

Purpose: When establishing aircraft system complexity, the builder must carefully consider the aircraft mission. The following statements relating to subsystems selection are generally true but may require that additional factors, unique to your situation, be considered prior to implementation. A reliable well equipped amateur built aircraft will be a successful integration of all of its various fallible subsystems, each one being the simplest approach capable of serving the designated function.

Consider: Parts not installed never fail and weigh nothing, however, all parts which perform critical functions in systems necessary for the safe completion of flight should have some form of safety back-up for failure recovery and a way of promptly notifying the pilot of primary system failure.

Nuckolls' Laws:

- (1) "Things break".
- (2) "Systems shall be designed such that when things do break, no immediate hazard is created".
- (3) "Things necessary for comfortable completion of flight require backup".
- (4) "Upgrading the quality, reliability, longevity or capability of a part should be because you are tired of replacing it, not because it nearly got you killed".

Tech Credits: Bob Nuckolls of the Aeroelectric Connection, Tony Bingelis of EAA and my own personal observations obtained during the building of several Experimental aircraft.

A. Type of Ignition and Number of Engines

1. All ignition units, be they magnetos or electronic modules, require continuous cooling during operation for reliability purposes. Mount them securely and duct cooling air to them.
2. Single Engine Magneto Ignition Systems. For single certificated aircraft engines having two magnetos, only simple shielded ignition wiring is used. No closed primary circuit switch contacts or grounding are necessary for continuous magneto ignition. P-lead(s) are switched to ground to disable the magneto ignition. High quality keyed ignition switches with or without starter feature are readily available at modest cost from common sources of supply, although other types of common switches may be used. After engine start, battery power (and grounding) is not necessary to maintain the continued functioning of a magneto ignition, but are needed for forming the alternator field, stabilizing the alternator output and powering other essential accessories for a time if there is a loss of the alternator/regulator. The use of an Essential Bus may be desirable depending on complexity. If an Essential Bus is used, it should draw no more than 3A to 5A continuous, the goal being to provide power only to **essential** systems for 3-4 hours (9-20Ah). Essential in this context means: Required for continued safe flight under current conditions.
3. Single Engine Electronic Ignition Systems. For single engine certificated aircraft or automotive conversions having one or more electronic ignition systems in lieu of magneto(s), continuous battery power and reliable grounding is critical to continued engine operation. For dual electronic ignition systems, the use of a small back-up battery is strongly encouraged. Reliable closed primary circuit switches are needed for continuous ignition, therefore good quality switches and redundant power and ground circuits are highly recommended. Power to an electronic ignition unit should come directly from the Battery Bus thru switch(es) and fuse/breaker(s) or switch type breaker(s). Special toggle switches are available to allow for main vs aux power source to ignition units in a progressive manner. For IFR aircraft having electric gyros and/or EFIS systems, the use of two batteries (approximately 25Ah and 17Ah) charged by two separate alternators (60A and 20A) controlled by two separate regulators is advised.
4. Twin Engine Systems. Twin engine systems should begin as two independent systems on a single airframe. There is an opportunity to take advantage of an opportunity for natural redundancy of two independent electrical systems. Cross connection capability provides the ability to function completely on one electrical system should the other system fail, however, it is unwise to take-off without verifying that both systems are completely functional.

B. Day VFR vs Night VFR vs Full IFR

1. Day VFR. No external lighting or Gyros are needed, although an electric Turn Coordinator and Strobes are highly recommended safety equipment for all aircraft regardless of mission. An Aircraft Transceiver should be installed in every aircraft and used at both controlled and uncontrolled facilities. Transponder with Mode C encoder is required for operation within 30 nm of Class B airspace and within Class B and C airspace.
2. Night VFR. Add Attitude Gyro, lighting (Instrumentation, Position and Strobe). Directional Gyro and Landing lights are highly recommended.
3. Full IFR. Add full (electric or Vacuum) Gyro complement, Heated Pitot/Static system and additional navigation aids. Gyro power source and static port redundancy is highly recommended.

C. Venturis vs Single Vacuum pump vs Vacuum pump w/backup vs Electric Gyro System

1. The Venturi is still a very reliable source of vacuum on slower VFR aircraft where there is only a slight drag penalty. One large venturi per gyro instrument is generally necessary to obtain adequate volume. Full flow fittings should be used although they are more expensive. Venturis are also simple backups for dry vacuum pumps provided that they are not relied upon to function in actual icing conditions.
2. Dry vacuum pumps are less troublesome than are wet pumps, however, common Airborne dry types (one type is CCW rotation, one is CW rotation) can still die in as little as 20 hrs or as many as 1000 hrs. Frangible safety couplings are designed to separate if rotor vanes frag so as not to affect engine power. Newer Sigmatek dry pumps are not sensitive to directional rotation as are the Airbornes. All dry vacuum pump vanes are sensitive to being damaged by ingestion of foreign materials (oil, dirt, etc.). Cooling shroud kits are readily available at modest cost and may help extend pump longevity.
3. Backup systems are available which run off of engine manifold vacuum to provide temporary power to gyros in emergency situations when there has been a loss of the primary system, however these systems only function well if manifold pressure is at least 4 inHg below ambient. This occurs only with partial throttle settings.
4. Other back-up systems use an electric motor to turn an auxiliary vacuum pump.
5. Electric Attitude and Directional Gyros are somewhat pricey (\$1300 each).

D. Heated and Unheated Pitot/Static Systems

1. Day VFR aircraft do not normally require heated pitot/static systems.
2. Night VFR aircraft may benefit from the use of heated pitot/static systems.
3. IFR aircraft should always have heated pitot/static systems
4. Heated pitot/static sources require significant power (10-15A@14V resistive) in order to have good icing recovery capacity.
5. On all aircraft, an alternate static source available in the cockpit via a valve may be a beneficial safety device. Static plumbing should be planned to allow for easy isolation of Altimeter/Encoder from the balance of the system to facilitate periodic calibration. Pitot and static systems should be carefully tested periodically for leakdown.
6. Pitot/static system should be plumbed to ensure that there are no low spots which could trap water and then freeze. A static sump is beneficial to trap moisture prior to reaching instruments. When mounted on the fuselage, two static ports on opposite sides should be incorporated to cancel out the effect of slips and

crosswinds. The cross-connection should go up and over to facilitate draining moisture. A valve accessible auxiliary static source is also recommended for IFR aircraft.

E. Composite vs Metal Airframes

1. Electrical grounding should be accomplished the same way regardless of primary structure (all tied thru a low impedance to one common point), although a metal primary structure provides opportunities for local grounding thru structure for some lighting and other simple peripheral system returns.
2. Composite structures may use copper rods, tubes or 2 AWG wire buried in the structure as efficient power and ground buses, but remember, copper is heavy. For long wire runs to battery, power and ground wires twisted together approximately two twists per foot may reduce noise. Additional shielding of certain low level signals may be more necessary in the composite structure.
3. Composite structures allow for the use of internal antennae unless carbon fiber is used. Furthermore, adequate ground planes must be provided at the base of each antenna even if carbon fiber is used. Lower fuselage surfaces work best for communication with ground based stations. Upper fuselage antenna sites are best for satellite based communications. Composite wing tips are good antenna sites for both ground and satellite communications although the transmission and reception pattern can be more irregular. Bear in mind that comm channels are vertically polarized and nav channels are horizontally polarized and the antennae should be in the same plane as the signals it receives for best results. Antenna signal splitters are available for various multi-signal reception applications.
4. Metal structures are more tolerant of antenna position provided they are placed externally. Composite structures may require the addition of a substantial ground plane. This may be foil or screen.
5. Metal aircraft experiencing radio static may benefit from equipotential bonding straps across all hinged control surfaces to equalize static build-up and minimize some types of radio noise, although the use of discharge wicks on Experimental aircraft is rare. Antistatic waxes may be beneficial in reducing tribocharging in composite aircraft. Do not expect that hinges and such movable joints will maintain acceptable electrical continuity between two structures.
6. Composite structures can suffer from heat soak when sitting on a hot ramp and a solar panel may be used to power a fuselage fan to circulate cooling air while aircraft is parked.

F. Single vs Multiple Comm Transceivers

1. Only modern 760 channel radios are recommended. They should be interfaced with modern electret mic equipped headsets for best noise rejection.
2. Multiple panel mounted comms provide redundancy and may reduce pilot workload when flying in complex airspace under ATC control.
3. An Audio Panel for multiple radios is required only if the Marker Beacon feature is desired.
4. Consider avionics stack cooling for multiple radio installations. Some newer avionics trays incorporate 5/8" dia ports for "Ice Box" type cooler hose connections.
5. Digital recorders are most helpful when obtaining IFR clearances. These are available as options to some intercoms. If music sources (AM/FM radio, CD or Tape players) are to be fed into the intercom Aux input(s), the intercom and headsets should be equipped with stereo capability.
6. Good quality aviation headsets are readily available in the 12-20 dB passive noise reduction range and should be used at all times to reduce fatigue and long term hearing loss. The same type of headset should be used for both pilot and passenger(s) to avoid loading problems with some intercom output stages.

Follow intercom manufacturer's instructions as to whether or not the sleeve of the headset/mic jacks must be isolated from local ground.

7. Active Noise Reduction (ANR) equipped headsets attempt to reduce the amplitude of the offending ambient noise by feeding an opposite phase signal together with the original noise signal in order to obtain some degree of cancellation (up to 24 dB additional active noise reduction). ANR retrofits to some commonly used headsets are available. Some inexpensive ANR systems do not allow for accurate music reproduction.
8. A speaker for the radio is simple to install and convenient for ground listening to ATIS, etc. It does not need to be an "aircraft" speaker, but the impedance must be correct for the radio output stage.

G. GPS, VOR, ADF, HDI, Stormscope, Autopilot, etc.

1. GPS today should be the primary navigation tool. Loran and VOR are still supported but are life limited.
2. VOR is still a good backup nav system for now. This can be a handheld nav/comm.
3. Backup for a single panel mounted GPS/comm system can be a handheld VOR/comm or GPS/comm.
4. GPS units need a data download connector which can be placed somewhere other than the instrument panel in order to save panel space.
5. Some avionics manufacturers suggest the use of multiple power and ground wires. Follow manufacturer's recommendations where feasible.
6. Inexpensive single-axis autopilots can reduce pilot workload especially on long trips. More expensive 2 and 3-axis units are available for those aircraft that are sophisticated enough to require them. Most will slave from the GPS unit for simple course tracking.

H. Manual vs Electric Primer

1. Cold starting an aircraft engine without a primer can be hazardous if fuel drains into the airbox and ignites. Proper technique is to pump the throttle after the engine is turning over in order to draw fuel up into the cylinders.
2. Manual system requires two 1/8" dia copper fuel lines plumbed thru the cabin area. It is important to lock the piston after each use or a rich mixture condition could result.
3. Electric primer system requires only simple wiring. Simultaneous activation of boost pump thru 2 circuit push-button enhances function. No primer fuel lines are necessary in cabin. Further, a one port per cylinder electric primer system could be tuned to provide an alternate fuel delivery system in the event of carburetor or fuel system blockage. For best redundancy in this case, the primer line tap should be as far upstream in the system as possible.
4. Either system requires proper primer fittings (Cone Union type atomizer) for best results. Running primer to two or more jugs is adequate.

I. Fuel Systems

1. For gravity flow systems in high wing aircraft only a single fuel pump must be provided. For low winged aircraft two fuel pumps (one engine driven mechanical type and one electric boost type) should be provided. If pumps are of the "flow thru with check valve" design, they may be series cascaded with the electric pump as near the fuel selector as is feasible and the engine driven mechanical pump between the gascolator and carburetor. Non check valve equipped units may be paralleled if series check valves are added.

2. Facet electric fuel pumps should be installed with the outlet inclined 45° from the inlet to allow the piston to rotate and wear evenly over its life.
3. Use Fuelube or Sealube on all fittings and 'O'-rings. DO NOT use teflon tape.

J. Manual vs Electric Trim Systems (Elevator, Aileron and/or Rudder)

1. For flight safety reasons, trim system limits of travel must be well established by design. Always ensure that the aircraft can be handled and landed with trim tab(s) in any position. There have been scattered reports of MAC servo actuation rods failing due to vibratory fatigue so keep rod length short (higher resonant frequency). Aluminum tubing placed over the rod can provide additional columnar strength.
2. Manual system requires only a reliable mechanical actuator (such as a vernier cable). Visibility of precise anti-servo tab position may be difficult to provide with this system.
3. Electric system requires a MAC type servo (and relay deck for dual stick/switch operation) for each axis to be trimmed. Matronics speed governor replaces relay deck and provides for servo speed reduction without loss of motor torque. Coolie hat switches for aileron/elevator trim readily available at modest cost. Converter is available to allow the use of standard potentiometer operated by trim wheel to drive MAC servos. Complete HOS systems are available. Visibility of anti-servo tab position is incorporated into the servo and presented via panel meters/LEDs.
4. Multiple trim switches (on two or more sticks) require the use of isolating relays or Matronics governor(s) in the servo circuitry to prevent contention problems.

K. Manual vs Electric Flaps

1. Manual system requires only a reliable mechanical actuator, notched latching system and a strong arm. Visibility of flap position should be provided if not directly observable from the pilot's seated position.
2. Electric system requires motorized actuator and DPDT switch wired for reversing direction. Complete HOS systems are available. Visibility of flap position can be added using MAC position sensor and presented via panel meter or LEDs. Simple systems using a three position DPDT switch having a center OFF position, momentary up ON and momentary down ON positions must be held in their ON positions until full travel in the desired direction is complete. Furthermore, these depend on a motorized actuator that freewheels at both ends of travel. Complex systems use mechanically actuated limit switches to cut motor power at the limits of up and down travel and therefore may use a DPDT switch with a maintained ON position for retract.

L. Strobe Light (Anti-collision) System (Night VFR and IFR)

1. A system which provides 400 effective candles at the strobe head is required on all new installations.
2. Single head system must be on top of vertical stabilizer. If not baffled properly, this position can illuminate the upper wing surface of low winged aircraft, contributing to pilot disorientation at night. Single head capable power supply is small and easily located in the peripheral structure to keep shielded wiring runs to minimum.
3. Dual head systems can be installed in wing tips if they remain visible from the rear. Two single head power supplies may be used and mounted in the adjacent structure to keep shielded wiring runs short. Flash synchronization is achieved by interconnecting the external sync lines. Multiple head capable power supplies alternate flashes between strobe heads, are more economical, but must be centrally located between the two strobe heads, so shielded wiring runs are necessarily longer. Tie shield drain wire(s) to ground only at the power supply end (not at the strobe head).

4. Three head systems can be installed in two wing tip leading edge lighting systems and the rudder (or other far aft structure). Three single head power supplies may be used and mounted in the adjacent structures to keep shielded wiring runs short. Flash synchronization is achieved by interconnecting the external sync lines. Multiple head capable power supplies alternate flashes, are more economical but must be centrally located between the three strobe heads, so shielded wiring runs are necessarily longer. The third strobe head robs some power from the two wing heads when using the multiple head power supply.

M. Position, Landing and Cockpit Lighting (Night VFR and IFR)

1. Position lighting systems (with or without strobes) are available or adaptable for every possible aircraft platform. Tail position lights incorporated into wing tip mounted fixtures must both converge within 1000 ft directly to the rear of the aircraft in order to be strictly legal.
2. The proper way to wire MS25041 “push to test” type lamps is as follows: Pin 1 to the source return, Pin 2 to the source after the switch and Pin 3 to the source before the switch or a separate lighting bus. When not pushed, lamp is placed across Pins 1 and 2. When pushed, lamp is placed across Pins 1 and 3.
3. Halogen bulbs get extremely hot during sustained operation and can melt/craze plastic lenses in poorly designed landing light fixtures.
4. In-rush current limiters (ICLs) or filament “keep alive” circuits may be useful in maximizing landing lamp life in aircraft commonly flown at night.
5. Use switched automotive lighting relays for high wattage landing lights (>5A@14V lamp).
6. Use solid state dimmer unit (adjustable voltage regulator) or alternately a 25W rheostat for controlling instrument lighting. Some avionics have internal sensors for enabling illumination and don't require a separate connection to dimmer.
7. A Pulselite system or wig/wag relay can be used to alternate the landing lights ON and OFF and increase the visibility of the aircraft in congested areas.

N. Engine Instruments

1. Individual or integrated gauge systems in analog, digital or a combination of both are available at reasonable cost from common sources of supply. These compare very favorably with high quality discrete gauges, are much easier to install and generally take up less of your precious panel space.
2. New Glass Cockpit Systems (EFIS) are available which incorporate all engine, attitude and navigation functions via computer and flat panel display.
3. All sensors should be mounted to minimize and withstand vibration. Firewall mounting is preferred. Pressure sensing ports should have flow restricted fittings (.040-.050” dia for oil, .020-.025” for fuel) for connecting hoses to pressure transducers. Hoses should travel uphill to transducers in order to minimize fouling the small sensing orifices with suspended particulates.
4. Electronic sensors should be mounted away from engine heat.
5. Since there can be wide variations in CHT and EGT readings for each engine cylinder, the multi-port monitors are preferred.
6. Some Ammeters function differently depending on type and sensor/shunt placement. Loadmeter type can be used on the output lead of the alternator to show how much total current is being drawn by all loads (including battery but excluding starter) from the alternator. This is the preferred system if a voltmeter is present, as it is useful to know how much of alternator total capacity is being used. A loadmeter type can also be used on supply line to the Main Bus to show how much current is being used by the appliances

(excluding battery and starter), but this is a less useful reading. Automotive types show only whether the battery is being charged (+) or discharged (-).

7. Thermocouple wires on modern instruments may be shortened or lengthened as necessary unless expressly prohibited by the manufacturer. Thermocouple types J (wht/red), K (yel/red) and T (blu/red) may be used by certain gauges and are not interchangeable. For U.S. the red lead is always negative and polarity is critical. Thermocouple extension wire of the proper type should be used for providing additional length. Thermocouple wires may be extended or switched only if both wires get the same treatment or significant measurement errors can result. If one lead is to be switched thru a set of contacts, the opposite lead must be simultaneously switched thru a duplicate set of contacts. As long as the same treatment applies to both leads, any error will have a tendency to cancel out.

O. Fuses vs Thermal Circuit Breakers vs Solid State Poly-Fuses

1. Fuses are simple, light and inexpensive but not resettable in flight for nuisance trips, although nuisance trips are exceedingly rare in properly designed systems. Automotive types are more resistant to vibration than are cylindrical types. Fuse blocks are available from B&C.
2. Thermal type Circuit Breakers (P&B, Klixon, E-T-A) have a good service history in aircraft applications.
3. Solid State Poly-fuses have a self-resetting feature and are new to aircraft systems. The Control Vision unit is an example of this design approach.
4. Wire size is determined by the using appliance(s) maximum current draw and then the breaker or fuse value for that leg is selected to protect up to the maximum wire current. Alternately, if a larger AWG wire than necessary is used for the circuit, the breaker or fuse should be sized for 135-165% of the appliance maximum current draw, but never greater than the wire AWG can handle. The alternator B-lead fuse/breaker should be sized for 60A for use with 35A/40A rated alternators and 70A/80A for 50A/60A rated alternators in order to minimize nuisance trips under low battery charge conditions.
5. Each circuit off of the Main Bus must have circuit protection, although, in order to save space, up to three low current appliances may be fed from a single breaker/fuse, depending on the nature of the appliances. Major appliances should each get their own breaker/fuse so as to not risk the loss of multiple systems thru a single point of failure.

P. Battery, Alternator and Voltage Regulator

1. A reliable source of electrical power for the aircraft systems requires that a quality battery of adequate capacity be interconnected with an alternator capable of maintaining the battery at full charge under anticipated loads via the regulator. The battery should be maintained at peak charge and replaced every two to three years (well before it fails), particularly in Night VFR and IFR aircraft.
2. A good battery will continue to supply power long after an alternator, regulator or master contactor circuit gives out. An alternator needs battery power to the field on startup and the battery's stabilizing influence on-line. With an alternator B-lead Filter Capacitor, even an extremely weak battery is sufficient to stabilize an alternator.
3. An alternator should be selected which will provide adequate capacity for the total of all appliance and battery loads. Include >25% safety band for best longevity. Alternators with internal regulators are not recommended because they are not voltage limited to a reliable level. The pulley diameter should be sized so that even the lowest cruise rpm (1800-2000 rpm in standard aircraft engines) will produce full output. Cooling air should be directed via a 1" SCAT hose to the alternator diodes during operation. Even if fan equipped, cooling air should still be provided. Capacitor across the output can be used to filter out noise.
4. Alternators should be controlled by voltage regulators having true over voltage protection (crowbar) circuitry. Without this feature, a runaway alternator can explode a battery in short order. Modern solid

state regulators provide for more accurate long term control of alternator output and should be used in lieu of old automotive derived mechanical types. Some regulators require two separate reliable grounds.

5. The voltage regulator shall be capable of ensuring that the alternator provides a voltage at normal cruise power settings which will be optimum for the specific battery system (wet cell or RG type) being used. This varies between 13.8V-14.2V, depending on the Battery Manufacturer's recommendations, as measured at the battery terminals.
6. Wet cells are not recommended in aerobatic applications. Recombinant Gas (RG) type batteries are sealed and do not require a sealed battery box. The recommended charge is 2.35VDC per cell, or 14.1VDC for a 6 cell 12V RG type Battery. Main Battery for small engined homebuilts may be as small as 12Ah, but for homebuilts with standard aircraft engines, the 25Ah size is recommended. Back-up batteries may be of the 17Ah size. In sport aircraft there is seldom any compelling reason to use 28V systems over 14V.

Q. Switches/Relays/Contactors

1. Good quality switches with a positive snap action should be used. Switches having a good low voltage DC current rating are preferred but not required. Remember that switches, relays and contactors are normally rated for resistive loads. Inductive and lamp loads are each progressively more demanding.
2. Although rare, there have been scattered reports of unintentional starter contactor actuation from high g-loads. Endeavor to place contactors in an orientation which will allow them to not be affected by commonly seen g-loads. The master contactor should not trip out or the charging system may become unstable. The starter contactor should not engage unexpectedly during engine operation or the mechanism may become damaged. Sustained g-loads on an improperly oriented starter contactor can close it long enough to burn it out or weld contacts.
3. A 1N5402 diode should be incorporated across relay/contactor coil terminals (cathode stripe to +12V, anode to ground) to minimize switch contact pitting due to collapsing flux field during de-energizing the coil. A Metal Oxide Varistor (Panasonic ERZ-C05DK180 or equivalent) may be placed across switched contacts to minimize transient spikes.
4. Use only continuous duty type (coil measures 12-20 ohms) Battery Master contactor. This contactor is energized by switching ground across the right side of the Split Master Switch (left side of split switch controls alternator field supply). The two sides of this split switch are interlocked to prevent supplying alternator field power without the battery being on-line but still allow for shedding of the field load during start-up, if desired.
5. Use intermittent duty (coil measures 3-5 ohms) Starter contactor. The contactor is energized by applying 12V to the 'S' terminal. The metal case or mounting bracket is usually internally tied to one side of the primary coil, requiring the mounting bracket to be grounded for the contactor to work. The 'I' terminal of the intermittent duty type is used primarily for load shedding relay in automotive applications.
6. Battery Master Contactors have been known to fail. An alternate feed path via push/pull or switch type 50A circuit breaker from the Battery Bus directly to the Main Bus or Essential Bus (if so equipped) around a failed Battery Contactor should be provided for all Night VFR and IFR aircraft.

R. Wiring Design and Execution

1. A properly designed and installed modern wiring system with proper circuit protection devices should last the life of the airframe.
2. Use only stranded high temperature MIL-W-22759/16 Tefzel airframe wire or MIL-W-16878/4 Teflon hookup wire if possible. Tefzel wire smaller than 22 AWG is very stiff, straight and the strands very weak by comparison, so make sure it is well supported with minimum stresses. Avoid the use of common PVC

automotive wire as the unplated wire strands can easily corrode and the flame by-products of PVC are toxic.

3. Ground Bus should be a common point on the airframe or alternately a low impedance path to that common point. For best results, battery ground lead should travel to engine case first, then to airframe ground. 2 or 4 AWG (depending on distance) copper wire should be used. Terminations should always be made with internal tooth star washers between the electrical terminal and the wire lug for good electrical bonding.
4. Power bussing strategy should be established early. Battery positive lead should travel directly to Battery Master Contactor input (BAT). 2 or 4 AWG wire (depending on distance) should be used, as modern starters can draw nearly 250A @12V.

Battery Bus (all points connected electrically to the positive battery terminal),

Main Bus is connected to the Battery Bus thru the Battery Master Contactor which is energized by grounding the small side terminal.

Auxiliary Bus is connected to the Main Bus via a cross connect contactor and is normally tended by a second auxiliary alternator/regulator/battery combination.

Essential Bus is connected to the Main Bus and is isolated via a high current diode (>25A forward current rating, heat sunk for 30W minimum) and runs about 1V below the Main Bus. The Essential Bus provides the ability to by-pass the Battery Master Contactor and redirect remaining battery power only to systems critical to the safe completion of flight in the event of battery master contactor, alternator or regulator failure.

5. Appliances feed off the Battery Bus, Main Bus, Auxiliary Bus and/or the Essential Bus depending on system criticality.
6. Shielded cable is necessary for magneto P-leads and certain low level sensing, radio, intercom, audio and/or nav circuits. Coaxial Cable (RG-58 50 ohm, with a stranded primary conductor) is to be used for all normal antenna connections. RG-142 has dual shields and may be used for excessively long runs. Transmitting antenna cables should cross other wiring at right angles where possible.
7. Output B-lead from alternator (8-10 AWG) need not be shielded and connects thru a properly sized circuit breaker or fuse (which exceeds the capacity of the Alternator) to the output terminal of the Battery Master Contactor (or the input side of the Starter Contactor). Common Master Switches are dual rocker types with interlocked rockers to ensure Master OFF turns alternator field OFF, although progressive toggle switches may be used instead. If alternate methods are used, consider that it should not be possible to turn OFF the Master Contactor while the Field is still ON. The output terminal of the Battery Master Contactor connects to the input terminal of the Starter Contactor. A separate wire of the same (or larger depending on length) AWG as the alternator output (also unshielded) connects from the Starter Contactor Batt terminal to the Main Bus.

S. Reliability, Single Points of Failure and Fault Tolerance

1. Consider the effect of a single component failure on the aircraft mission. Ask yourself what would happen if a given circuit which is normally open would short or, alternately, a given circuit which is normally shorted would open unexpectedly and at the worst possible time. The risk of simultaneous multiple points of failure is more complicated to assess and much less likely to occur.
2. Night VFR and IFR equipped aircraft demand a higher fault tolerance than Day VFR.
3. A properly maintained battery has a finite life of several years (but should be replaced every 2-3 yrs), will degrade slowly and generally gives some warning before death. By contrast, alternators (or their diodes) and regulators may die without warning.

4. Reliable components are great, but redundancy is the key to fault tolerance.
5. Avoid tying the GND terminal of the common keyed ignition switch to any ground other than that seen thru the shields of the P-leads which are to be grounded at each magneto, as undesirable ground loops can be created.

T. Other

1. Always wire an auxiliary power jack (cigarette lighter socket) off a separate circuit breaker or fuse as a convenient point for powering or charging portable items. Provide fuse or circuit breaker for 10A.
2. There are two ways to power a Hobbs Meter. On a four-cycle application (two-cycle applications are different because there is usually no pressure lubricating system), the negative terminal always connects to the normally open contact on a pressure switch sitting on the oil pressure line and the common contact goes directly to ground. The positive terminal of the Hobbs meter goes thru a circuit breaker either to the Main Bus or the Battery Bus. The advantage of connecting to the Main Bus is that if the oil pressure switch fails shorted while sitting on the ramp, power will still get shut off by the Master switch anyway so the battery does not drain. The disadvantage primarily affects planes used for hire, in that a nefarious pilot can periodically shut off the Hobbs in flight simply by turning the Master switch OFF and continue to fly.
3. Consider providing for future expansion in your panel, if space permits.
4. If using Vision Microsystems Engine Monitor, use plug headers to assist in terminating wiring to the DPU since the DPU will have to be removed in a few years for internal backup battery replacement.
5. AMP sells inexpensive cylindrical plastic connectors (CPC type) in various sizes to allow for easy logical separation of wiring harnesses. 20 AWG contacts are rated for 5A continuous, 8A momentary. 16 AWG contacts are rated for 8A continuous, 13A momentary. Power contacts are rated for 25A continuous, 35A momentary. Put connectors only where you really need them as each connector adds three new joints to each wire.
6. Always support wire bundles so that the terminations see no stress.
7. Always use high quality terminals/contacts, proper termination tools and techniques. Pull test should cause wire to break in tension before the terminal slips off.
8. A properly crimped solderless termination on stranded wire is more reliable than a soldered joint.
9. Endeavor to make all items above the glareshield a dark color to avoid potentially dangerous reflections in the windshield.

U. BATTERY AND STARTER CONTACTOR INFO (LGTERMINALS ARE 5/16", SM TERMINALS ARE 3/16")

3-terminal battery contactor, Stancor P/N 70-918 or White-Rogers P/N 70-111226-5
80A@12V continuous duty, 150A@12V inrush 16 ohm coil, one end tied to BATT terminal

3-terminal battery contactor, Cole-Hersee P/N 24115 (**RECOMMENDED**)
85A@12V continuous duty, 750A@12V inrush 17.5 ohm coil, one end tied to BATT terminal

4-terminal battery contactor, Stancor P/N 70-902 or White-Rogers P/N 70-111224-5A
80A @ 12V continuous duty, 150A @ 12V inrush 16 ohm coil isolated from case

4-terminal battery contactor, Cole-Hersee P/N 24059
85A @ 12V continuous duty, 750A @ 12V inrush 17.5 ohm coil isolated from case

4-terminal battery contactor, Stancor P/N 124-902
100A @ 12V continuous duty, 400A @ 12V inrush 13.2 ohm coil isolated from case

4-terminal battery contactor, Stancor P/N 120-901
100A @ 12V continuous duty, 400A @ 12V inrush 16 ohm coil isolated from case

4-terminal starter contactor, Federal-Mogul P/N 7000022735, Capsonic P/N 227035, Cole-Hersee P/N 24021 or 24138
400A @ 12V intermittent duty only 4 ohm coil, one end tied to mounting bracket

3-terminal starter contactor, Cole-Hersee P/N 24022 **(RECOMMENDED)**
400A @ 12V intermittent duty only 3.5 ohm coil, one end tied to mounting bracket

4-terminal starter contactor, Stancor P/N 70-914 or White-Rogers P/N 70-111225-5
80A @ 12V continuous duty, 150A @ 12V inrush 16 ohm coil isolated from case
recommended only for small engines

3-terminal starter contactor, Stancor P/N 124-906
100A @ 12V continuous duty, 400A @ 12V inrush 13.2 ohm coil, one end tied to case

