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## 25. Electrical System

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### Introduction

Whilst in general electrical items are not included in the Europa kit - mainly because virtually every builder will want a customised instrument panel, this is a good stage at which the electrical installation could be carried out.

We have included an Annex (Annex D) at the back of the manual, which gives a good introduction to the theory and general principles of electrical design and installation.

What follows in this chapter is a set of recommendations specific to the Europa, but which is sufficiently general to apply to most installations.

### Planning

It is important to plan the electrical system at an early stage. While there are many possible solutions which will work, you should aim for a safe, reliable system which will operate in a logical and straightforward manner. Ensure that your inspector is kept informed of your plan for the system and has the opportunity to advise you on anything you may be unsure of before it becomes difficult or impossible to change. You are strongly recommended to work to a detailed circuit diagram and layout plan, having gathered components in each area together to ensure they will *all* fit before cutting or drilling mounting points. You will know every cable and connector by the time you have finished the system, but a month later the details will have faded from memory.

### Weight considerations

Although there is often a great temptation to give your Europa cockpit a mini 'biz-jet' look by packing the panel with all kinds of gadgets, ask yourself first "will I really need this?"

The addition of a second radio, for example, although offering redundancy if the first one fails, will most likely be dead weight that will be carried on every flight you make. Consider also that with each piece of extra equipment there will almost always be more wiring, connectors, another circuit breaker or switch, all adding to the already added weight.

### Switches

The rule for operation of switches in aircraft is UP/FORWARD for ON, DOWN/BACK for OFF.

Contact numbers marked on the switches to identify terminals may be shown, and the contact positions markers "normally closed" (NC) or "normally open" (NO).

## **Circuit breakers**

An important characteristic of a circuit breaker is that it can be reset, usually by pushing a button in or pressing a rocker switch. Some designs allow the breaker to be held in contact even if the overload persists : this is a good way to discover which way the smoke circulates in your cockpit, but is not recommended. The preferred type for aircraft is “trip-free”, which means it cannot be reset while the overload persists. Whatever type is fitted, the rule is that you should never make more than one attempt to reset a breaker in the air - and then only if that circuit is needed. Remember that resetting will not cure the fault that caused the breaker to trip.

Some circuit breakers are designed as switches. This saves having a separate switch to control the circuit. Do not use other types of circuit breaker as switches, as their reliability may suffer, although they may be tripped for maintenance purposes on an occasional basis.

## **Wiring standards**

Wiring and connections should be of aircraft quality. Because homebuilt aircraft are not to certified standards, you do not need to pay for every item to come from a certified source ; we strongly recommend that you satisfy yourself as to the quality of all material being suitable for aircraft use.

In particular, you should avoid wiring with poly-vinyl chloride (PVC) insulation, as this is flammable and gives off toxic fumes when overheated or burnt. Insulation coatings such as ethylethene/tetrafluoroethylene (ETFE, trade name TEFZEL, to specification MIL-W-22759/16) or polyvinylidene fluoride (PVF, as in Raychem Type 44) have good insulation and abrasion resistance and low toxicity of fumes, with temperature ratings to 150°C (heat-shrink sleeving can be added where necessary without risk of damaging the wiring in the process).

Stranded wire cables should always be used in aircraft. Single conductors are less flexible and more prone to fatigue fracture under conditions of aircraft vibration -especially if the wire has been nicked in the course of stripping its insulation while preparing to terminate it. Multi-strand cables are more reliable, although care should be taken to see that all strands have entered the crimp ferrule or solder bucket: stray strands are a sure way of getting short-circuits and testing the circuit protection! All wiring should use appropriate terminations - it is not acceptable practice in aircraft to clamp bare wires into screwed terminals. Each wire should be secured by crimping or soldering to a terminal or contact which is then clamped with a screw or held in a connector.

Cables should be restrained from movement, especially near the termination so that there is no movement between the wire and its terminal - plugs with cable clamps are very good; where a number of wires emerge from a terminal block or row of switches they should immediately be tied together with lacing thread or tie wraps to form a loom, then the loom should be clamped to the structure at frequent intervals so that it does not have a chance to move about, always ensuring that each wire is long enough to avoid pulling on its termination or being kinked into a sharp bend. A rule of thumb is that no individual wire should be bent into a curve sharper than a radius of 6 times its diameter (including insulation), and no loom should have a bend radius less than 10 times that of the largest diameter cable in it.

Identify each cable at both ends so that you can match it with your diagram and trace it if required at a later date.

### Wiring - current rating

We recommend the following conservative ratings be used to connect electrical equipment on the Europa, based on each item's current consumption on a continuous basis, but remembering that a larger gauge may be needed to reduce voltage drop in long runs.

Wire size - a.w.g.	Rating - amps (continuous)	Cross-section (mm <sup>2</sup> )	Weight (g/M)	Volt drop V/M @ 40°C (rated current)
22	4	0.3	5	0.26
20	6	0.5	8	0.24
18	9	0.9	10	0.18
16	12	1.3	16	0.18
14	18	2	20	0.18
12	24	3	32	0.16
10	35	5	50	0.13
8	50	8	80	0.12
6	70	13	130	0.10
4	100	21	210	0.09
2	135	33	330	0.08

*Table 1. Wire sizes*

The above figures are for copper conductors. The resistance of copper increases by about 25 % between 20°C and 85°C; the more current the cables carry the hotter they get and the greater the volts drop. Note how rapidly the weight increases with the larger cable sizes: if you decided to use 10m length of 20 a.w.g. instead of 22 a.w.g., you would add only 30 g (about 1 ounce), whereas upgrading 10m of 6 a.w.g. to 4 a.w.g. would add 800g (nearly 2 pounds).

Aluminium cables are not recommended for the Europa. They require special care in preparing the terminations to ensure reliability, and would only be worth considering for heavy-duty starter currents where you have a very long cable run from a rear-mounted battery, and you have a severe weight problem.

Because aluminium is not as good a conductor as copper, a larger cable cross-section is needed (e.g. 2 a.w.g. instead of 4 a.w.g.) for the same current. If you must use aluminium cables, get specialist advice on termination, installation and husbandry.

## **Connectors**

Connectors come in a very wide range of types and sizes. They serve 2 prime purposes: to connect aircraft wiring to an item of installed equipment, where you have no choice but to use the plug or socket designed to mate with whatever socket or plug is fitted to the item; and to provide an accessible means of disconnecting a cable or group of cables at a convenient point without having to undo the screwed terminations - this is especially useful for the instrument panel, so that it can be fitted out while removed from the aircraft, then installed and quickly connected to the rest of the aircraft wiring. It can equally easily be removed for maintenance.

Aircraft standard connectors are designed to be light in weight, with a screwed or bayonet ring, with environmental seals to avoid moisture ingress, and cable clamps to ensure that stress on the wiring loom does not cause strain between the cables and the contacts they are connected to. Contacts may be crimped onto the cables and subsequently inserted into the connector, or cables may be soldered onto fixed contacts. Catalogues show a bewildering variety of options, but once you have decided where you want to use them, the number and sizes of cables to be connected, you should be able to select the correct plugs and sockets. Normally a “bulkhead” or “chassis” socket or plug will only mate with a matching “free” or “cable” plug or socket - so one half should always be mounted (using a flange or a jam nut) - you should not attempt to have a free plug and free socket connecting 2 parts of a loom.

For safety reasons, the “live” side of each connection should be a socket contact so that an inadvertent short circuit is less likely (e.g. while disconnected for testing).

If you have a circuit where integrity of connection is vital (e.g. pitch trim) it is possible to connect 2 pins in parallel to ensure a single failure does not cause a problem. However it is not considered good practice to use this method to share the current where the contacts are too low a rating to carry the load through one pin - use a connector with adequately-sized contacts.

Aircraft standard connectors are expensive, but are not essential for a homebuilt aircraft, and other types of multi-way connector can be used. Make sure they are of good quality, with some positive means of locking to prevent disconnection under vibration.

## **Battery**

Batteries are available in a variety of sizes and types. The main battery should be capable of cranking the engine under all conditions you are likely to operate the Europa, especially at low temperatures when battery output is low, and the torque needed to crank the engine is high because oil viscosity is high. Rotax recommend a minimum of 16 AH to operate their 912 engine. If you wish to fit a large capacity battery, remember that battery weight increases rapidly with higher capacity.

The battery is mounted in one of the spaces below the floor of the baggage bay. You should ensure the mounting is strong enough to keep it securely in place.

## **Alternator**

The type of alternator fitted will vary with different engine designs.

The Rotax 912 and 914 engines have an integral alternator on the rear of the engine. The magnetic field is produced by permanent magnets which rotate with the crankshaft, and the electrical output comes from 10 coils arranged radially - 2 of these coils form independent magnetos, each supplying current to a separate ignition circuit, while the other 8 coils provide the output to the rectifier / regulator which is mounted away from the engine.

There is no field circuit to switch the output on or off, and Rotax warn that the installation should avoid too large a voltage drop between the positive side of the battery and terminal C on the regulator, or the output voltage could overcharge the battery.

The MidWest rotary engine has an integral flywheel mounted 26 amp alternator with a separate rectifier/regulator.

## **Basic electrical system design**

The wiring diagram at Figure 1 at the end of this chapter shows how you might connect the electrical system of a Europa with a Rotax 912. This section explains why each part of the circuit is arranged this way, and indicates some of the places where you can choose differently.

The first thing to know about the connections to the rest of the aircraft is that the 2 short brown leads coming out of the ignition units must be connected to ground to stop the engine - magneto circuits are live when the switches are open. Any good quality SPST switch (toggle, rocker or key-operated) can be used, with a minimum rating of 250 volts/0.5 amp. It is important that screened cable is used to avoid electrical interference causing spurious triggering of the ignition; the screens should be grounded at both ends, and the cables routed away from other wiring - especially the alternator output cables.

The alternator output comes through 2 yellow flexible cables (screened by metal braid grounded at the engine end) from the left side of the ignition housing. These are connected to the 2 terminals marked 'G' on the rectifier/regulator, which can conveniently be mounted on the front of the firewall. The output feed from the rectifier/regulator comes from the '+B' terminal: it is linked to the 'R' terminal, and connected to the positive side of the battery circuit through a 25 amp slow-blow fuse, with a 22000  $\mu$ F 25V capacitor to ground. A slow blow fuse is a standard wire melt type or thermal circuit breaker. The fuse is there to prevent damage to the alternator/regulator system in the event of an overload, while the capacitor is there to reduce the effect of electrical 'spikes' which could damage the regulator (especially if the output became disconnected from the battery, which would happen if the fuse blew).

A rugged polar aluminium electrolytic capacitor such as Radio Spares 105-408 is suitable, and is available from Europa Aviation, but make sure the '+' terminal is connected to the regulator output and '-' to ground. The 'C' terminal is there to feed the busbar voltage to the regulator, and we recommend the fitting of a charge-indicating lamp between the 'L' and 'C' terminals.

The wire sizes shown in figure 1 comply with the Rotax recommendations for a minimum of 2.5 mm<sup>2</sup> for connections to terminals G, R, +B, and 1.5 mm<sup>2</sup> to C. We can use size 20 a.w.g. for the lamp connections because this should be adequate to take the 5 amp breaker current in the event of a fault, and the 12 volts 3w lamp would draw only 0.25 amp.

The starter solenoid is operated by a momentary contact switch fed via a breaker from the main busbar. A push switch or key-operated switch (which may be combined with the magneto switches, as "OFF-L-R-Both-Start" should be used, or a gated spring-loaded toggle (the gate is a cover to prevent inadvertent operation).

In the U.K. you are required by the CAA to fit a 'starter-engaged' warning light, which should be connected to the starter motor side of the solenoid. Figure 1 shows a 1 amp in-line fuse to protect the wire.

The starter solenoid should be mounted on the firewall, and we recommend a diode across the coil to improve reliability (this is now a requirement on certified aircraft). A small silicon rectifier diode, e.g. 1N5404, is appropriate and available from Europa Aviation. It will reduce sparking on the starter switch contacts.

When fitting the diode, note that the symbol "points to positive" - if checked on a multimeter, it will show a low resistance passing current in the direction of the arrow, but will block current the other way.

Remember that the starter circuit draws very heavy currents, and good connections are needed to keep the resistance low for good cranking. Use the correct size tinned copper ring-tongue crimps to fit each of the screwed terminals, with ferrule size to match the 4 a.w.g. cables. Prepare the cable ends carefully, ensuring none of the copper wire strands is nicked while stripping the insulation and that the length of each piece is the shortest which will avoid strain on the terminals (allowing for movements of the engine on its resilient mountings. If you do not have the right hydraulic crimping press for these terminals, you are strongly recommended to take the leads to the nearest aero-, auto- or agricultural shop that does, rather than solder them.

The ground return between the engine block and the battery negative terminal can be a tinned copper braided earth strap of at least the same cross-section as the positive feed (minimum 16 mm<sup>2</sup>). You are strongly recommended to provide the exposed positive battery and solenoid terminals with insulating covers - neoprene sleeves or nipples are preferable to heat-shrink sleeving for this purpose, as they can be re-used when removing and refitting the battery, and can be slid aside to check the terminals are tight.

In the case of the Rotax 912 the other connections with the engine are for the tachometer, oil pressure and temperature and cylinder head temperature. All these instruments need a 12 volt supply and a ground return, and are fed from sensors mounted on the engine. The wiring for these instruments is shown in figure 2. The tachometer receives voltage pulses from the ignition system: the white/yellow and blue/yellow wires emerging from the lead out of the ignition module can be connected either way round.

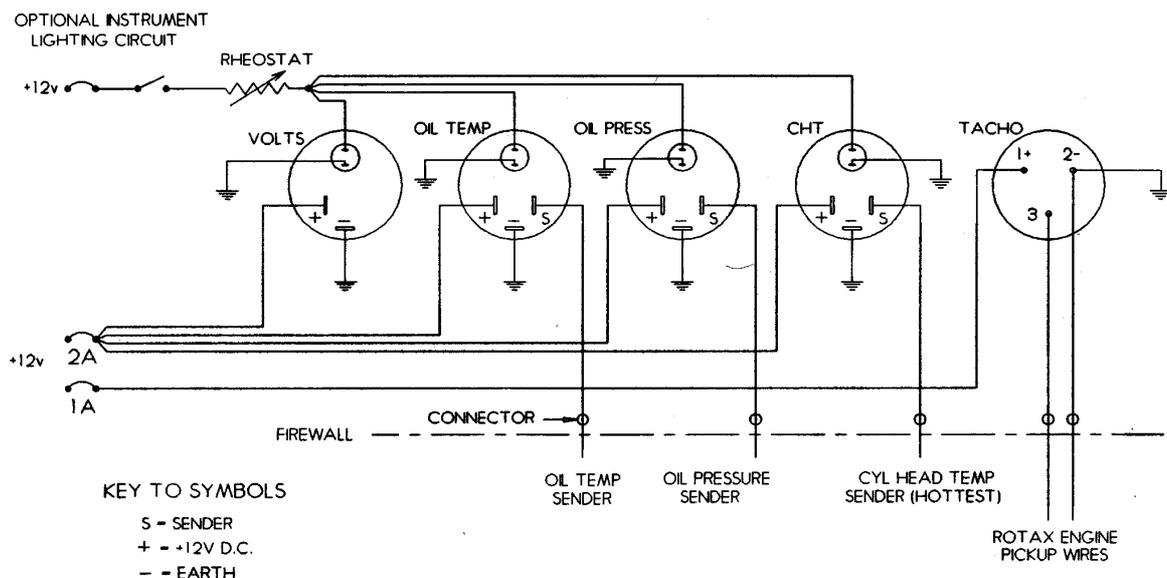


Fig 2. Rotax 912 instrument wiring diagram.

Remember that circuit breakers or fuses are there to protect the wiring in the event of a short circuit or equipment fault. The wire sizes suggested in Table 1 are large enough to carry the current without overheating before the breaker trips or the fuse blows. Whether you need a switch in the circuit depends on whether you have to control it (e.g. electric fuel pump) or you normally want it working whenever there is electrical power on the busbar (e.g. instruments). In the latter case, some builders prefer to keep things simple and do without a switch - it saves weight and is one less thing to go wrong. You can still pull the breaker or remove the fuse if you need to isolate the system.

## Avionics

Avionics equipment can be connected to circuit breakers or fuses off the main bus, but if you prefer to have a separate avionics bus this can be isolated from the main bus with an avionics master switch (as shown in Figure 1) or a relay. Because some avionic equipment may be damaged by abnormally low voltage supply or by voltage spikes created while the engine is being started, it is good practice to ensure all avionics are switched off during engine start. Since most equipment is fitted with an integral ON/OFF switch, cockpit drills can be used rather than a master switch.

Avionic equipment is often designed to fit into a mounting tray, to the back of which all connections are made. Ensure that there is sufficient clearance between the back of the mounting tray and the firewall for the connections to be made without the cables having to be bent at too tight a radius, or being in danger of chafing against the firewall.

## **VHF radio**

For UK registered aircraft, a Certificate of Approval of Aircraft Radio Installation is required from the Civil Aviation Authority (CAA). Application forms are available from the PFA who will issue a recommendation of approval to the CAA for correctly made installations.

## **Pitch trim**

The MAC pitch trim servo is supplied complete with a double pole double throw (DPDT) rocker switch and a position indicator for mounting on the panel or the top of the tunnel, together with a suitable length of 5-core cable for interconnection. We recommend that this trim circuit is connected directly to the battery via a 1 amp breaker or fuse (as shown in figure 1). This will allow you to continue to use the trim in an emergency when you have switched off the master switch. The circuit breaker must be of the pull-to-break type, otherwise a separate switch should be included so that the trim circuit may be isolated quickly.

You may wish to fit a 5-way plug and socket (not supplied) to the trim servo, to make disconnection and reconnection easier in the event that you have to remove and refit the servo. The colour-coded wiring should be connected in accordance with the MAC instructions supplied.

## **Clock**

If you wish to fit a clock to your panel you should take a supply direct from the battery as for the trim circuit : this is a good candidate for a fuse of very low rating (say 100 milliamps).

## **Ammeter**

If you wish to fit an ammeter to show the rate at which the battery is being charged or discharged, you are recommended to use a type with a separate shunt located on the firewall. This avoids bringing heavy-duty cables which are live to the battery up to the instrument panel. The 22 a.w.g. leads to the instrument can be protected by 1 amp in-line fuses on the firewall. The rating of the shunt should allow it to pass currents up to 25 to 50 amps, and the instrument should be calibrated to read  $\pm 20$  amps or more, depending on the total load on your system.

## **Intercom**

Some VHF radios are fitted with an integral intercom system, otherwise you may have a separate one. In either case, the wiring should be arranged together with each crew member's press-to-transmit (PTT) switch so that when either person operates their PTT the other person's microphone is disconnected: this is to avoid intercom talk being transmitted over the R/T.

We recommend installing the microphone and telephone jack sockets in the headrests or the cabin roof - this allows you to plug in your headsets in a convenient place without the leads getting in the way.

Another feature of an intercom worth considering is voice activation. Without voice activation the intercom will be permanently on, allowing engine noise to be always present in the earphones. A separate intercom switch could be used in this case of course.

### **Flydat option**

The Rotax Flydat is available as an option to provide a display of all engine monitoring functions on one instrument, replacing the tachometer, oil temperature and pressure, and cylinder head temperature gauges. In addition it can give a warning of exceeding preset values, and records values of parameters including engine running hours. The Flydat does not include voltage or amps indication, and a voltmeter (or ammeter) should still be fitted.

All data is displayed digitally, not in conventional analogue form as with the separate instruments.

### **Master switch / solenoid**

The master switch controls the connection between the power sources (battery and alternator output) and the main 12 volt busbar. The 10 a.w.g. feeder cable is protected by a 25 amp fuse on the firewall. It is shown in figure 2 as a DPST switch with both poles wired in parallel for increased reliability. The contacts should be rated at 12v DC / 20 amps.

We recommend the use of a master solenoid to isolate the battery, which must be a continuously-rated type. The coil can be connected to the positive lead and operated by a master control switch in the cockpit to complete the circuit to ground (but make sure that if the coil is grounded to the solenoid outer casing that this is isolated from the aircraft ground/ battery negative - otherwise the solenoid coil would have to be operated by a positive feed from the master switch).

Since the battery is mounted in the rear of the aircraft it is appropriate to install the master solenoid next to it. This will enable you to isolate the heavy-duty feed to the engine compartment.

### **Load calculations**

If you are fitting only the normal range of flight and engine instruments and basic avionics, there is no need to carry out any detailed load calculations because the power available from the engine alternator is sufficient to supply these loads and charge the battery at cruise RPM. If you want to install heavier loads such as lighting, you should calculate the total loading to see whether you need additional power (such as the Rotax external generator option) or whether you can manage without.

**Typical loads in amps :**

Battery solenoid coil	1.0
Engine instruments	0.5
Artificial horizon	1.3
Turn and Slip	1.2
Directional gyro	1.2
VHF Comm (standby)	1.0
VHF Comm. (transmit)	5.0
Transponder	1.8
Intercom	0.5
GPS / Skymap	1.0
Strobe lights (set of 3)	7.0
Nav lights (set of 3)	4.3
100 W landing light	8.3
Pitot heater	10.0

This suggests a normal continuous load for electric instruments and avionics of some 8.5 amps (9.5 amps with battery master solenoid), which would allow a set of strobe lights to be fixed without overloading the system. Note that in the case of the Rotax 912, although the alternator is rated at some 19 amps, the voltage will drop below 13 when the output is more than about 15 amps -this means that it should not be expected to keep the battery charged at the same time as delivering the maximum load. We do not recommend the fitting of a heated pitot head, but have listed the 10 amp load to illustrate the high consumption of power.

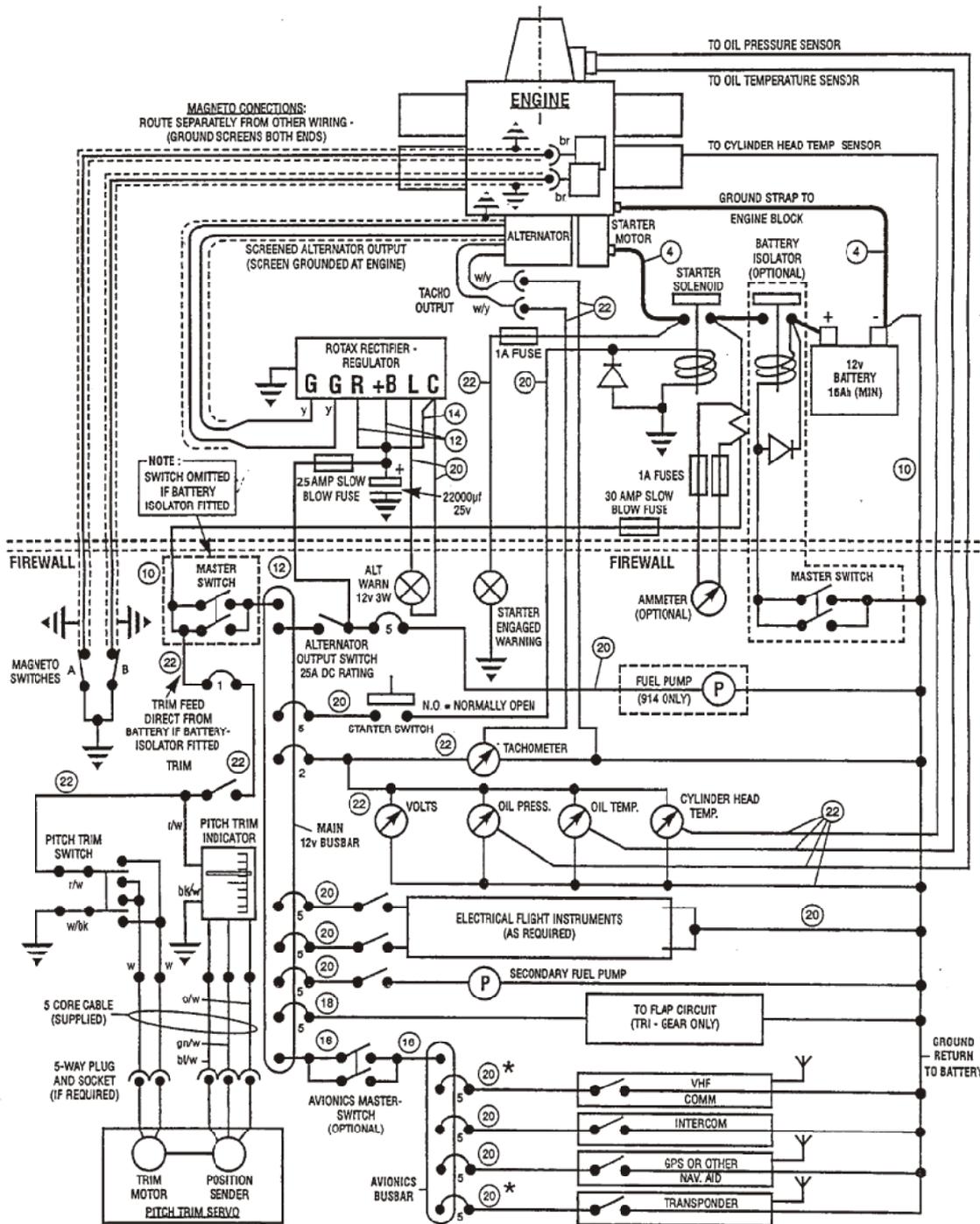
**IMPORTANT : ENGINE RELATED WIRING MUST COMPLY WITH ROTAX INSTALLATION MANUAL**

**KEY - WIRING COLOURS**

y - YELLOW	bk - BLACK
w - WHITE	gn - GREEN
bl - BLUE	r - RED
br - BROWN	o - ORANGE

**KEY**

(20)	WIRE SIZES IN AWG.
5	FUSE/CIRCUIT BREAKER AMP RATING



**AVIONICS INTERCONNECTIONS OMITTED FOR CLARITY**

\* COMMS AND TRANSPONDER MAY REQUIRE HIGHER RATING CIRCUIT BREAKER/FUSE AND WIRING - ACCORDING TO POWER RATINGS

INTENTIONALLY BLANK