Experimental Aircraft Electrical
(interpreting and applying AC43.13 to an RV)

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Prepared for EAA 162
Nashville, TN
Legal Disclosure

The following presentation is solely for the purpose of sharing the author’s electrical system design considerations made during the construction of an experimental aircraft.

This information is presented with the understanding that the author is not trained, licensed, or authorized to provide aviation related technical advice. If you are seeking guidance or assistance then you should seek the competence of a FAA licensed technician.
You don’t have to have the “knack” to understand AC43.13!
Topics:

AC43.13-1B Ch. 11 is about reliability!

- Material selection
- Electrical basics
- Design considerations
- Tools
- Installation
- Reference
1: Inspection and Care

- If you don’t have time to do it right the first time...
  - Buy or borrow the right tool for the job
  - Do use exceptional quality materials
  - Assemble clean, keep it clean
  - Practice skills on scrap (not your project!)
  - Check it, then check it again
  - Strive for excellence, not for perfection

*Reliability is the goal!*
2: Batteries - Selection

- AGM (Absorption Glass Matt) VRLA (Valve Regulated Lead Acid) battery technology (e.g. Odyssey brand)
  - No spill: acid suspended in glass fibers
  - No gassing or venting
  - Mounts in almost any configuration (no inverted)
  - Costs less than traditional aircraft batteries
  - Better performance
  - Longer warranty
2: Batteries - Installation

- Mount securely, but don’t squeeze case
- Pay special attention to torque specs and only use a calibrated wrench
- Apply No-Ox to bare copper surfaces
- Use terminal insulating boots on all exposed connections
2: Batteries - Charging
Charging is a key factor in the proper use of a rechargeable battery. Inadequate or improper charging is a common cause of premature failure of rechargeable lead acid batteries. To properly charge your premium ODYSSEY battery, EnerSys has developed a special charge algorithm. It is designed to rapidly and safely charge these batteries. Called the IUU profile (a constant current mode followed by two stages of constant voltage charge), Figure 6 shows it in a graphical format. No manual intervention is necessary with chargers having this profile.

NOTES:
1. Charger LED stays RED in bulk charge phase (DO NOT TAKE BATTERY OFF CHARGE)
2. LED changes to ORANGE in absorption charge phase (BATTERY AT 80% STATE OF CHARGE)
3. LED changes to GREEN in float charge phase (BATTERY FULLY CHARGED)
4. Charge voltage is temperature compensated at ±24mV per battery per °C variation from 25°C
2: Batteries - Charging
3: Installation – Equipment & Loads

- Design for accessibility
- Plan a load analysis on paper
- Select an alternator that operates at \(< 80\%\) of design capacity
- Control and monitor electrical loads
  - Alternator ANL current limiter or breaker
  - Voltmeter
  - Low voltage warning
4: Circuit Protection – Breakers/Fuses

- Breakers and fuses protect wiring; not the device!
- Install as close to the power source as possible
- Loads can be combined, but not to more than 80% of rated capacity of the fuse/breaker
- Don’t use a circuit breaker as a switch
- Cycle circuit breakers (under no load) to clean
- Size to open before wire capacity (table 11-3)
### 4: Circuit Protection – Ratings

<table>
<thead>
<tr>
<th>Wire AN gauge copper</th>
<th>Circuit breaker amp</th>
<th>Fuse amp</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>7.5</td>
<td>5</td>
</tr>
<tr>
<td>18</td>
<td>10</td>
<td>10</td>
</tr>
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<td>16</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>14</td>
<td>20</td>
<td>15</td>
</tr>
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<td>12</td>
<td>30</td>
<td>20</td>
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<td>8</td>
<td>50</td>
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<td>6</td>
<td>80</td>
<td>70</td>
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<td>4</td>
<td>100</td>
<td>70</td>
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<tr>
<td>2</td>
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<td>100</td>
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<tr>
<td>1</td>
<td></td>
<td>150</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>150</td>
</tr>
</tbody>
</table>
4: Circuit Protection – Fuse Blocks

- ATC Fuse blocks
  - Economical alternative to breakers
  - Offers equal or better protection
  - Simplified installation
  - Weight savings
  - Used by automotive industry for years

+$21.70 = $240.00
4: Circuit Protection - Switches

- Use good quality switches (e.g. Carling)
- 125 VAC ratings generally equate favorably to 14VDC*
  - Lighting/pitot switches will have reduced life
  - Install “catch diodes” for switches with inductive loads (battery & starter contactors)
- Fast-on equipped make for easy, reliable connections
- up or in = ON; down or out = OFF
- Gear and flaps = toggle moves in same direction
5: Wire Sizing – Short Wires

- Max continuous current will determine wire size for shorter length wires
- Match the wire to the fuse size of circuit
- Don’t use 24 or 26 AWG for single wire connections (harness use only)
- Opt for 18 AWG as smallest wire for general use
- If not, carefully support 20 AWG or smaller wires

<table>
<thead>
<tr>
<th>AWG Wire Size</th>
<th>Max Amps</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>18</td>
<td>9</td>
</tr>
<tr>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>10</td>
<td>26</td>
</tr>
<tr>
<td>8</td>
<td>57</td>
</tr>
<tr>
<td>6</td>
<td>76</td>
</tr>
</tbody>
</table>
5: Wire Sizing – Long Wires

- Resistance will determine wire size for longer length wires.
- As current encounters resistance in a wire, a voltage drop occurs.
- AC-43.13 specifies 0.5 volts maximum allowable drop across a wire for 14V systems (ignoring aircraft structure return).
- Incandescent lighting is rated at 13.5V; at 95% voltage only 80% intensity is produced!

<table>
<thead>
<tr>
<th>AWG Wire Size</th>
<th>Resistance (ohms/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>0.03</td>
</tr>
<tr>
<td>22</td>
<td>0.016</td>
</tr>
<tr>
<td>20</td>
<td>0.01</td>
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<tr>
<td>18</td>
<td>0.006</td>
</tr>
<tr>
<td>16</td>
<td>0.005</td>
</tr>
<tr>
<td>14</td>
<td>0.003</td>
</tr>
<tr>
<td>12</td>
<td>0.002</td>
</tr>
<tr>
<td>10</td>
<td>0.0012</td>
</tr>
<tr>
<td>8</td>
<td>0.0007</td>
</tr>
<tr>
<td>6</td>
<td>0.0004</td>
</tr>
</tbody>
</table>
5: Wire Sizing – Long Wires

- Switch SPST
- Wire Resistance
- Fuse
- DC 14V
- Chassis Ground
- Whelen A650 Nav Light
- Chassis Ground

Chassis Ground
5: Wire Sizing – Long Wires

\[ V_{\text{drop}} = I \times R \]

- \( I = \) current in Amps
- \( R = \) resistance in Ohms
5: Wire Sizing – Long Wires

\[ V_{\text{drop}} = I \times R_{\text{pf}} \times L \]

where \( R_{\text{pf}} = \text{Resistance per foot} \)
and \( L = \text{Length, in feet} \)

then...
5: Wire Sizing – Long Wires

\[ V_{\text{drop}} = 2 \times 0.006 \times 20 \]
\[ V_{\text{drop}} = 0.24 \]

Amps = 2 (mfg. data)
Rpf = 0.006 Ohms (18 gauge wire)
Length = 20 feet (SPST to lamp)

- Composite A/C must include return path in calculation!
5: Wire Sizing – Starters

Starter circuits

- Battery voltage at start is 12V, not 14V!
- Consideration must be given to voltage drop across cable, main, and starter solenoids
- A good rule of thumb: firewall 4 AWG, baggage 2 AWG
6&7: Wire Selection

- Choice for aircraft is Tefzel
- MIL-W-22759
- Printed ID along length
- Superior abrasion resistance; exceeds Teflon, PVC
- Superb temperature tolerance; ideal for use firewall forward
- Available in many colors
- Use special strippers that cut the durable jacket but not knick wire (section 12)
6&7: Wire Selection

- RG-400 coaxial cable
- Superior to traditional RG-142 or RG-58
- Double shielded
- Solid polyethylene dielectric
- Tinned copper conductor
- MIL spec
- Lower loss & RFI
8,9&11: Wire/Cable Installation

- Adel clamps, grommets, standoffs, or other means of support no more than 24” apart
- Adequately supporting wire is critical to prevent excessive movement in areas of high vibration or risk terminal fatigue
- Follow guidelines for minimum bend radius
The primary function of a service loop harness is to provide ease of maintenance. The components, mounted in the instrument panel and on the lower console and other equipment that must be moved to access electrical connectors, are connected to aircraft wiring through service loops.” - AC 43.13-1B
12: Wire Insulation

- Additional measures should be taken to provide mechanical protection to wiring from:
  - Abrasion
  - Corrosion (exposure)
  - Flame/Heat
  - Impact
  - Environmental conditions unique to aircraft
12: Wire Insulation - Stripping

- Stripping wire in preparation for terminals, you must
  - Use sharp, quality tools – especially when working with Tefzel
  - Remove no more insulation than is necessary
  - Ensure damage does not exceed limits in 11-13
## 12: Wire Insulation - Stripping

<table>
<thead>
<tr>
<th>Wire Size</th>
<th>Strands</th>
<th>Allowable Nick/brkn</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-24</td>
<td>19</td>
<td>2/0</td>
</tr>
<tr>
<td>10-12</td>
<td>37</td>
<td>4/0</td>
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<tr>
<td>4-8</td>
<td>133</td>
<td>6/6</td>
</tr>
<tr>
<td>1-2</td>
<td>665</td>
<td>6/6</td>
</tr>
</tbody>
</table>
13: Splicing

- Keep to a minimum or avoid altogether!
- Don’t use to fix a mistake; run a new wire
- Use solder sleeves where environment can be a factor
14: Terminals

- Use the exceptional quality AMP PIDG (Pre Insulated Diamond Grip)
- Sleeve crimps both wire and insulation
- Avoid kits found automotive and hardware stores
- The correct crimping tool is ~ $40; integrity of the crimp depends on it!
14: Terminals

- For larger 2 and 4 AWG terminals (starter, battery) soldering is the better choice
- Use T&B die crimpers (best) or impact crimp tool
- Use small butane torch or ~200W soldering iron
- Electronic grade rosin core solder; not plumbers!
- Heat shrink and boot
15: Grounding & Bonding

- Single point grounds eliminate “gremlins”
- “Island of tabs” located at firewall
- Front/rear connections minimize firewall penetrations
- Kits available or roll your own
16: Wire Marking

- Printed paper / heat shrink
- Wire marking cards
- Dymo Rhino Pro 5000
- Sharpie on heat shrink
- Color coded Tefzel

Building a show plane? Mark everything!
Or...don’t mark anything
Once a wire is connected, you know where it’s going!
17: Connectors

- Correct installation is critical to optimum radio performance
- It requires the right tools and right technique
- Amp mil-spec connectors
- Avoid additional connections in wing root & bulkheads (loss)
- Avoid clamps that may distort the cross-section of the cable or “choke”
18: Conduit

- Corrugated riser/plenum rated inner duct makes great aircraft conduit!
- Low smoke/flame propagation is ideal for A/C use
- Sizes from 1” to 2”
- Ribbing allows it to be locked into place and easily supported
- Locating small lengths for A/C use can be difficult to locate (eBay!)
19: Unused Connectors & Wires

- Firewall and avionics connectors should have unused cavities filled with spare contacts or stubs.
- Remove unused wires from avionics plugs – a ~22” wire extending from an RS232 DSUB acts like an aircraft band antenna!
20: Symbology

- Symbols are standardized based on ANSI (American National Standards Institute) Y32.2-1975
Resources

- FAA AC-43.13b [www.faa.gov](http://www.faa.gov)
- Bob Knuckols, Aeroelectric Connection, [www.aeroelectric.com](http://www.aeroelectric.com)
- Greg Richter, Aircraft Wiring for Smart People, [www.bluemountainavionics.com](http://www.bluemountainavionics.com)
- Stein Bruch [www.steinair.com](http://www.steinair.com)
- Bill Bainbridge [www.bandcspecialty.com](http://www.bandcspecialty.com)
- Aircraft Spruce [www.aircraftspruce.com](http://www.aircraftspruce.com)
Q&A?