems with the charge system (aka "flashing", which conjures all sorts of connotations).

   To do this the 2 resistors would be wired in parallel.



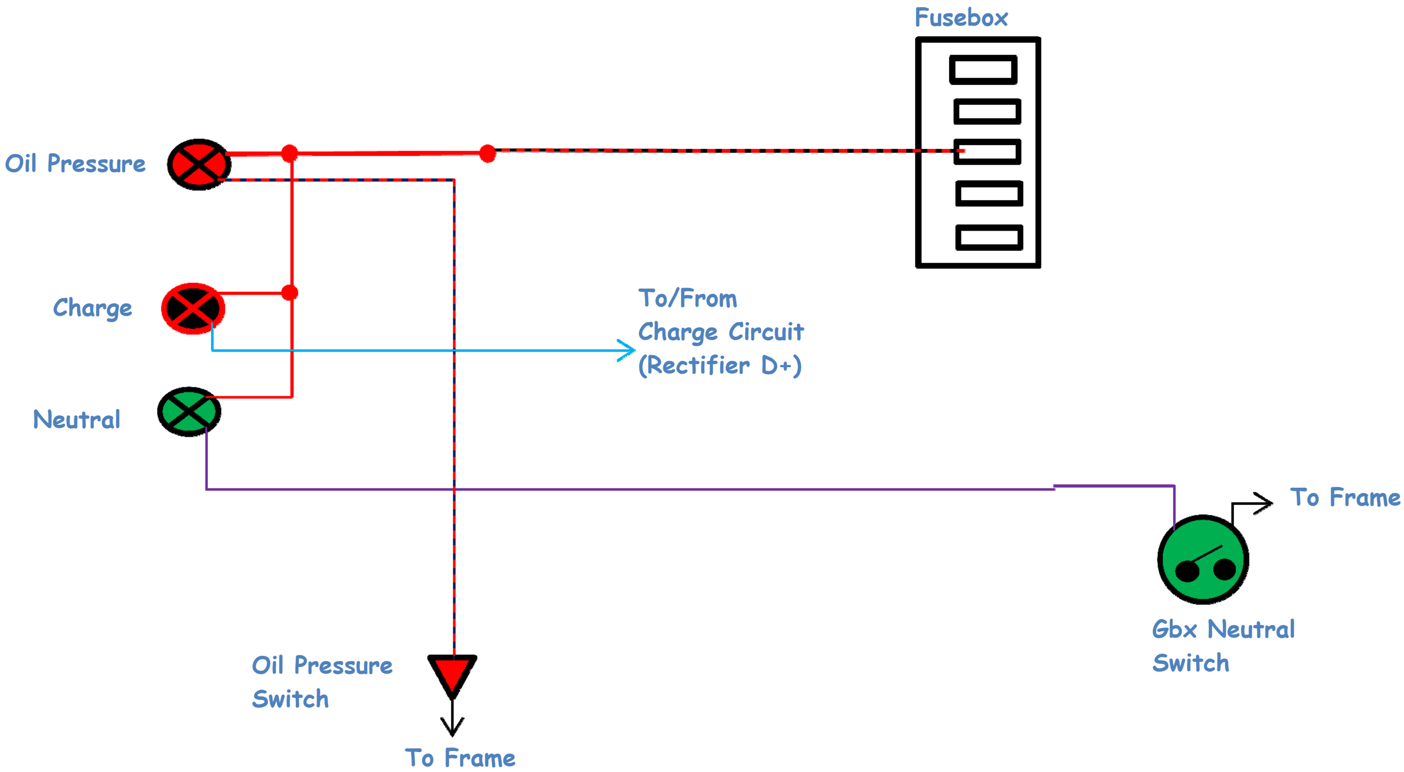
The Accessories Circuits

Rather than try to place all the circuits into one diagram, I'll break them down individually.
The individual circuits can have interaction between them, so this way is not perfect, but in most cases it should be sufficient. It doesn't take anything away from how these circuits operate but does make it a lot easier to understand. The problem with a wiring diagram is not complexity, in essence the individual circuits are straightforward. It's simply too much information concentrated on one sheet. Once the individual circuits are understood, the full Monty wiring diagram becomes a lot clearer.

The subsystems I'll cover are

The Warning Lights Circuit (specifically Neutral, Charge & Oil Pressure)
The Lighting Circuit
The Turn Signal Circuit
The Brake Light Circuit
The Horn Circuit
The Starter Circuit

The Warning Lights Circuit



A supply is taken from fusebox #3 this is energised when the ignition is on. The wire changes colour at the multi-connector from black/red to solid red and is paralleled to all 3 lamps.

As explained earlier the Charge lamp extinguishes when the "rectifier" sends a voltage to the bulb (blue wire) side and balances the voltage on the "battery" (red wire) side, as long as the alternator, rectifier and regulator are all functioning. The other 2 lamps are termed "switched negatives" meaning the negative side of the lamp determines when the lamp is lit, completing the path to frame. Another way of expressing "switched negative" would be to state a device "downstream" of the component activates it. All other lamps on the bike are "switched positives".

The oil pressure light comes on when the pressure switch completes a path to the frame through a pressure switch at the front of the bike. This has a very low setpoint typically around 2-4 psi. There is no actual frame wire, the switch connects to the frame via its and the engine's casings. As an aside if it ever does illuminate immediately kill the engine and investigate, you have seconds before doing costly damage if the pressure has dropped low enough to illuminate the bulb.

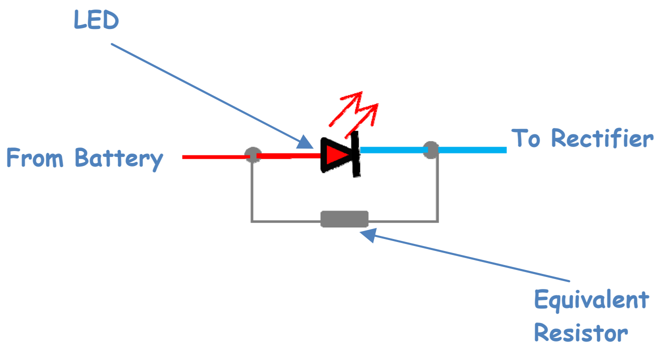
The neutral light operates in a similar manner. In this case the switch in the gearbox is not really a switch in the strict sense of the word, but just a metal plate that contacts a dimple on the selector drum when in neutral (or somewhere in the vicinity of neutral, if you've much experience of this fickle little light). Again it connects to the frame via the casings.

Switched negatives are fine if you ride in the dry. If you're a frequent wet weather rider and the electrical connections are not up to snuff they can induce hysteria bordering on full blown paranoia. The problem is if any water gets into the connections between the lamp and the switch, it will probably result in a temporary connection to the frame or engine and the light illuminates. Neutral is not so much of a problem but it's no joke to suddenly see the oil pressure warn flicker or worse light and stay lit. If you place any value on the engine at all; you'll absolutely freak. It's worth going the extra mile when conducting any maintenance in this area to ensure the connections are well sealed.

Modifications to the Warning Lights Circuit

Warning Lights

As mentioned with monotonous regularity, LEDs can be used to replace bulbs. Ensure the LEDs are the correct voltage rating (12) and if possible match the colour of the warning light lenses. The warning light bulbs for the oil pressure and neutral can be replaced with LEDs, but NOT the CHARGE WARN unless the circuit is modified. The charge warn requires a lower resistance; approx 120 Ohm. A circuit like the one below could be used to install an LED.



The formula to calculate the resistor is

$$Req = V^2/(Pb - Pl)$$

Where

Req	=	Individual Load Resistance required (Ohms)
V	=	Voltage (nominally 12) (Volts)
Pb	=	Power of the original bulb (Watts)
Pl	=	Power of LED replacement (Watts)

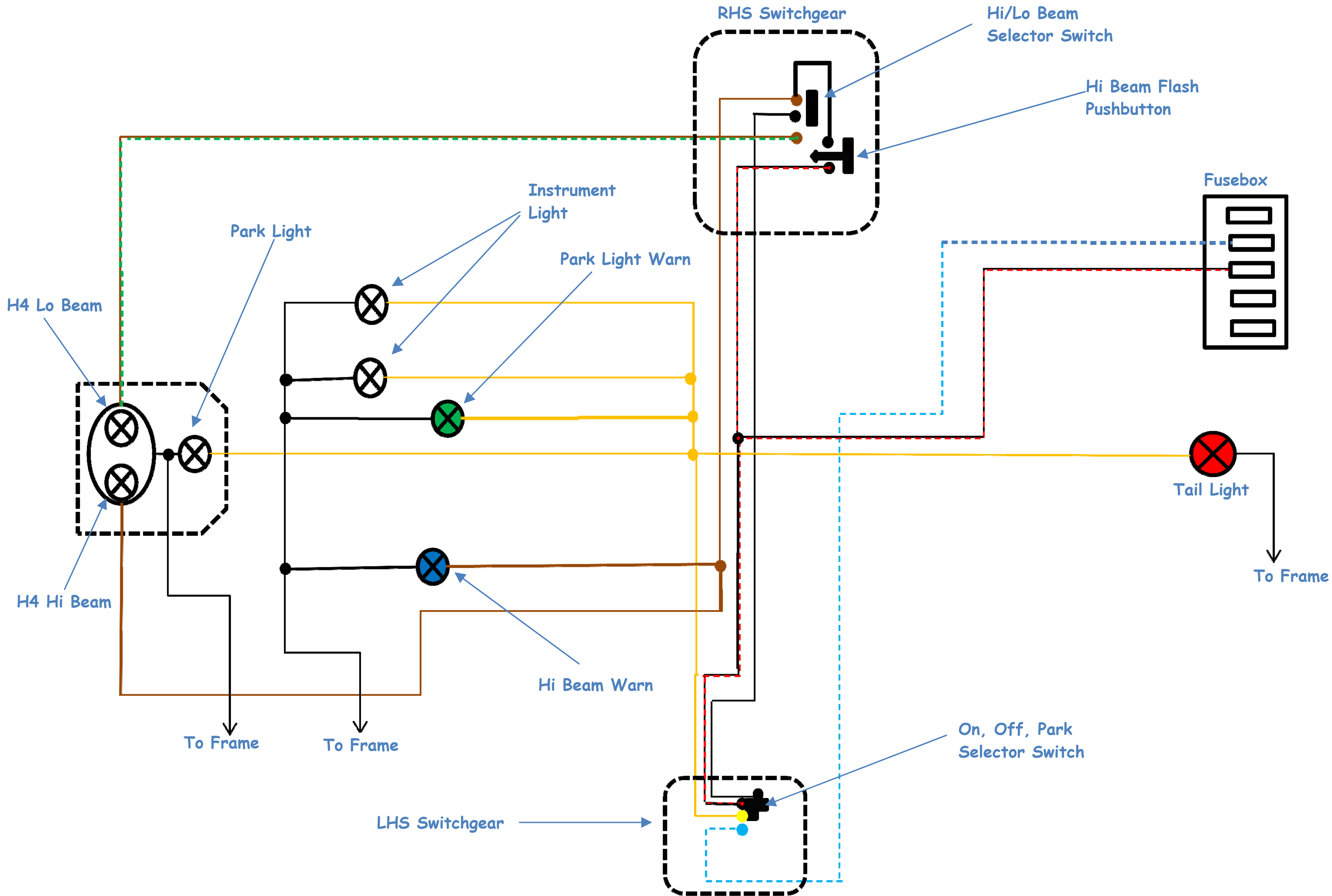
If for example the LED replacement is 0.2W, 144 Ohm is the result, so a 150 Ohm resistor would be required.

For the sake of power rating use the wattage of the original bulb and go up one rating, for example 1.2W original bulb so rate the resistor at 2W minimum.

Oil Pressure Switch

If installing a mechanical oil pressure gauge replacing the oil pressure switch may be a consideration, the quality of the standard component is not the best. I installed a replacement switch with a variable 0.5-15psi setpoint. A higher setpoint setting or switch could illuminate the warning light at idle; leading to every stop light becoming a whole new adventure. Oil pressure can drop to around 10psi on a hot engine at idle.

The Lighting Circuit



The switchgear on my bike is slightly different to the wiring diagram; all the lighting controls are on the LH bar, however apart from that it functions in an identical manner.

There are 2 feeds from the fusebox #2 & #3, if you go back and look at the Core circuit fuse #2 is fed from the ignition switch and is used for the park light (aka running light). Fuse #3 is only powered when the ignition is switched on.

Fuse #2 is fed to the On/Off/Park selector via a blue/white cable. When the selector is moved to "Park" it feeds all the yellow (shown as orange) cables from fuse #2. This will then light the park light in the headlamp, the tail light, the park warn light and the instrument lights (why the instrument lights?). This would also be the case with the ignition switch "On" as the ignition switch feeds fuse #2 in either the "Park" or "On" position. My diagram for the selector switch did not come out as well as intended, with the selector switch in the "On" position the black, yellow and red/black wires are all connected together. In the "Off" position none of the wires are connected and in the "Park" position the blue/white and yellow wires are connected.

When the selector switch is moved to "On" the switch no longer receives a feed from the blue/white cable from fuse #2. Instead it's powered from the red/black cable through fuse #3 (only live when the ignition switch is selected to "On"). This feeds all the yellow wires as before but also the black wire which is connected to the RH switchgear. The black wire is the live feed for the Hi/Lo beam selector switch. In the position shown it's in the "Hi Beam" position; the brown and black cables would be connected. The brown cable then goes to power the H4 headlamp Hi beam filament and the Hi beam warn lamp. If the Hi/Lo beam selector was moved down to the "Lo beam" position the brown wire would be disconnected with the black and green/brown connected together. This would then power the H4 Lo beam filament.

Last but not least we have the Hi Beam Flash Pushbutton. Before I traced it all out it was source of wonder to me, many beers ago, that if I pushed the Flash button on the bars, the light would seem brighter than selecting Hi beam with the selector switch. With the diagram it's easy to see why. The Hi Beam Flash Pushbutton has a supply fed directly from the red/black wire from fuse #3. When the button is pressed it powers the Hi beam circuit and does nothing to the Lo Beam. In short if you push the Flash with Lo Beam on, both Lo and Hi beam filaments in the bulb will receive power and "in a blinding flash" you get both beams at once. For a short flash its fine, but hold onto that button for any length of time and you'll probably overheat the H4 bulb and have to make your way home very slowly using the Park light.

I simplified the return cables to the frame. Although it's all valid, the actual earthing via the connectors on the loom is a bit of a nightmare to trace going from connector to connector to connector. If your offspring like puzzle books, give them a highlighter pen and put them to work. Trust me though this is how it works.

Modifications to the Lighting Circuit

Headlamp

Responsible for a reduction in Interweb performance and clogging of forum hard drives; recruiting more Loo men.

H4 Bulb Replacement

First off, is replacing the bulb with one of the newer improved types. There is endless discussion about these. I'd steer clear of the "Blue" types with increased colour temperature. Increasing the colour temperature above 4300 Kelvin and definitely above 5000 K, will result in less not more light. The colours go from yellow to white to blue to purple.

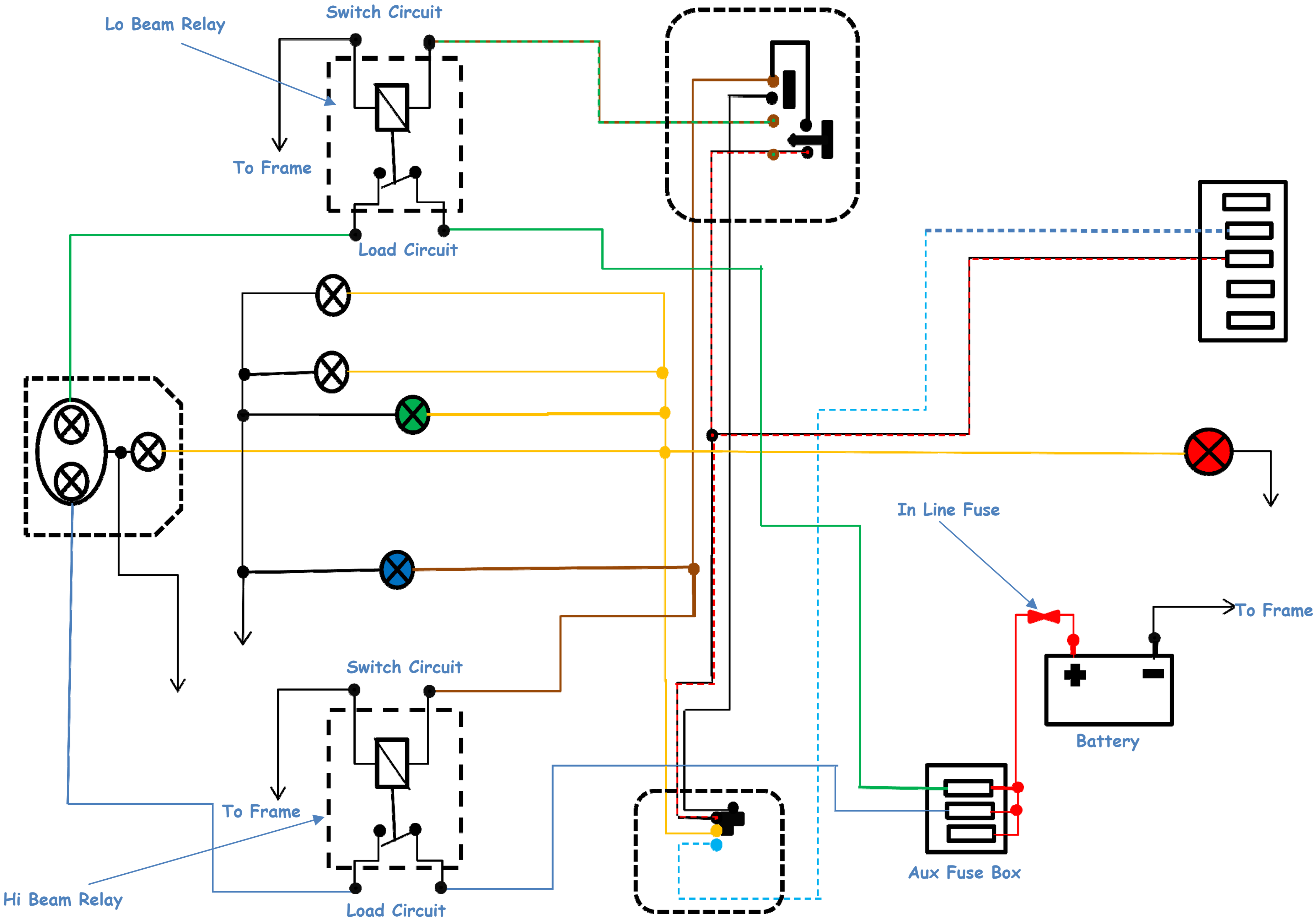
There are H4 bulbs available which will give a brighter light, this is achieved by using thinner filaments. The trade off is bulb life, as the filament burns hotter, bulb life is compromised.

Unless replacing the wiring and upgrading the charge system I wouldn't recommend installing a bulb with significantly higher wattage ratings (5W to 10W should be Ok but not much more) on either Lo or Hi beam. Three things can happen.

1) Melting of the bulb holder, the standard type is nylon although, a ceramic holder can be purchased cheaply.
2) Blow fuses/damage the wiring, through overloading the system. The fuse may not blow (it's heavier rated as it has other circuits to account for). The wiring may become very hot and either melt or just get hot enough to cause embrittlment of the insulation over time.
3) Overload the charge system, this itself won't damage the charge circuit but could cause the bike to misbehave, misfiring etc: or worse drain the battery down and leave you stranded (another good case for having a Volt or Ammeter installed).

Relay Installation

The best modification that can be made is to purchase a specialized relay or relays, or make up a system to run the headlamp through standard relays. This minimizes voltage drop so more volts are at the lamp and it will be brighter. It will also give the switches at the bar an easier time and longer life. Both Sachse and Eastern Beaver can supply nice relays. Eastern Beaver can also supply a wiring kit if it's required.

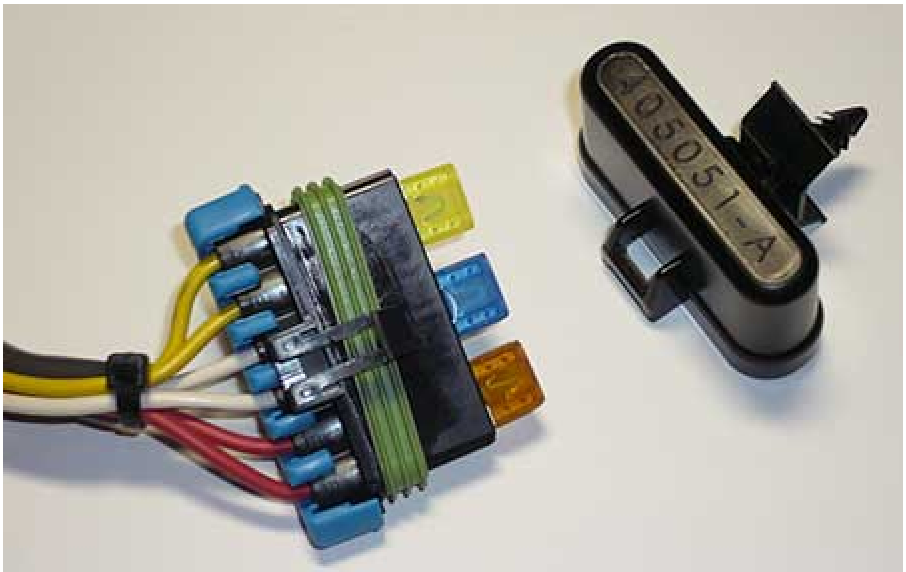


Lo Beam Relay
Switch Circuit
To Frame
Load Circuit
In Line Fuse
To Frame
Battery
Switch Circuit
To Frame
Hi Beam Relay
Load Circuit
Aux Fuse Box

In the above circuit relays have been added to the Hi & Lo beam circuits and an auxiliary fuse box, apart from that it's identical to the original Lighting circuit. The relay switch circuits are activated from the switchgear and then taken to the frame. This reduces the current through the switches prolonging their life. The load circuits are fed from the auxiliary fuse box, the blue wire is the Hi beam, the green the Lo beam. Using heavier gauge wire on the load circuits and minimum 20A relays will reduce the voltage drop and improve the bulb brightness.

The auxiliary fusebox could just as easily be wired using in-line fuses or the main box, providing the feedwire from battery to fuse box is sufficiently heavy cross section. Separate fuses are used to provide the supplies, the same fuse for both is not ideal, a fault would take out both circuits, this way the circuits are not totally autonomous but there is some separation.

Again Eastern Beaver can provide an aux fuse box



<u>HID or LEDs?</u>

The final solution is a technology change. The 2 available are HID and LED. LEDs will in time, become the ultimate solution, just not yet. Currently LEDs, capable of producing the required light, are horrendously expensive and are not as efficient as HID, with the added bonus that HID conversion kits are getting cheap as chips, slight exaggeration, but you get the picture.

High Intensity Discharge aka Xenon lighting. The main drawback of using HID, is beam pattern. Using optics designed for Halogen with Xenon can result in less than satisfactory beam patterns; resulting in discomfort to other road users. Some hate these systems passionately, insisting they should be never be used without self-levelling and custom designed optics. There may also be legislation governing there legality, it's worth checking your local laws to determine if there are any restrictions on their usage. At the time of writing new amendments to UK MOT rules, state that HIDs may result in a test fail if beams are not self levelling. The jury is out on how these rules will be implemented and interpreted.

The advantages are; twice as much light, as a minimum, whiter light and lower power consumption. Bulb life is also longer, there are some caveats on this, more of which later.

The technology is constantly improving and worries regarding warm up time, restrike time, initial current draw, Ballast resistor and bulb life are things of the past. HID uses Xenon gas to strike an arc inside the bulb, there is no filament and the bulb operates at a far higher voltage, in the kilovolt range. When striking the arc there is a heavy current draw but it is of very short duration and modern systems generally have max current draw of 7A or less. Older systems required a lead direct to the battery but again this is now very rare (and in my opinion to be avoided). Bulb life is longer but HIDs are more sensitive to switching and bulb life is generally a function of starts as opposed to hours. When using HID I leave the lamp off until the engine is running steadily and I'm ready to leave. Switching them on right away, having them extinguish or suffer low voltage when starting the engine, then restriking doesn't do them any favours. That said a few do this and they still seem to stand up to the abuse.

Systems available are 35W and 55W typically. The 35W should be more than adequate, will give off less heat and give the charging system an easier time.

To accommodate these requirements the bulb requires control gear to strike and maintain the arc. With H4 kits, the current kits use a single HID bulb with a solenoid operated bulb holder. Hi and Lo beam patterns are obtained by switching the solenoid; the bulb position is deflected, emulating the twin filaments of the original Halogen bulb, the bulb is always lit and beam selection instantaneous with no loss of light at changeover.

Physically there is more equipment, 2 boxes, a power supply and a ballast resistor. There will also be more wiring and plugs; the bulb and holder are also larger. Somewhere will need to be found to mount it all, it won't all fit inside the headlamp shell. Most kits come with a plug which mates with the original H4 headlamp plug, and powers the system. Due to limited space in the shell the original H4 plug and the mating connection have to be installed outside the shell as there is only enough space for the HID bulb and plug.

With the setup I installed (sadly removed until MOT rules are clarified), using a Bosch H4 headlamp reflector, the bulb fitted inside the reflector and the bulb shield, inside the reflector did not need to be removed. The bulb holder and rear of the bulb projecting out of the back of the reflector however were sufficiently bulky to prevent the shell fully closing with the original clip assembly. It was very close however and a zip tie was used in place of the clip and worked fine, if worried about waterproofing a thin rubber strip would probably seal it. The next problem was the plugs, see the previous paragraph, due to the small hole for cables in the shell I had to remove and disassemble the plugs leaving only the metal pins, to feed the connections between bulb and control gear through the cable hole. A larger hole drilled in the rear of the shell would alleviate this and could be sealed with a large grommet, but it was a step too far for me. The superseal connectors can be disassembled with either the appropriate tool or a Jeweller's screwdriver, but it's a fiddly frustrating job.

Depending on the supplier a third switchbox may be included to permit positive and negative switching. Some wiring systems use a switch on the supply before the bulb to turn it on, positive switching; Guzzi lights are positively switched. Others keep the negative or frame path open, so although the system receives voltage, no current can flow and the system can't work until the path to frame is completed, negative switching.

Installing it all is not as bad as it sounds, it took me a while to figure it all out but it's not beyond the average home bodger.

Enquiries prior to purchase (and my decisions in brackets)

1) Does the system require a lead direct to the battery? (if it does go elsewhere)
2) Max current draw on start? (around 7A or less is fine)
3) Is the system guaranteed? (look for a lifetime guarantee on the ballast)
4) Physical dimensions, get as much information on the bulb, bulb holder, ballast and power supply box sizes to make sure it all fits (I'd also go for a slimline ballast)
5) Does the system require positive or negative switching or can it accommodate both? If both how does it accommodate this? (positive or both is fine, if it can do both you might end up with an extra box to mount and hide)

Considerations at time of purchase

1) Power 35W or 55W (35 should be more than enough)
2) Bulb colour temperature, approx 4300 Kelvin is the optimum for maximum light, this will be intense white with no blue, if not available 5000 Kelvin, just a hint of blue. Lower than 4300 Kelvin light becomes progressively yellow, higher than 4300 Kelvin becomes increasingly blue turning to purple around 8000 Kelvin. Most suppliers on the web have charts to illustrate this, check DDM Tuning. Light output beyond 6000 Kelvin becomes seriously compromised. (4300 Kelvin, if not available I'd choose 5000 Kelvin)

Summing up

Definitely install relays, no downside (apart from your pocket). For maximum light HID, but be aware of the drawbacks. If HID is a step too far then one of the upgrade Hi performance halogens, not the blue light type but the higher performance white light models, be aware that bulb life might be shorter. Only if upgrades to the charging system, heavier cabling and a ceramic bulb holder are being implemented, should larger wattages be considered.

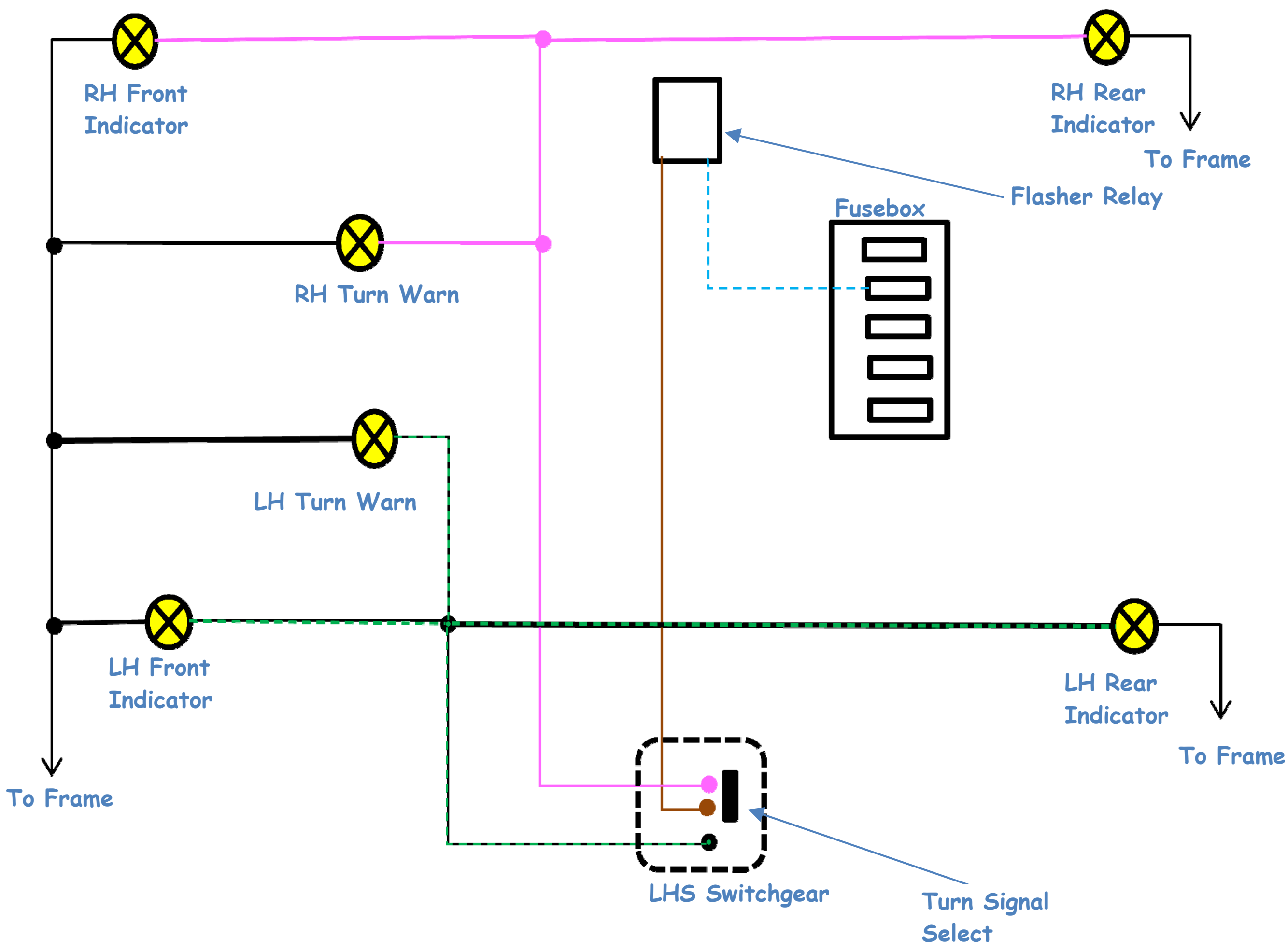
Running/Park Light

In order to give the charging system an easier time an LED can be used to replace the standard bulb. The standard Park light is 4W, at one time I had a 20W halogen installed and used this as a running light as opposed to burning the Lo beam. I replaced this with a 16 SMD type, 12V, 3W and it's brighter than the halogen bulb. Try to get a white one, many will have a hint of blue to match HIDs and can look a little odd.

Tail Light

The standard tail light can be replaced with an LED unit; this would also cover the brake light as well. Depending on your preference there are types available with red or clear lenses in a dizzying array of shapes and sizes. Another alternative would be to replace the bulb with an LED type. Purchase a red LED if possible no matter which type of lens is on the bike. The SMD type of LED can be obtained with 16 or more LEDs on the bulb. These have LEDs on the side, and front, to emulate the performance of an incandescent bulb more effectively. Obviously check the voltage rating, fitting type and the physical dimensions. Either of these options should help the charge system (albeit just a little) and LEDs are more reliable.

The Turn Signal Circuit



This layout was taken from the wiring diagram and is peculiar in that the feed is taken from Fuse #2, which is energised when the ignition switch is either in "Park" or "On". This was because of the Hazard Warning circuit which is not present on my bike. The only difference is the feed from the fusebox may be from a different fuse (my bike is now custom rewired, so I can't check), apart from that the layout is identical.

Power to the flasher relay is taken via the blue/white wire. The brown output wire from the relay runs to the centre pole of the indicator switch. Moving the switch to left or right selects the appropriate circuit, which have the bulbs in parallel. When selected the left or right bulbs provide load for the relay and a path to the frame and all the lamps flash at the rate dictated by the flasher relay.

About the only peculiarity of this system is the old 2 wire, flasher relay. These use a bi-metallic strip to govern the flash rate. The flash rate is therefore dependent on the current (wattage) of the indicator bulbs. If a non standard indicator or an upgraded bulb is used there is a high probability the indicators will flash; too fast/too slow/don't flash at all, if the total load is not identical to the original.

Modifications to the Turn Signal Circuit

Indicators

For reliability, looks and possibly, power consumption reduction, LED indicators, or LED bulb substitutes may be a consideration. There are all sorts of styles available. LEDs appear very bright when viewed head on, but brightness reduces dramatically when viewed at an angle. If just replacing the bulbs there are models available with LEDs installed onto the sides of the device, these closer emulate incandescent bulb performance. SMD types can have 16 LEDs or more installed on a single unit, check the voltage rating and physical size. When choosing an LED the best colour is yellow or amber, irrespective of the lens colour (LEDs work better if their colour matches the lens colour).

If the original flasher relay is being used with LED units or LED bulb replacements, for both front and/or rear a single resistor on each side could be installed to return the circuit load back to its original value. The resistor would be installed in parallel with the bulbs. See the diagram on the following page.

The original relay and the circuit load were originally matched to obtain the correct flash rate, a different load results in a different flash rate.

The formula to calculate the system load resistance would be

$$Rsys = V^2/(2 * Pb - Pf - Pr)$$

Where

Rsys	=	Equivalent system resistor (Ohms)
V	=	Voltage (nominally 12) (Volts)
Pb	=	Power of one of the original bulbs (Watts)
Pf	=	Power of the new (or existing if not replacing) front indicator (Watts)
Pr	=	Power of the new (or existing if not replacing) rear indicator (Watts)

This formula will be applicable for a mixed LED and original bulb setup, LEDs with different power back and front & LEDs with the same power back and front

From the formula result use a resistor value nearest to the value the formula returns. The power the resistor will have to handle will probably be close to the original circuit load, typically it would require to be 50W.

It will get hot be very careful where it is mounted, preferably using a heat sink of some description.

Another approach is installation of individual resistors in parallel with the LED turn signals to bring the load of that particular section of the circuit back to its original load when bulbs were used. All resistors do is consume power and alter the circuit resistance (hence the name). Calculating equivalent resistances is not complex.

The formula to calculate the additional load resistance for an individual indicator would be

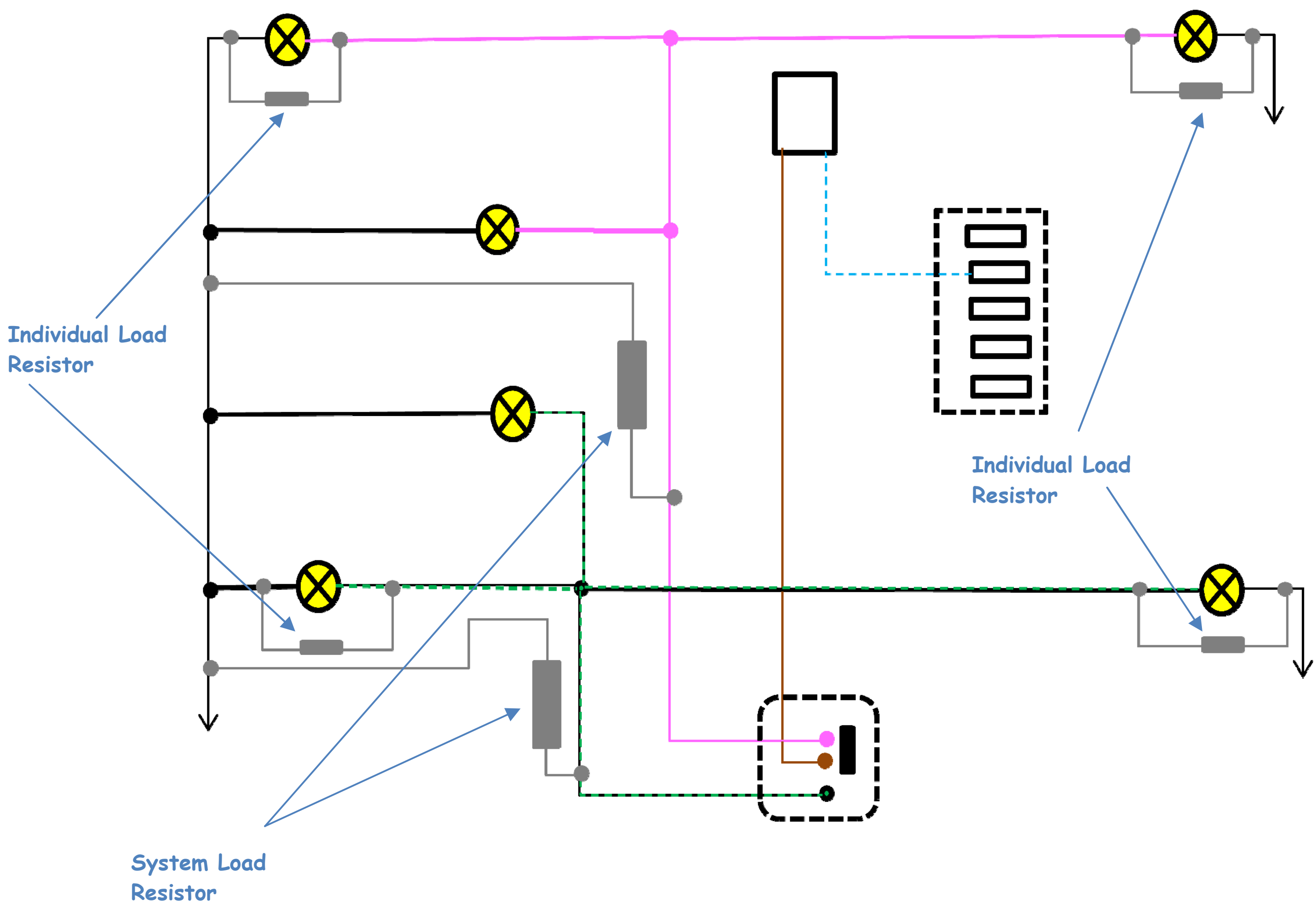
$$Ri = V^2/(Pb - Pl)$$

Where

Ri	=	Individual Load Resistance required (Ohms)
V	=	Voltage (nominally 12) (Volts)
Pb	=	Power of the original bulb (Watts)
Pl	=	Power of LED replacement (Watts)

From the formula result use a resistor value nearest to the value the formula returns. The power the resistor will have to handle will probably be close to the original bulb load, typically it would require to be 25W.

Installation of both system and individual resistors are shown below in grey. System and individual resistors are an either/or do not install both.



From my experience metal encased types such as the TMC series are preferred.

Resistors require mounting where they can dissipate heat and they get hot so they should not be mounted close to any components or materials that are temperature sensitive or will melt.

After all that, resistors are not an elegant solution, they get hot and just consume power. If installing LEDs it is preferable to change the flasher relay, see below. This helps the charge circuit a little and won't cost much more than the price of the resistors.

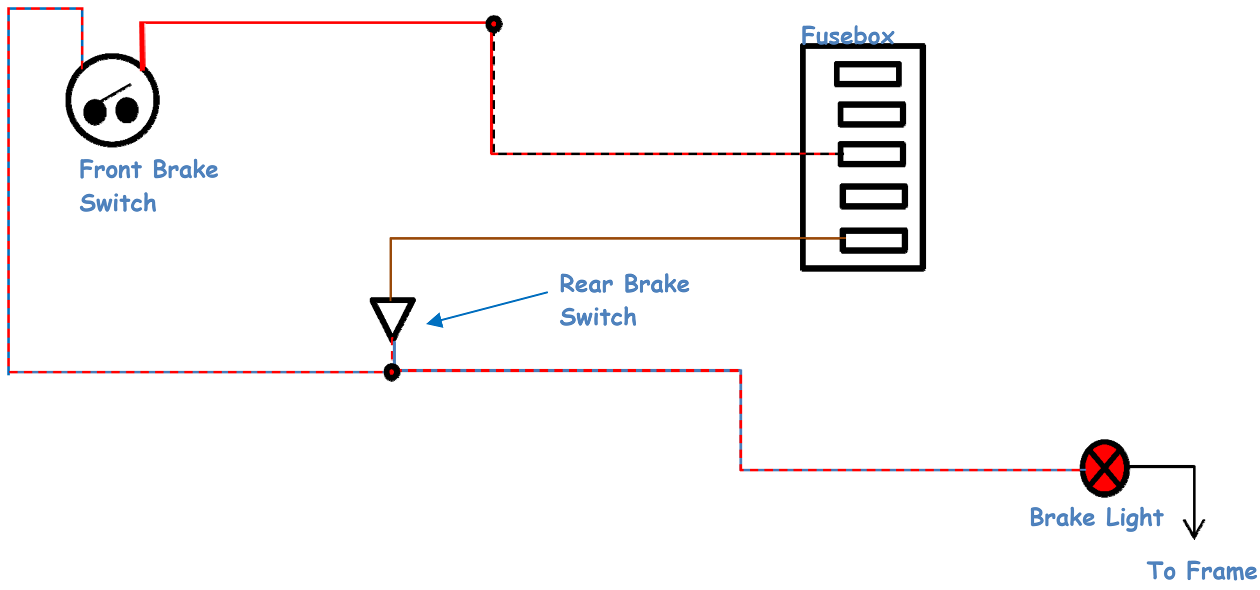
Flasher Relay

If replacing the flasher relay or installing LED signals as replacements an electronic flasher relay can be purchased for minimal outlay. These relays have their flash rate determined by a clock circuit inside the relay and the flash rate is independent of the load. They can therefore be used with bulbs, LEDs or any combination of the two.

Considerations at time of purchase

1) The load they can support (if for example the original bulbs were used the relay would need to be capable of supporting 2x21+1.2=43.5 so nominally 50W minimum)
2) The voltage (the usual 12v)
3) Type, typically on the older bikes a 2 wire type. Many can support either 2 or 3 wire types, the third wire is usually just a connection to the frame so can be easily wired in if required.

The Brake Light Circuit



This appears similar to the Warning Lights Circuit, having the red/black feed from fuse #3 and similar symbols. The positive red/black feed is the same wire, but that's all they share.

The reason for the different symbols for the front and rear switches is because the front brake switch is a mechanical switch operated by the lever, the rear is a pressure switch which operates when the rear brake fluid is pressurized.

This is quite a clever circuit, by using feeds from separate fuses #3 for the front and #5 for the rear, should a fuse blow providing the rider uses front and back brakes the light would still illuminate when braking.

The circuit is simply 2 switches paralleled together and running to the rear brake light.

Modifications to the Brake Light Circuit

Brake Light Switch

The front brake light switch is quite fragile and can quite often break. An aftermarket modification is to install a pressure activated switch; a pressure switch. Both single banjo and double banjo types are available in Steel and Stainless Steel, depending on your brake set up (single banjo is standard) and material preference. Pressure switches are more reliable than the contact micro switch type. To install requires completely draining the front brake system and then installing the switch. The differences to practical performance are pressure switches only operate after pressure is applied, therefore the switch will only light the lamp after braking has started. Generally the existing micro switch type is more sensitive, triggering the brake light the moment the front brake lever is moved.

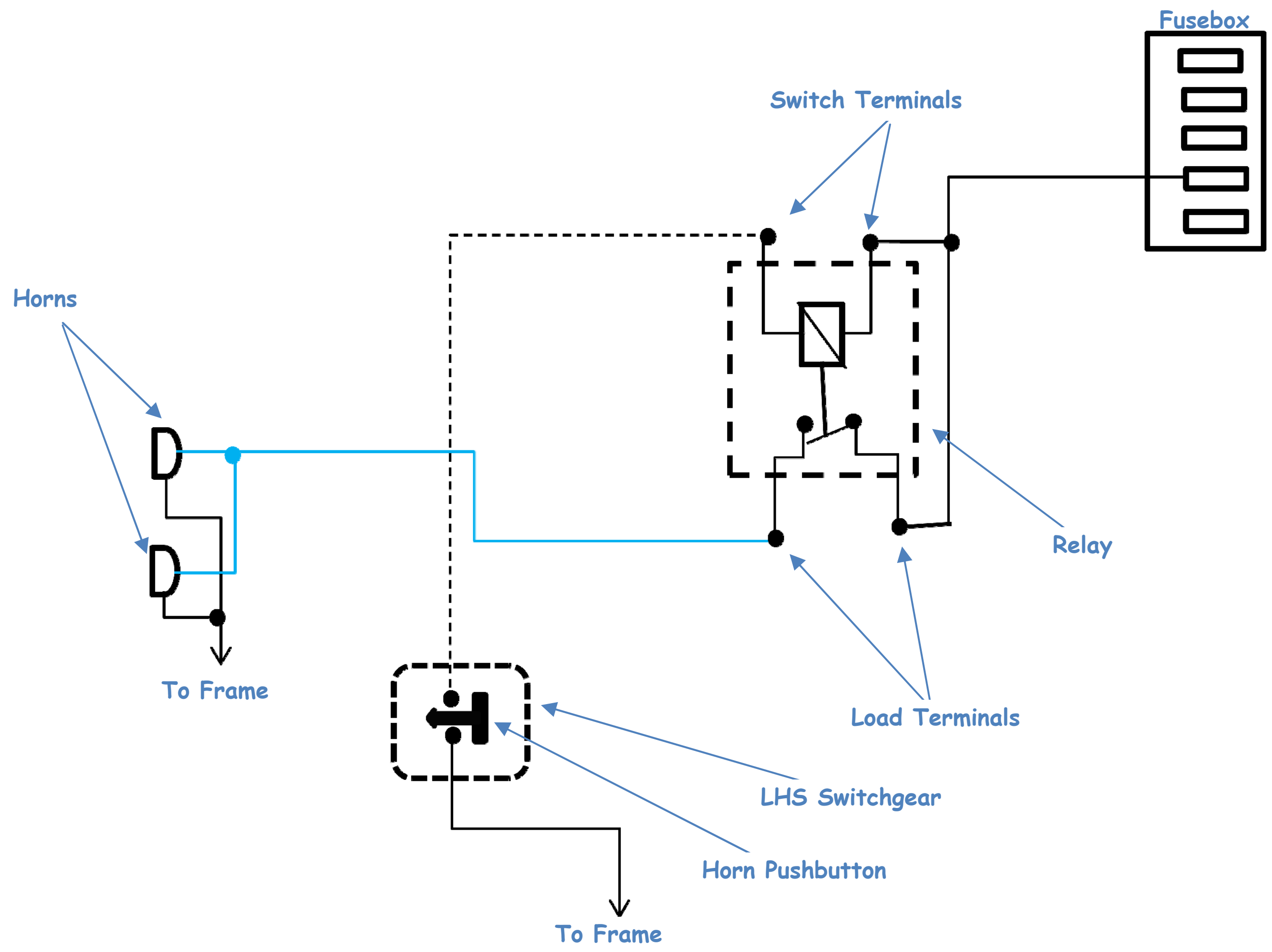
If you need to replace the front switch and want to use another micro switch. I've been informed Radio Shack in the U.S. can supply a suitable switch and I'm pretty sure RS or possibly Maplins would stock something suitable this side of the pond, if you're struggling to source a replacement.

The rear brake light switch is a pressure activated type.

Rear Brake Light

In order to reduce the load on the charging system and increase reliability of the brake light, the bulb or alternatively a whole new assembly using LEDs can be purchased. Red LEDs are preferable as they perform better with the red cover. Ensure the voltage rating is correct. Unlike the flasher system no further modifications are required to enable this system to function.

The Horn Circuit



This circuit is out of scale, the relay looks huge and physically it's a bit compacted. The diagram is however correct and shows the components and their interactions. This is quite a clever circuit as it's negatively switched at the horn pushbutton.

Power is fed from fuse #4 to the positive terminals of both the switch and load terminals. On the load side the blue wire is then fed to the positive terminals of the horns.

The negative side of the control circuit travels via the black/white wire to the horn pushbutton terminals on the LHS switchgear. When the button is pressed a path to the frame is completed on the switch circuit; closing the switch across the load terminals and activating the horns.

Modifications to the Horn Circuit

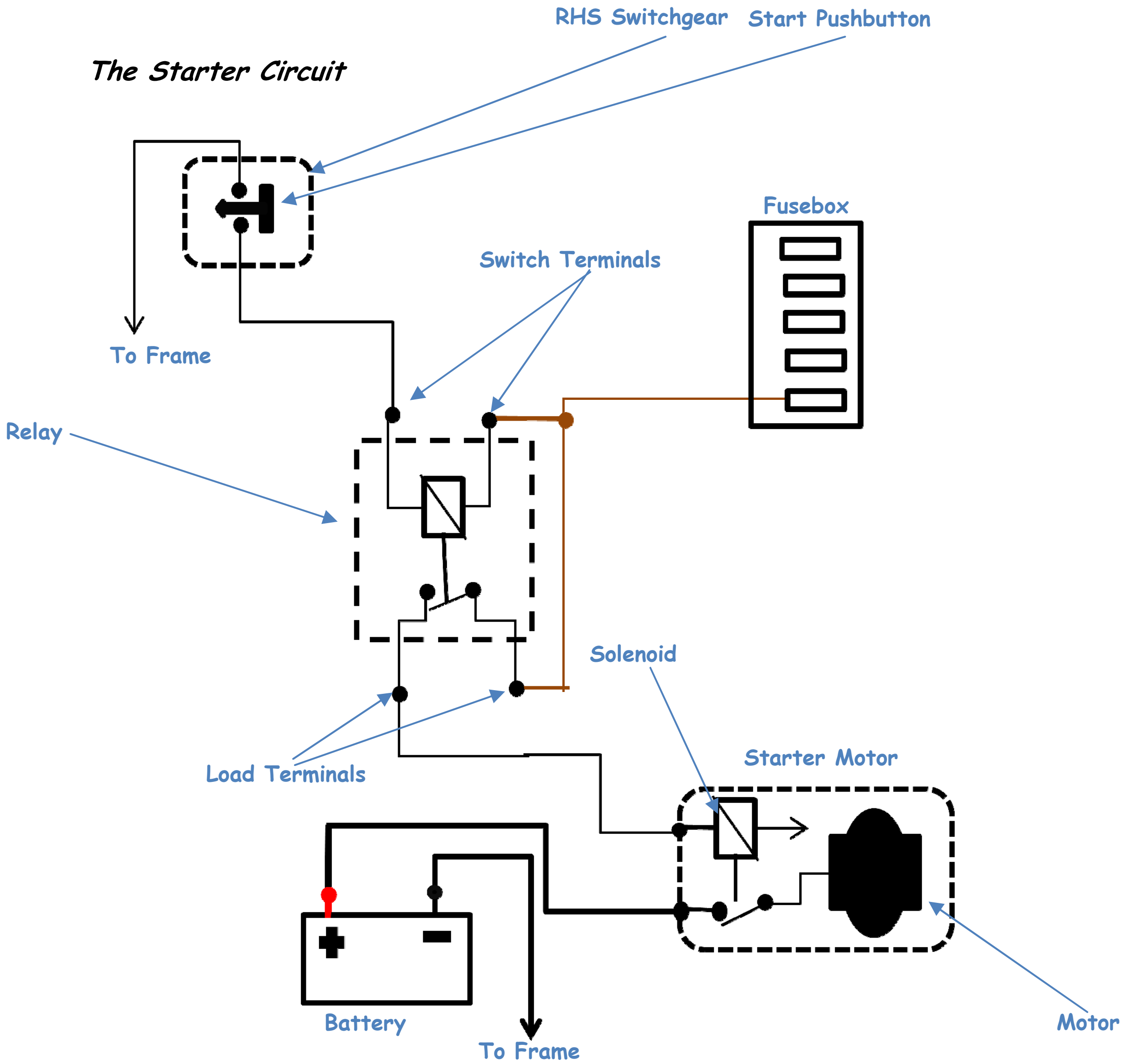
Horns

Replacing the standard diaphragm horns with either twin trumpet diaphragm or air horns are quite popular. Air horns offer the greatest output, but they are larger and have an associated compressor, all of which has to mounted and preferably hidden, they usually are rather unattractive components.

Twin diaphragm horns are smaller, although some still are relatively large. As a rule twin diaphragm horns don't require any circuit modifications.

If installing air horns however, it is worth checking the power consumption of the horns to ensure the load is not so high as to overload the circuit.

The Starter Circuit

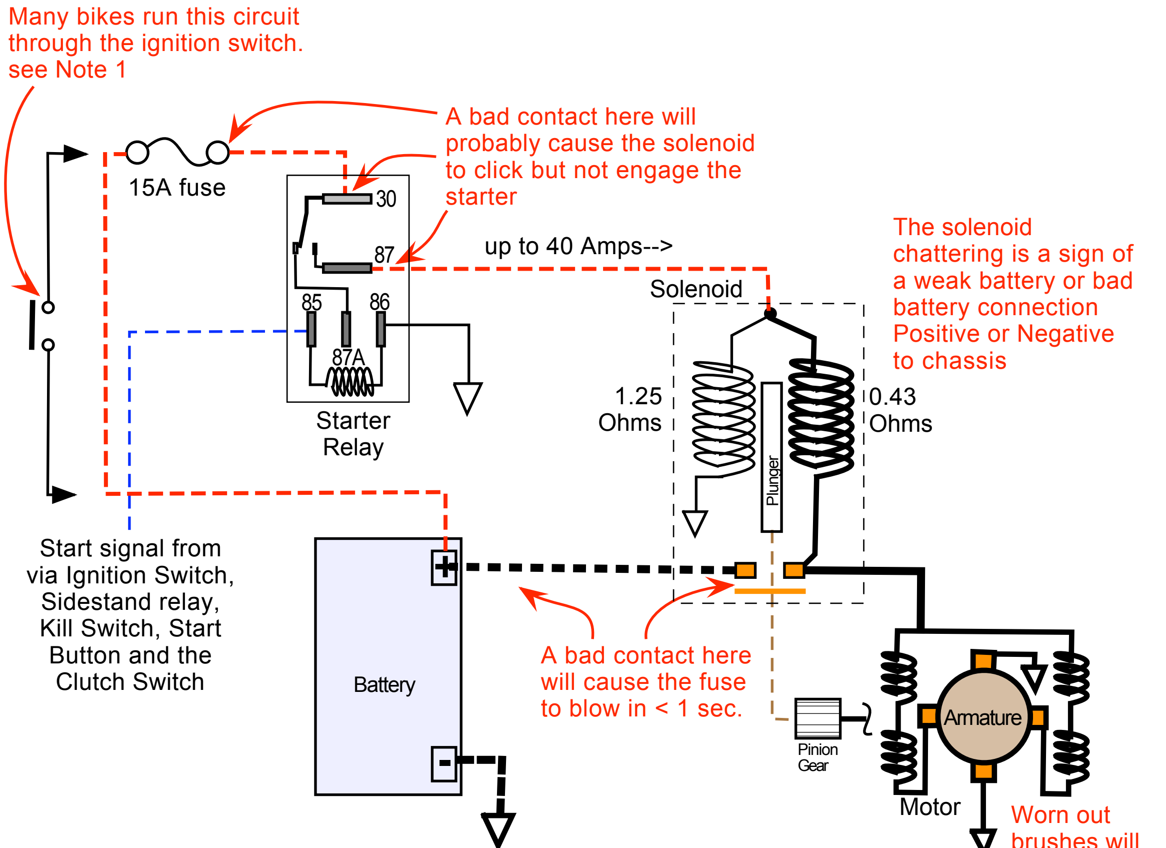


Does this look a bit familiar? Another relay operated circuit, with a switched negative on the relay switch circuit. Once more the components are out of scale but the wiring and the method of operation is correct.

Power is fed to the starter relay from fuse #5, feeding the positive side of both the load and switch circuits. Similar to the horn circuit the negative side of the switch circuit is fed to the start pushbutton, with the other contact on the pushbutton being connected to the frame. Activation of the pushbutton completes the switch circuit path to frame and operates the starter relay. The load terminals close and power is fed to the switch side of the solenoid inside the starter motor.

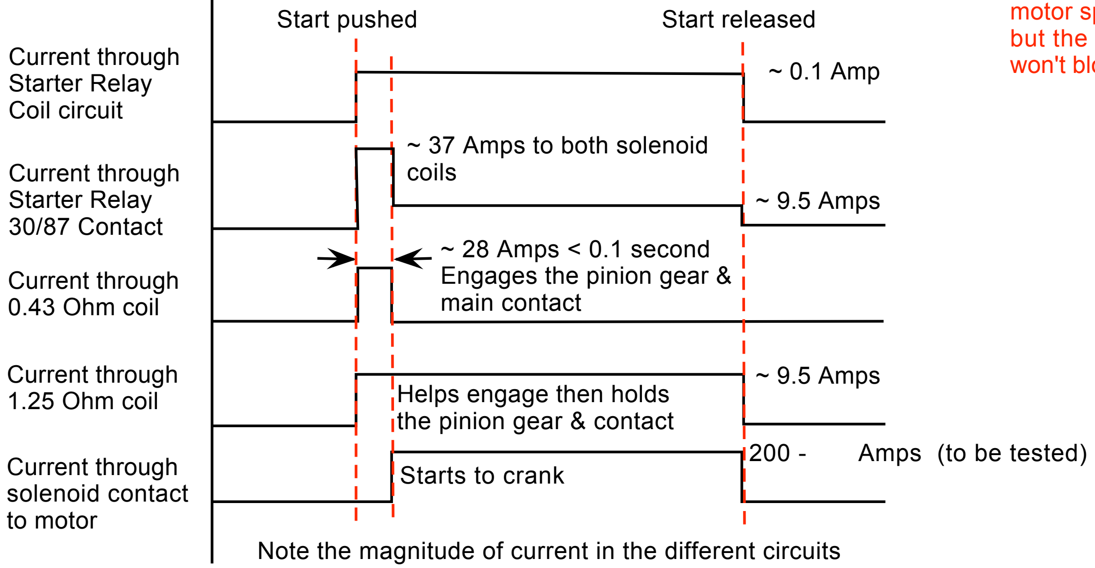
The solenoid inside the starter motor acts like another relay (when relays are daisy chained the term used is cascading). Internally a solenoid is of different construction and supports load currents that would fry a relay. The solenoid internal to the starter is operated by the external starter relay. This in turn closes the contacts on the heavy connection and cable directly between the battery positive and the starter motor, which in turn operates the motor (remember 150A or more).

The solenoid inside the motor is quite a clever piece of design. For the purposes of description here it's not necessary to go into the details. However on the following pages I have attached detailed descriptions of the starter motor's operation and some great tips. These bikes were originally supplied with a Bosch starter motor but many have been replaced with a Valeo unit. Descriptions for both types are included. These excellent sheets were conceived and made by Roy Matson and were just too good for me not to include. The diagrams do mention interlocks not present on the Tonti's; the start signal comes directly from the pushbutton on the bars and nothing else (leaving you free to engage the starter in gear and ride off into the Sunset with your sidestand down). Apart from that the system is identical.



The solenoid has 2 coils a high resistance one ~1.25 Ohms and a Low resistance one ~0.43 Ohms. The coils are actually wound one over the other but shown here side by side for clarity.
When the start signal energizes the start relay a heavy current (~40 Amps) passes through the 0.43 Ohm coil and the armature in series. At the same time a current of ~ 9.5 Amps passes through the 1.25 Ohm coil to the coil case. The combined current creates a very strong magnetic field pulling in the solenoid to engage the start gear and close the main contact.
A split second later when the contact closes providing a direct path from the battery to the armature there is no longer any voltage across the 0.43 ohm coil so the current through that coil drops to zero, the current through the 1.25 Ohm coil holds everything in place.
It's important that the solenoid contact closes quickly otherwise the high current through the 0.43 Ohm coil will blow the 15 Amp fuse in less than 1 second.

Timing Diagram (sequence of events)



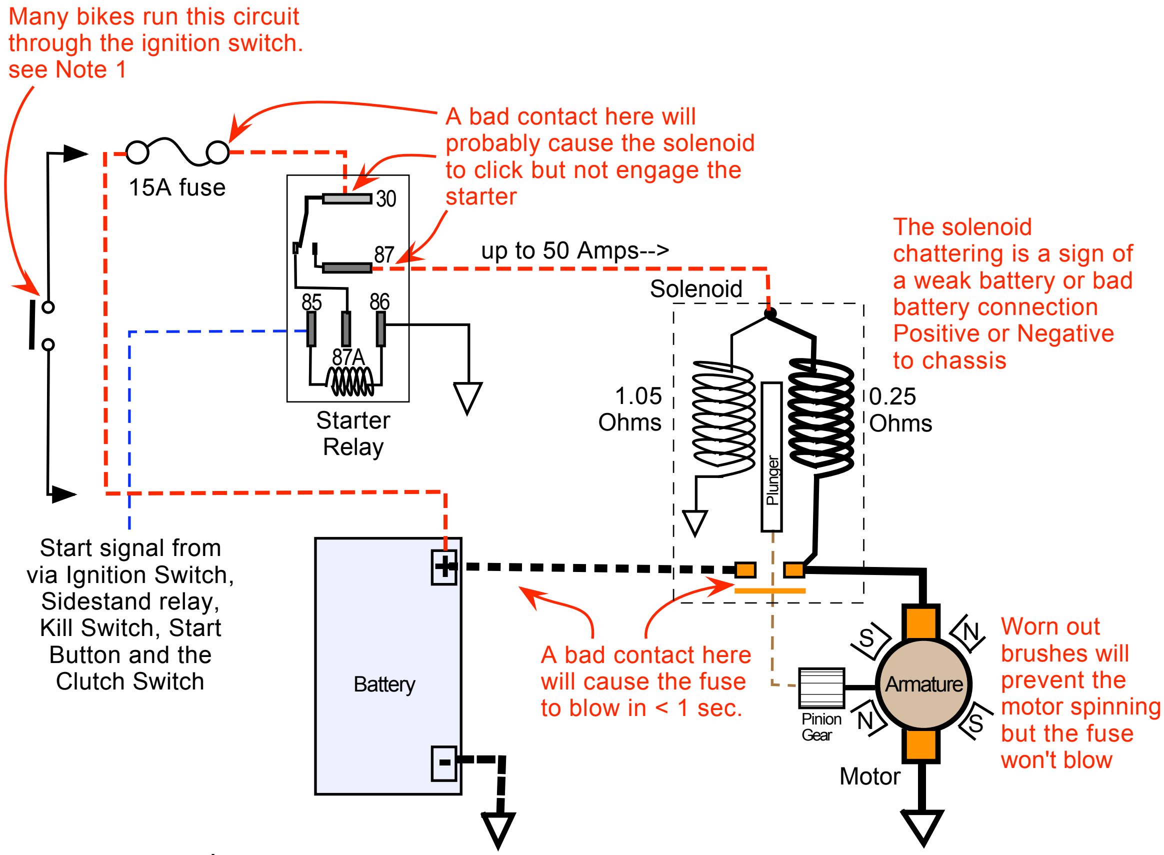
Note the magnitude of current in the different circuits

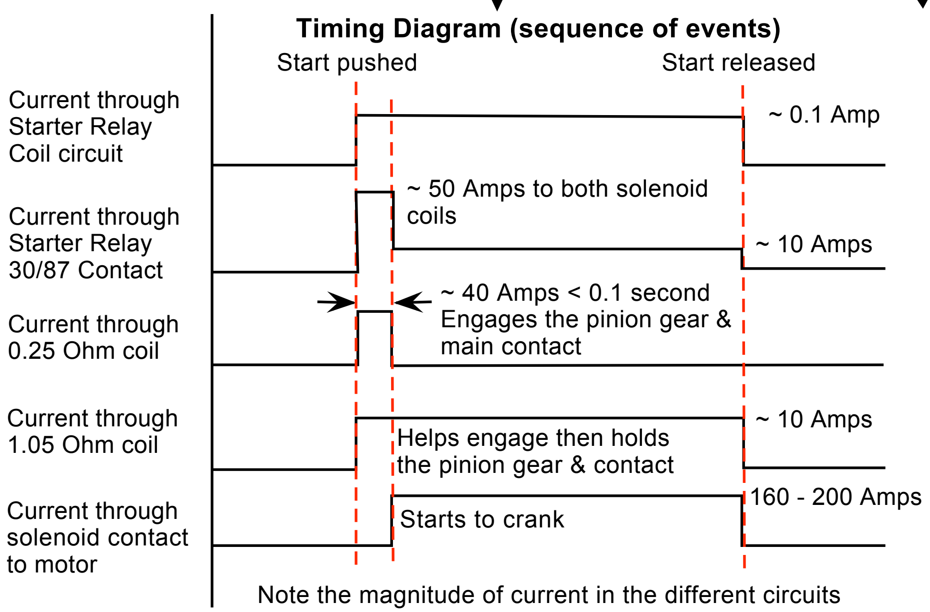
Notes
1/ Running the heavy current start circuit through the ignition switch is problematic. After a while the contact resistance may build up to a point where the starter solenoid is too weak to engage the pinion gear and close the main contact. It also introduces more wiring and connectors into the circuit.
2/ Currents are calculated based on 12 Volts
3/ The Bosch starter is a series motor unlike the Valeo which is a shunt type motor it has no planetary gearbox

Moto Guzzi Bosch Starter Circuit

Part No 1005 821 030

Jan 2012 By Kiwi_Roy





The solenoid has 2 coils a high resistance one ~1.05 Ohms and a Low resistance one ~0.25 Ohms. The coils are actually wound one over the other but shown here side by side for clarity.
When the start signal energizes the start relay a heavy current (~40 Amps) passes through the 0.25 Ohm coil and the armature in series. At the same time a current of ~ 10 Amps passes through the 1.05 Ohm coil. The combined current creates a very strong magnetic field pulling in the solenoid to engage the start gear and close the main contact.
A split second later when the contact closes providing a direct path from the battery to the armature there is no longer any voltage across the 0.25 ohm coil so the current through that coil drops to zero, the current through the 1.05 Ohm coil holds everything in place.
It's important that the solenoid contact closes quickly otherwise the high current through the 0.25 Ohm coil will blow the 15 Amp fuse in less than 1 second.

Observations
The inrush current to the solenoid coil calculates out at about 50 Amps but in actual fact I measured around 37 Amps, this can be attributed to the resistance of the wiring, fuse and relay contact and or batttery condition.
The main current from the battery positive to the large terminal on the solenoid is about 175 Amps so it probably varies from 150 - 200 depending on the bike.
Testing the theory that a bad contact in the solenoid will cause the 15 Amp fuse to blow resulted in it blowing in less than 1/2 a second.

Notes
1/ Running the heavy current start circuit through the ignition switch is problematic. After a while the contact resistance may build up to a point where the starter solenoid is too weak to engage the pinion gear and close the main contact. It also introduces more wiring and connectors into the circuit.

Moto Guzzi Valeo Starter Circuit

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