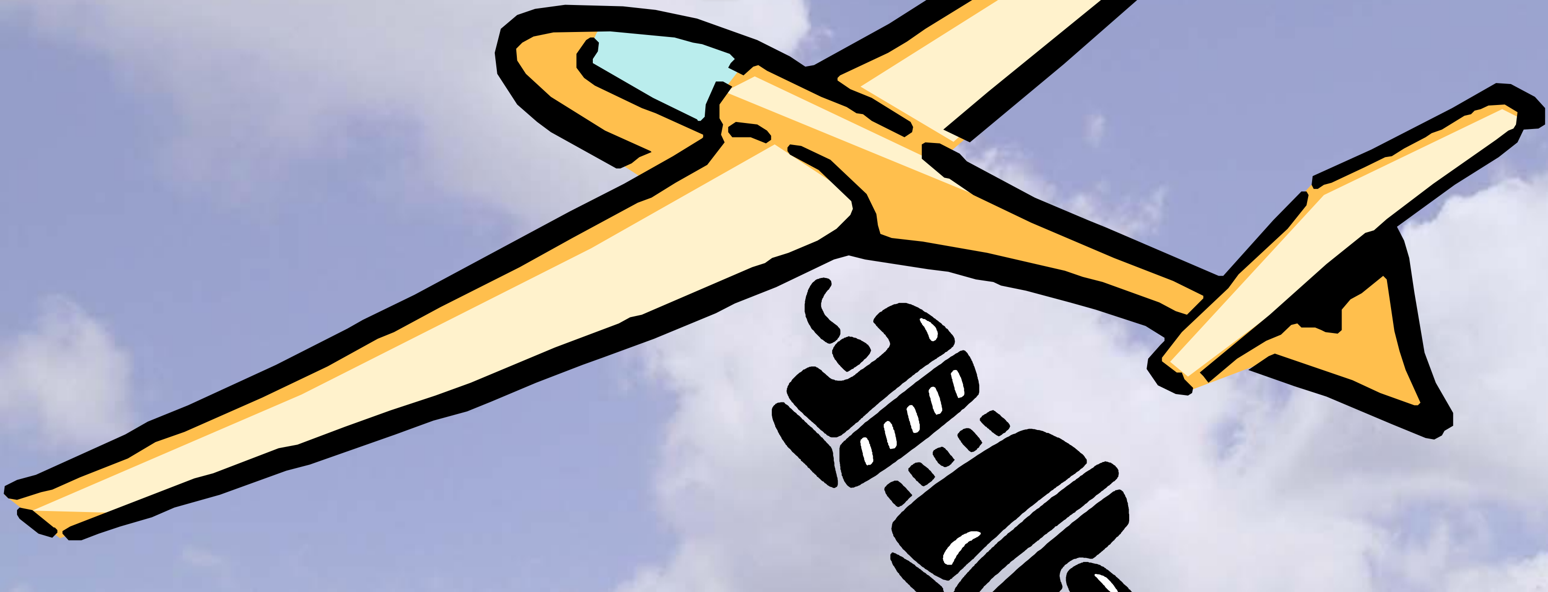
Soaring Aviation Electrical "Best Practices" Series

[Part 3 of 3]



John DeRosa OHM Ω
Updated: January 26, 2024

PLEASE NOTE

This document may have been updated with new information, changes, and corrections.

Be sure to visit my presentation web site and download the latest version of this document. It could make an important difference to your work!

http://aviation.derosaweb.net/presentations

Thank you, John

Disclaimers

- I am **not** an FAA licensed A&P or IA
- I am **not** an approved avionics technician
- You should know the difference between Experimental & Standard airworthiness certification, and what you can and cannot do to your glider
- Work closely with an IA to get your work properly inspected and signed off in your glider’s log book
- Proceed at your own risk.

Chapters

Part 1

1. Reference Information
2. Your Tool Box
3. Wires and Wiring
4. Making Connections
5. Other Things of Note

Part 2

6. Power Management

Part 3

7. **Examples of Battery Bus Sys.**
8. **Minimizing Lost Volts**
9. **Providing USB Power**

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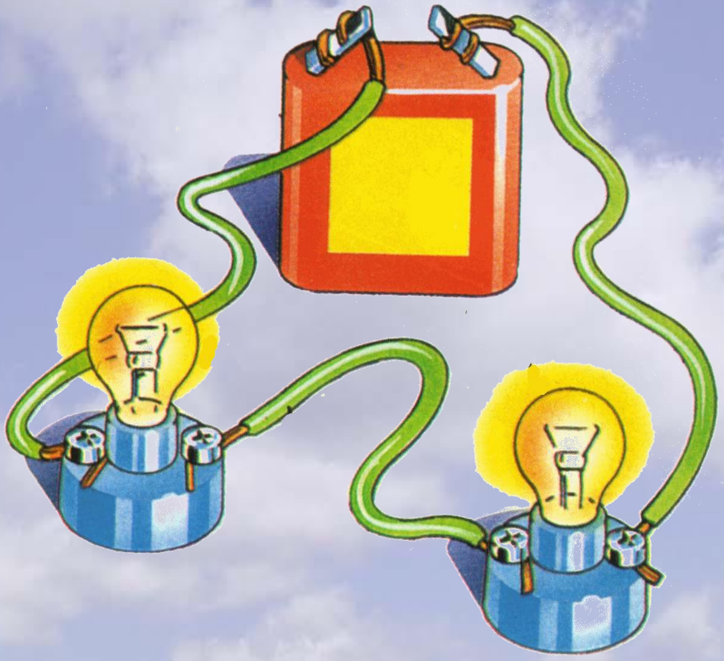
- Proceed at your own risk
- **'Nuff said, let's get started…**

Chapter 7

Examples of Battery Bus Systems



Examples of Battery Bus Systems

Single and Dual Battery Bus Systems

My General Comments

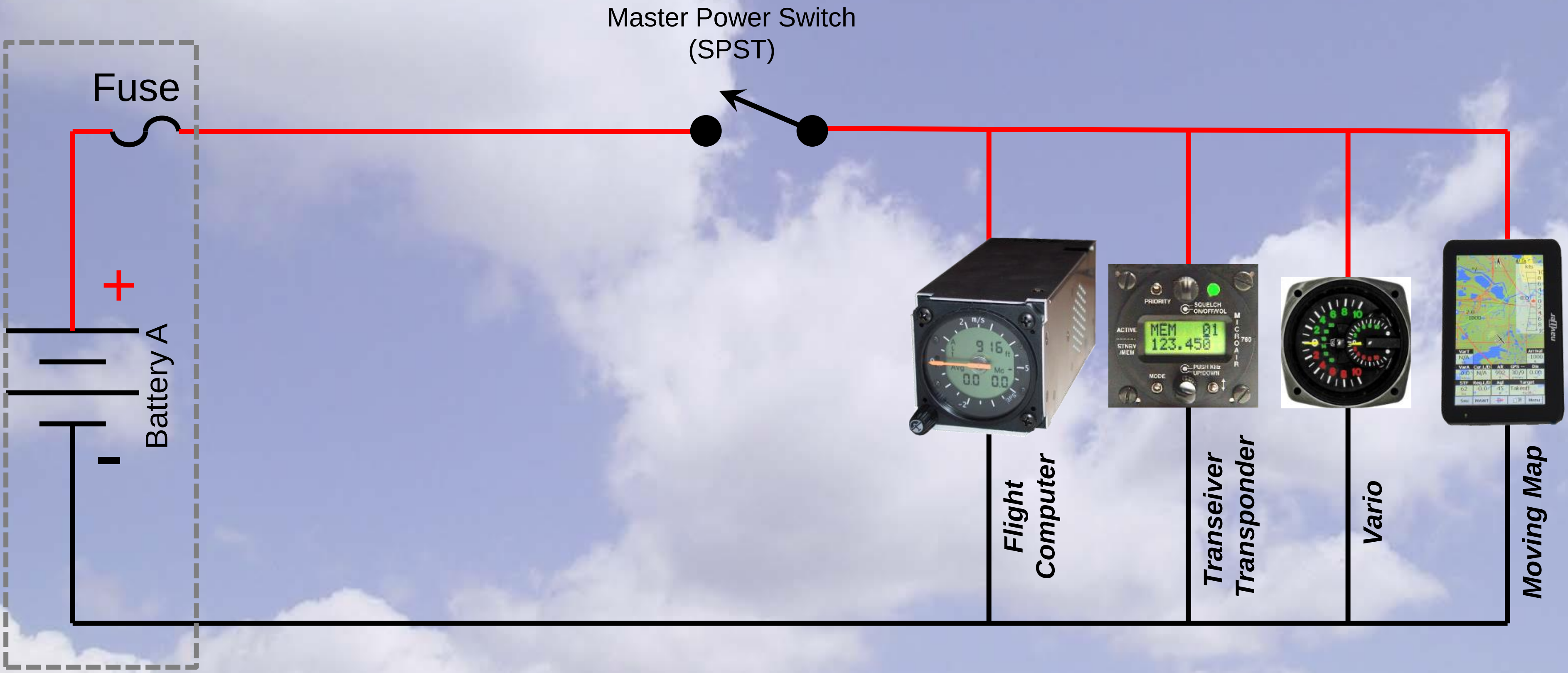
1) ***All systems must have a master switch easily accessible to the pilot on the panel.***
2) ***All batteries <u>must have a fuse</u> connected directly to their positive terminal.***
3) ***I prefer breakers, rather than a fuses, used for the main power bus.***
4) ***All fuses and breakers should be 5A or greater - see <u>Chapter 8</u> for reasoning.***
5) ***I don't feel that separate fuses for each device, or group of devices, is needed.***

Examples of Battery Circuitry

Basic Single Battery Bus Systems

Sample Power Bus Systems

Single Battery Switching



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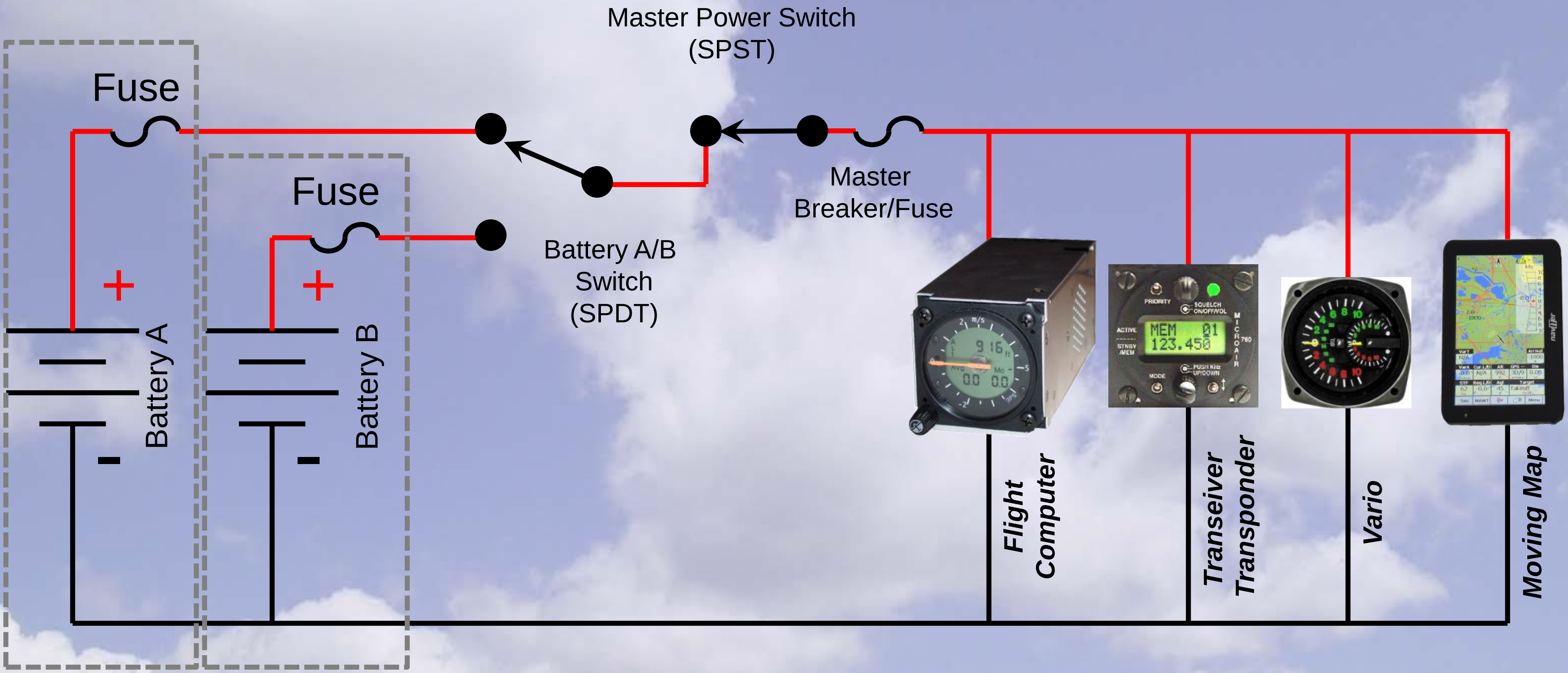
Examples of Battery Bus Systems

Dual Battery Bus Systems

Sample Power Distribution Circuits

Simple Dual Battery Switching



Master Power Switch
(SPST)

Fuse

Fuse

Master
Breaker/Fuse

Battery A/B
Switch
(SPDT)

+

+

Battery A

Battery B

-

-

Flight Computer

Transeiver Transponder

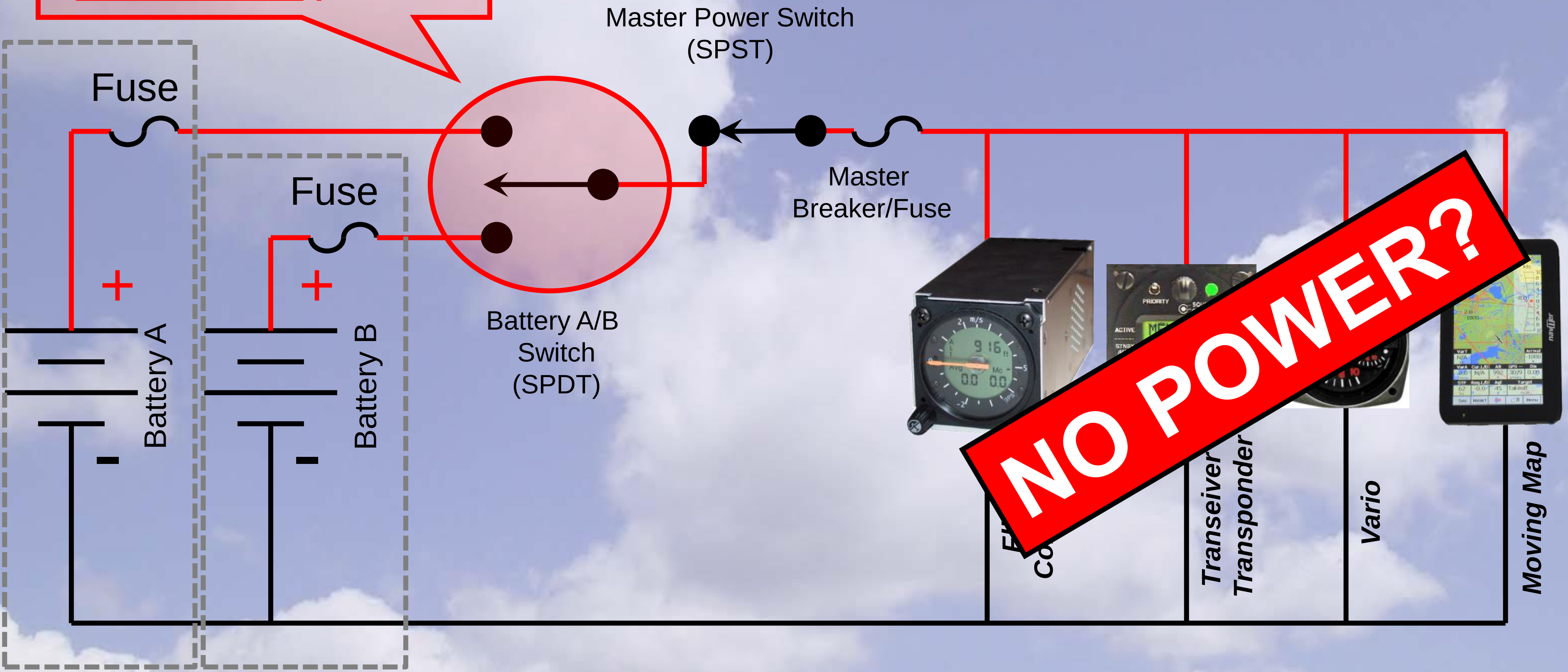
Vario

Moving Map

Sample Power Distribution Circuits

Problem - Dual Battery Switching

Switch is momentarily in the half-way disconnected position



Master Power Switch (SPST)

Fuse

Fuse

+

+

-

-

Battery A

Battery B

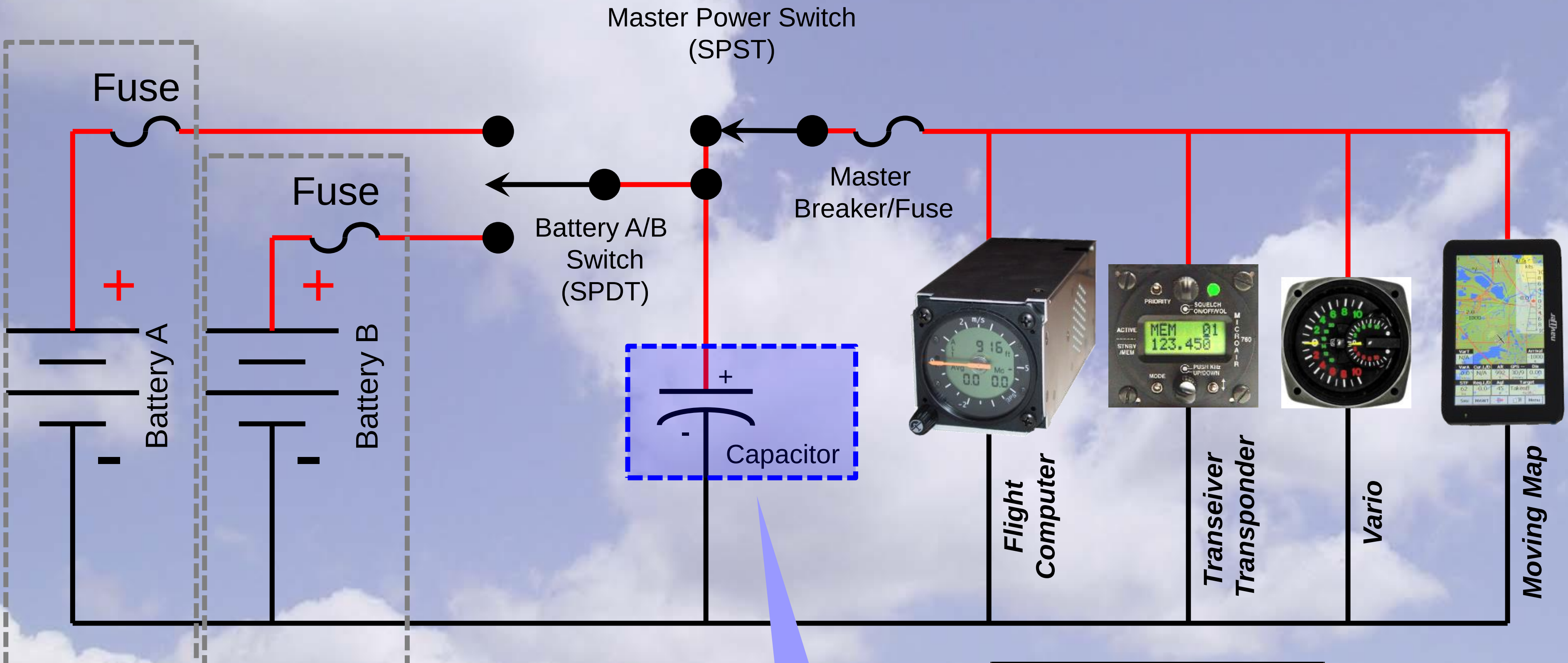
Battery A/B Switch (SPDT)

Master Breaker/Fuse

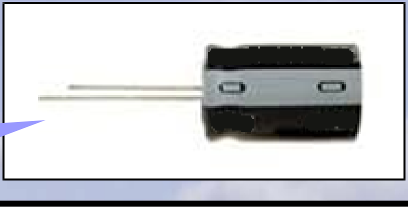
NO POWER?

Sample Power Distribution Circuits

Solution for Dual Battery Switching



During switching the electrolytic capacitor will hold a charge for a short period of time and should prevent the instruments from loosing power. The value should be very large (100,000uf or larger) and rated at 20Vdc or higher. Watch the polarity!



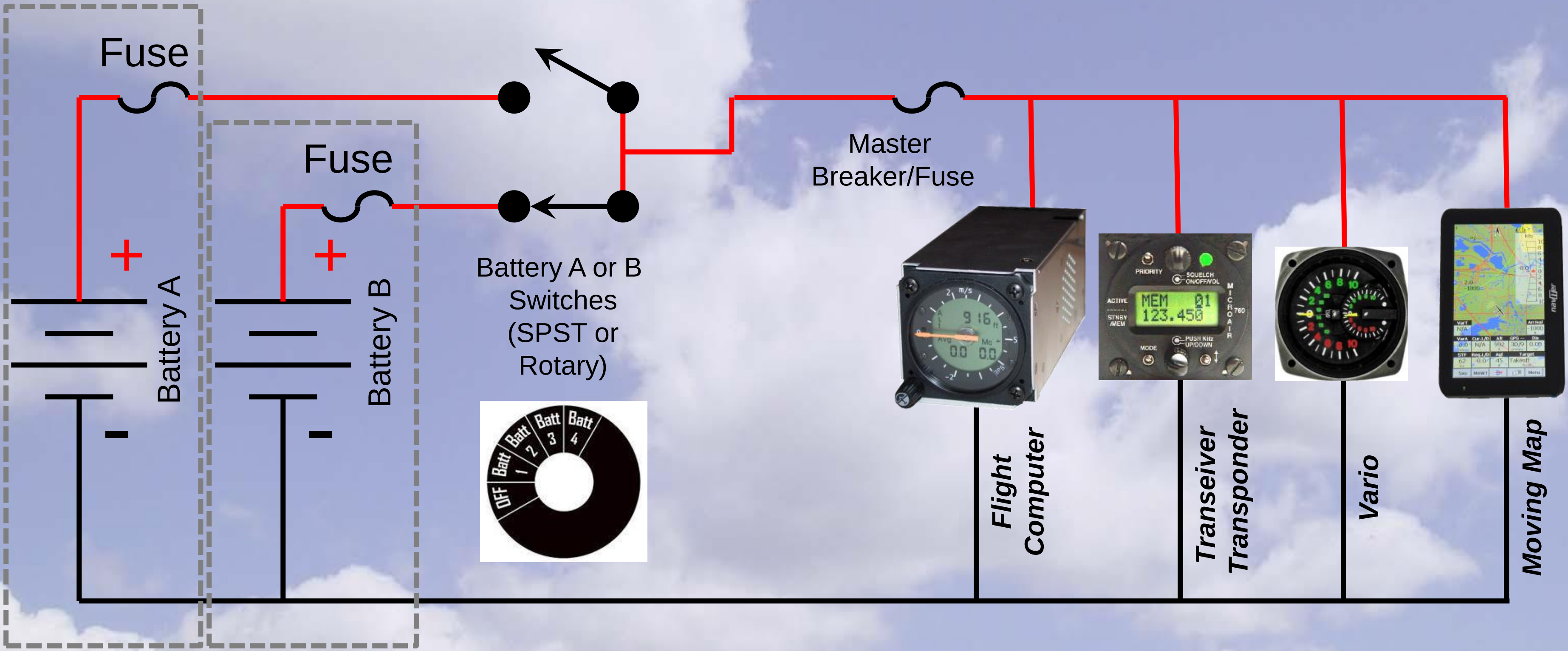
🡐 Note the negative polarity symbol on the capacitor

Examples of Battery Bus Systems

Better Two (2) Battery Bus Systems

Sample Power Distribution Circuits

Dual Battery Switching/Bridging

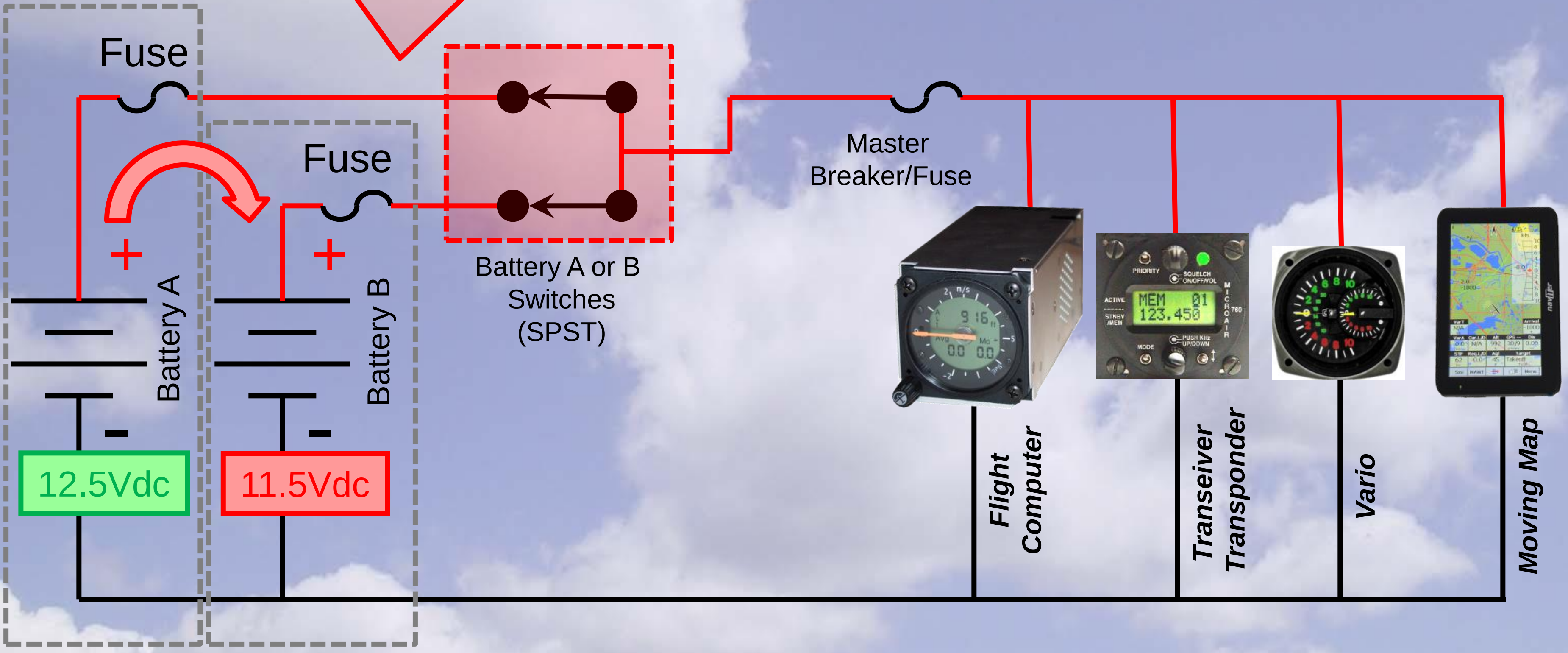


- Having two switches allows either battery to power the power bus. And allows a smooth transition from one battery to the other by momentarily connecting both batteries to the bus.

Sample Power Distribution Circuits

Problem - Dual Battery Bridging

When both switches are closed the batteries are “bridged” and can cross-charge one another if they are at a different state of charge. This may cause a current surge, blown fuses, battery damage, or worse.

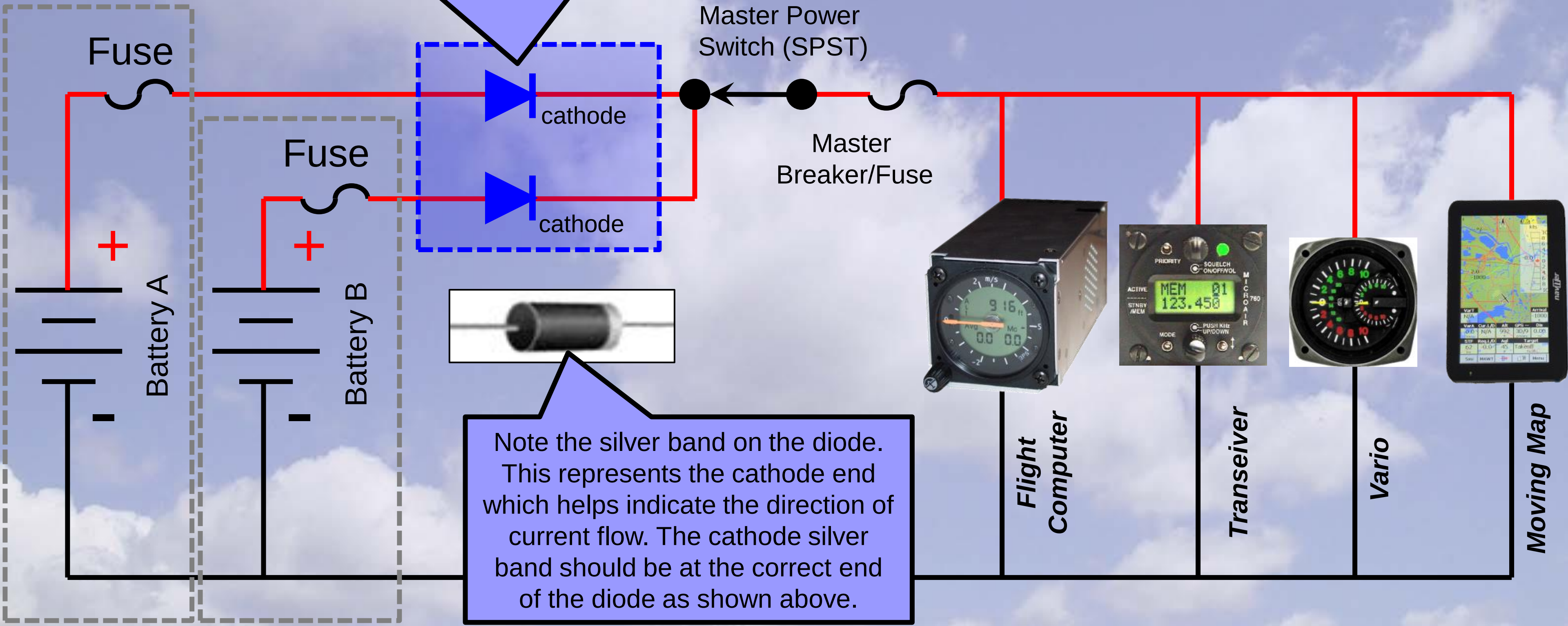


Sample Power Distribution Circuits

Solution - Dual Battery Bridging

The diodes prevent current surges by not allowing the batteries to cross-charge each other while still allowing either battery (the one with the most charge) to supply power to all the instruments

More details about this topic in Chapter 8.



Note the silver band on the diode. This represents the cathode end which helps indicate the direction of current flow. The cathode silver band should be at the correct end of the diode as shown above.

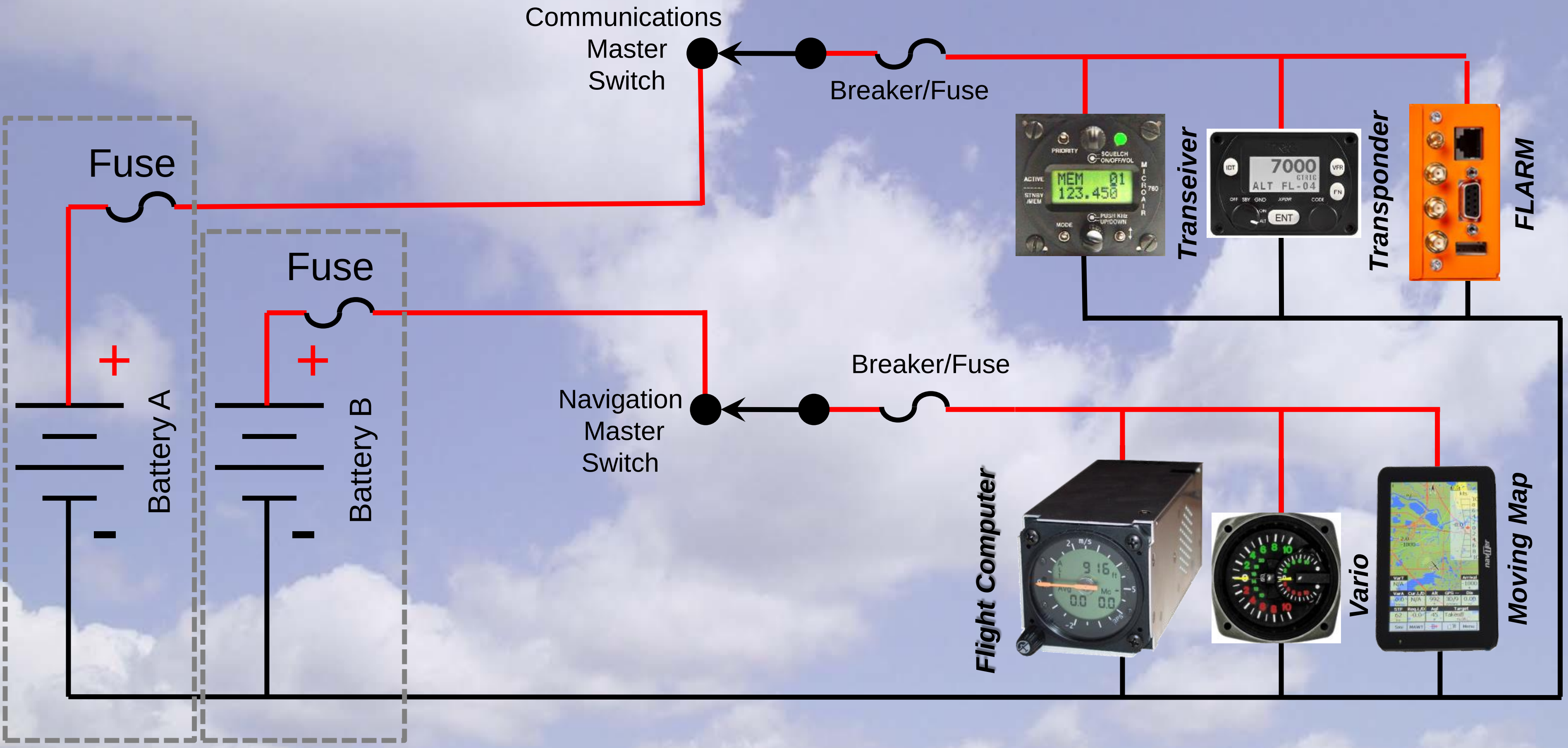
Examples of Battery Circuitry

Advanced Two (2) Battery Bus Systems

Sample Power Distribution Circuits

Separate Buses For Communications & Navigation

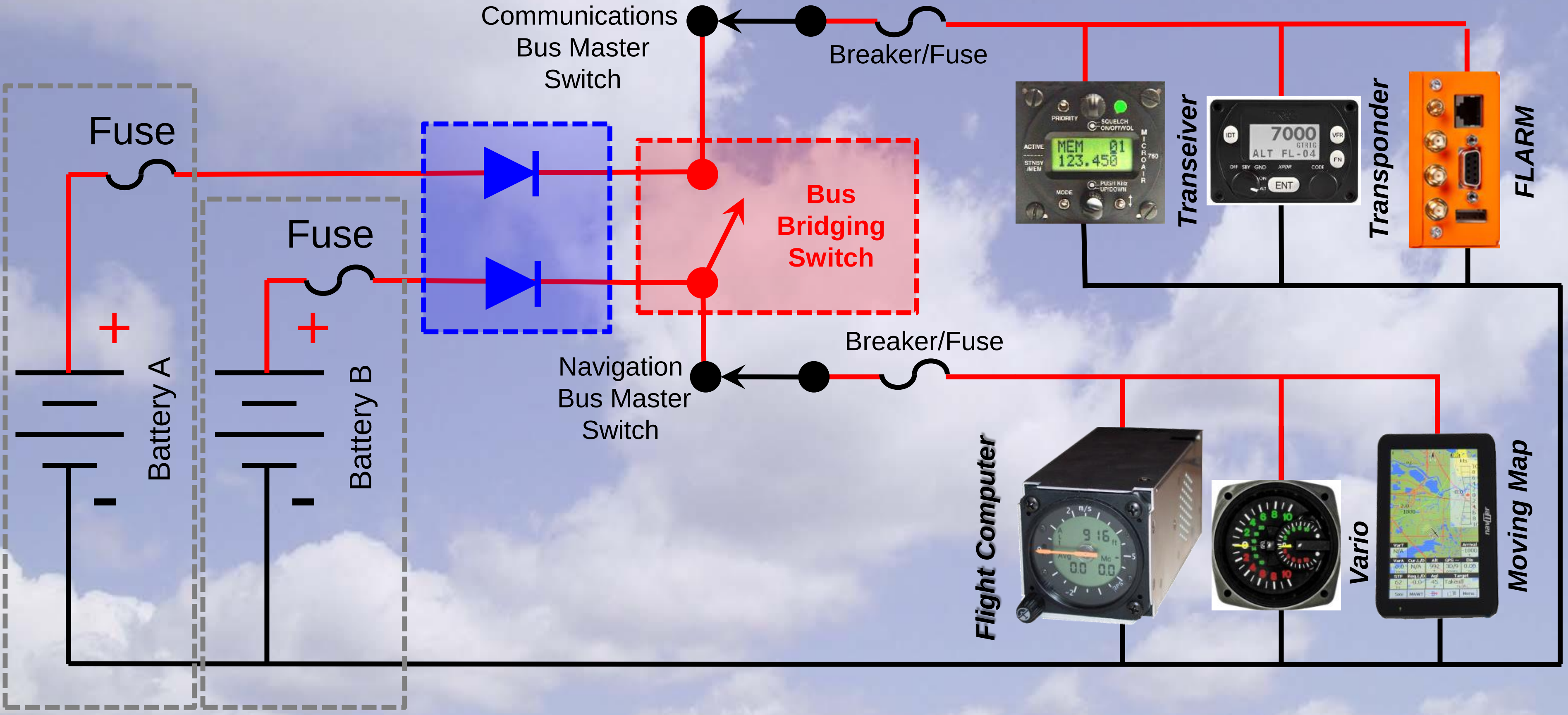
- Splitting a single power bus into two buses for 1) Communications and 2) Navigation equipment has the advantage of allowing different battery densities (amp-hours) for heavily utilized and critical avionics.



Sample Power Distribution Circuits

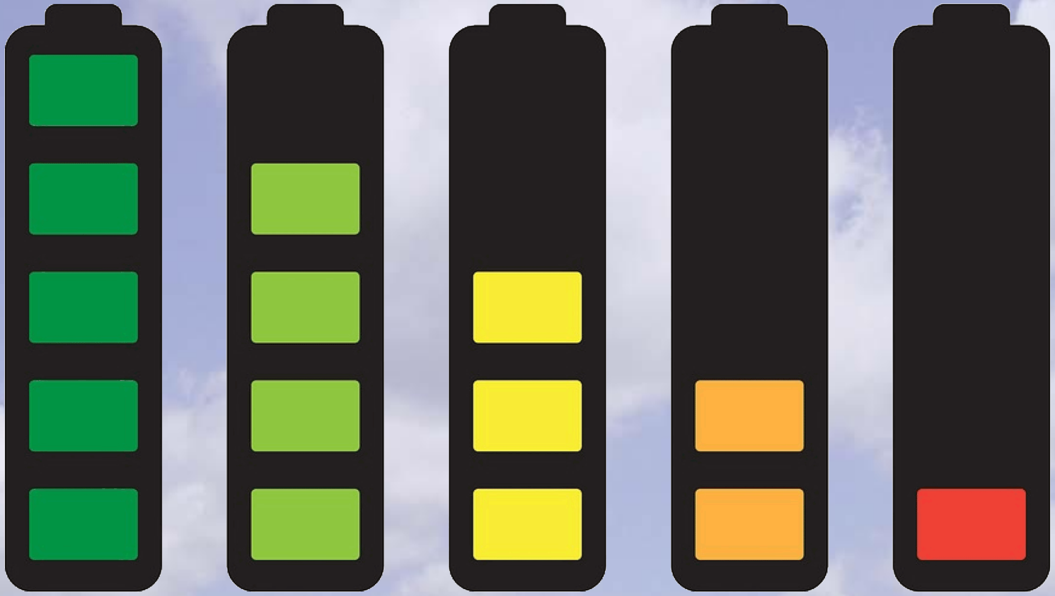
Dual Battery with Split Bus Bridging

- Bridging of the Communication and Navigation buses has the advantage of allowing for either battery to power either bus.
- This can be useful if one battery is “dead” allowing the pilot to choose which avionics is the most critical at the moment.
- While bridging the buses the battery with the highest voltage provides 100% of the power for both buses.



Chapter 8

Minimizing Lost Volts



Losing Volts & What to Do About It!

- Glider avionics need as much voltage as possible across their terminals because they don’t have generators or alternators.
- As the battery voltage goes down, the amps required goes up;
  - Power (watts) is always stays the same for a given device;
    - Power (W) = Voltage (V) times Amps (A)
  - As the voltage drops, current increases to maintain the power required
  - Higher current requirements may need larger wiring or battery or both
- Glider power systems can lose volts in many insidious ways. This means that devices may fail during long flights to operate poorly or not operate at all.
- Where do we “lose” volts & what can we do about it?

• Battery Types	(discharge “droop”)
• Too Small Wire gauge	(resistance per foot)
• To Small of Breaker/Fuse	(resistive load)
• Poor Connections & Grounding	(corrosion resistance)
• Cross Current Diode Types	(voltage drop)

Importance of Wire Size

Energy Source

Power Wiring

14ga wire

12ga wire

10ga wire

EVIL Wire Resistance!!

Devices

Incandescent Lights

Microwave

Electric Stove

As the Device's Power (W) increases the wire's resistance and gauge becomes important

Increased wire gauge means less resistance, less lost volts and more power!

Importance of Wire Size

Energy Source

Power Wiring

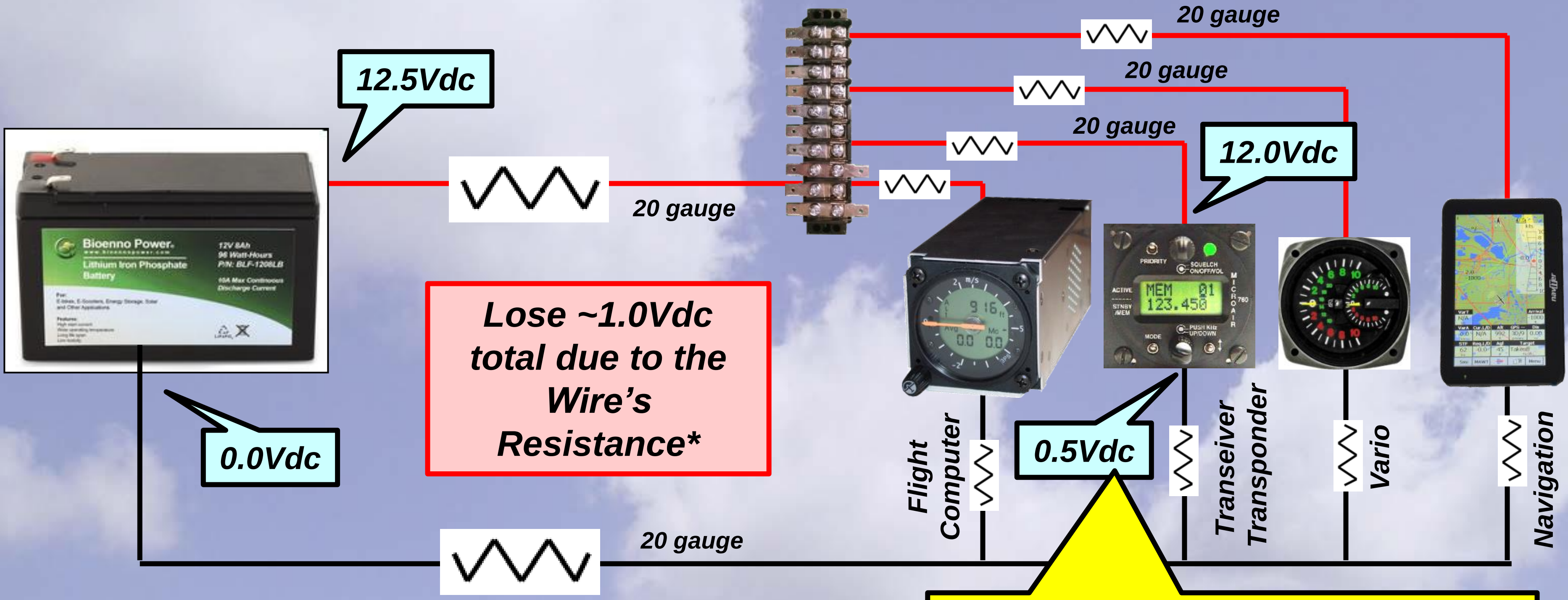
Evil Wire Resistance

Devices

The wire's resistance throws the battery's energy away as lost heat (and lost volts)

Device's current requirements can be thought of as it's own "Resistance"

Loosing Volts – <u>**20ga**</u> Example



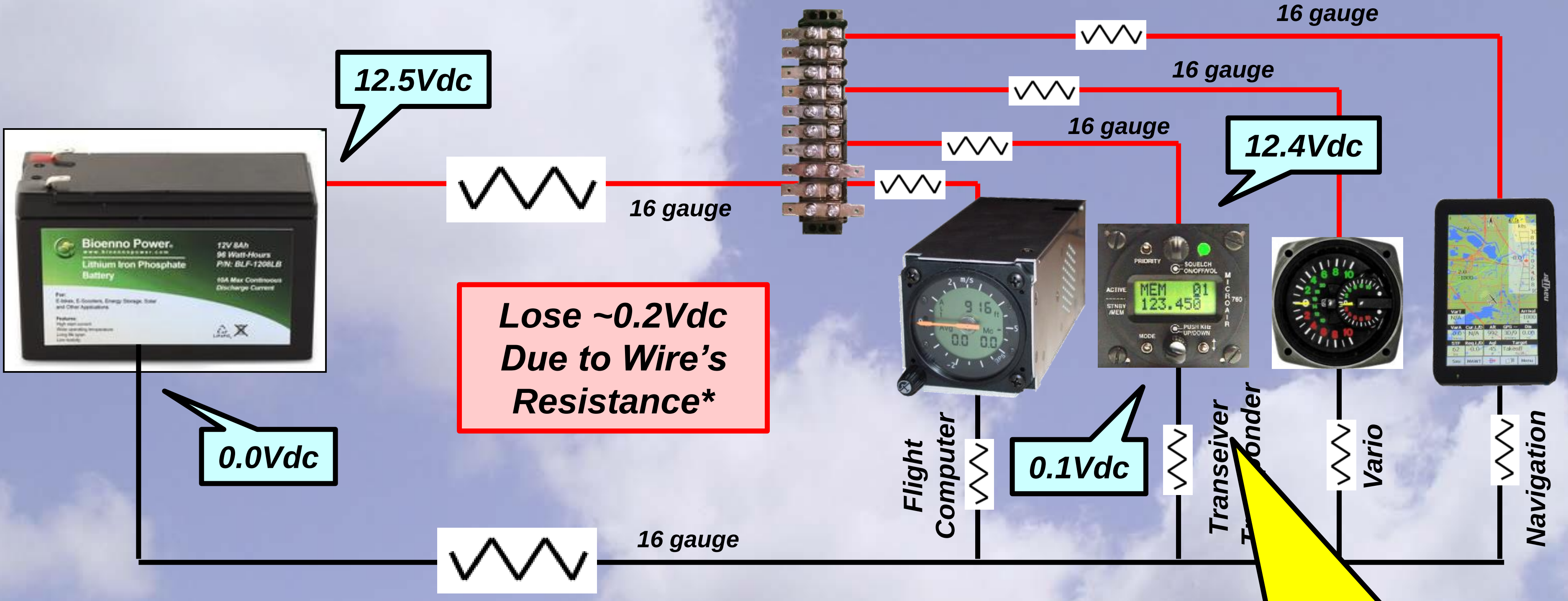
Lose ~1.0Vdc total due to the Wire's Resistance*

In this example the instruments have only 11.5Vdc across their terminals.

Voltage Drops Throws BATTERY Energy Capacity AWAY as Heat!

*Assumes 20ga, 20 feet of wire total, 12.5Vdc Battery, 1A Load
http://www.calculator.net/voltage-drop-calculator.html

Loosing Volts – **16ga** Example



Lose ~0.2Vdc Due to Wire's Resistance*

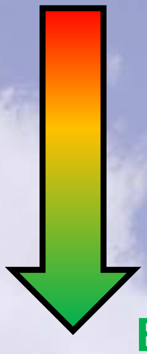
In this example the instruments have 12.3Vdc across their terminals.

- Voltage drops get worse as you increase the amount of current instruments are drawing, especially;
  - Transceivers keyed and transmitting
  - Transponders being interrogated (transmitting)
  - Sunlight readable brighter displays

*Assumes 16ga, 20 feet total, 12.5Vdc Battery, 1A load
http://www.calculator.net/voltage-drop-calculator.html

Loosing Volts - Wire Size

- How Wire Gauge Impacts Voltage Drop*
  - 24 gauge = ~1.0 volt lost
  - 20 gauge = ~0.5 volt lost
  - 18 gauge = ~0.3 volt lost
  - 16 gauge = ~0.2 volt lost
  - 14 gauge = ~0.1 volt lost
  - 12 gauge = ~0.06 volt lost



Worse

Better

*Assumes 20 feet of wire total, 12.5Vdc Battery, 1A Load
http://www.calculator.net/voltage-drop-calculator.html

Resistance of Wires

From FAA AC43-13-1B (Table 11-9)

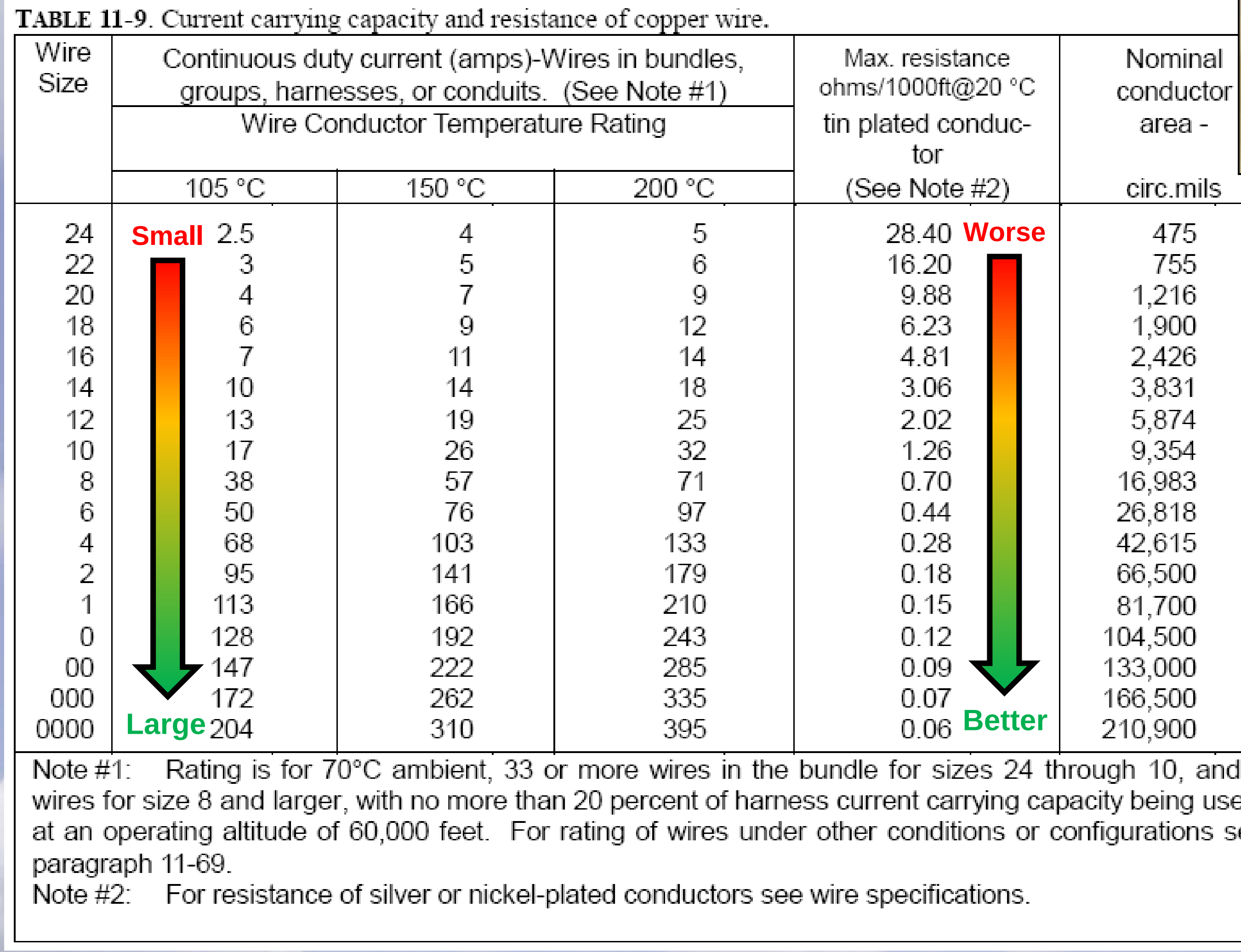


TABLE 11-9. Current carrying capacity and resistance of copper wire.

Wire Size	Continuous duty current (amps)-Wires in bundles, groups, harnesses, or conduits. (See Note #1) Wire Conductor Temperature Rating			Max. resistance ohms/1000ft@20 °C tin plated conductor (See Note #2)	Nominal conductor area - circ.mils
	105 °C	150 °C	200 °C		
24	2.5	4	5	28.40	475
22	3	5	6	16.20	755
20	4	7	9	9.88	1,216
18	6	9	12	6.23	1,900
16	7	11	14	4.81	2,426
14	10	14	18	3.06	3,831
12	13	19	25	2.02	5,874
10	17	26	32	1.26	9,354
8	38	57	71	0.70	16,983
6	50	76	97	0.44	26,818
4	68	103	133	0.28	42,615
2	95	141	179	0.18	66,500
1	113	166	210	0.15	81,700
0	128	192	243	0.12	104,500
00	147	222	285	0.09	133,000
000	172	262	335	0.07	166,500
0000	204	310	395	0.06	210,900

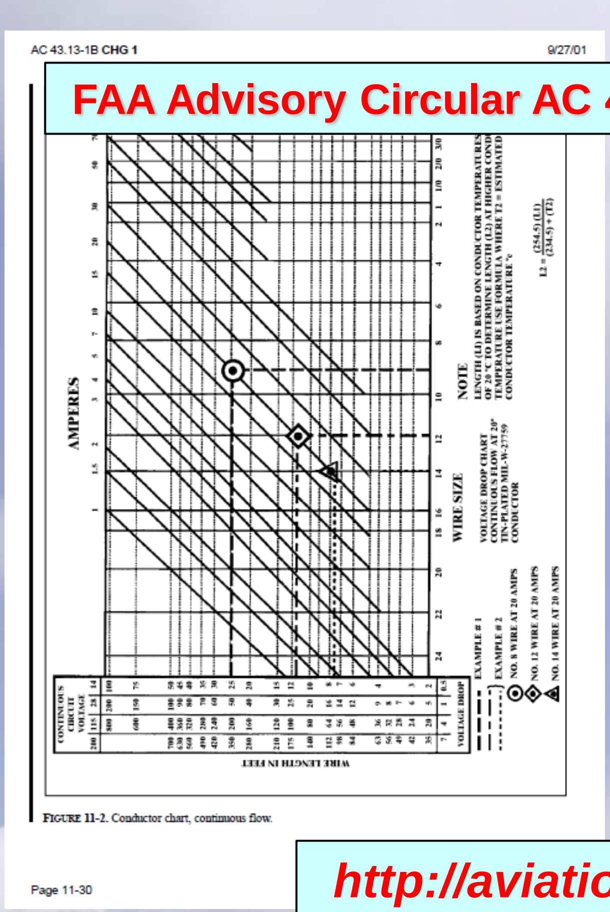
Note #1: Rating is for 70°C ambient, 33 or more wires in the bundle for sizes 24 through 10, and 9 wires for size 8 and larger, with no more than 20 percent of harness current carrying capacity being used, at an operating altitude of 60,000 feet. For rating of wires under other conditions or configurations see paragraph 11-69.

Note #2: For resistance of silver or nickel-plated conductors see wire specifications.

Selecting Correct Wire Gauge

As per the FAA Advisory Circular AC 43-13-1b

FAA Advisory Circular AC 43-13-1b, Chapter 11, Section 5, “Electrical Wire Rating”



AC 43.13-1B CHG 1 9/27/01

FIGURE 11-2. Conductor chart, continuous flow.

Page 11-30

To Learn More ➔ Read *“Selecting Wire”*
by Thomas Inman
in *Avionics News*, July 2020 Issue

series

THEORY & PRACTICE

BY THOMAS INMAN

Selecting Wire

http://aviation.derosaweb.net/presentations/documents/Avionics_News_Selecting_Wire_July_2020.pdf

“Suggested” Wire Gauges

Must Comply with FAA Advisory Circular AC 43-13-1b

- **12 to 14 gauge** - Main power lead from battery to power bus
- **16 to 20 gauge** - Power leads from power bus to individual devices
- **20 to 22 gauge** - Speaker wiring
- **22 to 26 gauge -** Control wires such as push-to-talk, air brake warning switches, flap switches, etc
- **Hint:** Leave extra length (slack) in the cables for future changes and modifications

Glider Power Wiring Quote for the Day

“It ain’t the current load that’s gonna’ get ya’ on that long flight. It’s the voltage drop!”

(More on this Subject Later Slides)

Where Else Do We Lose Volts?

Fuses

Breakers

Diodes

Circuit Protection Requirements

Reference

FAA Circular AC 42-13-1B

Chapter 11

Table 11-3

FAA Suggests <u>5 amps</u> is the <u>MINIMUM</u> for Breaker & Fuse Sizing

Using small amperage breakers and fuses less than 5A will cause a loss of voltage at your avionics increasing the current draw.

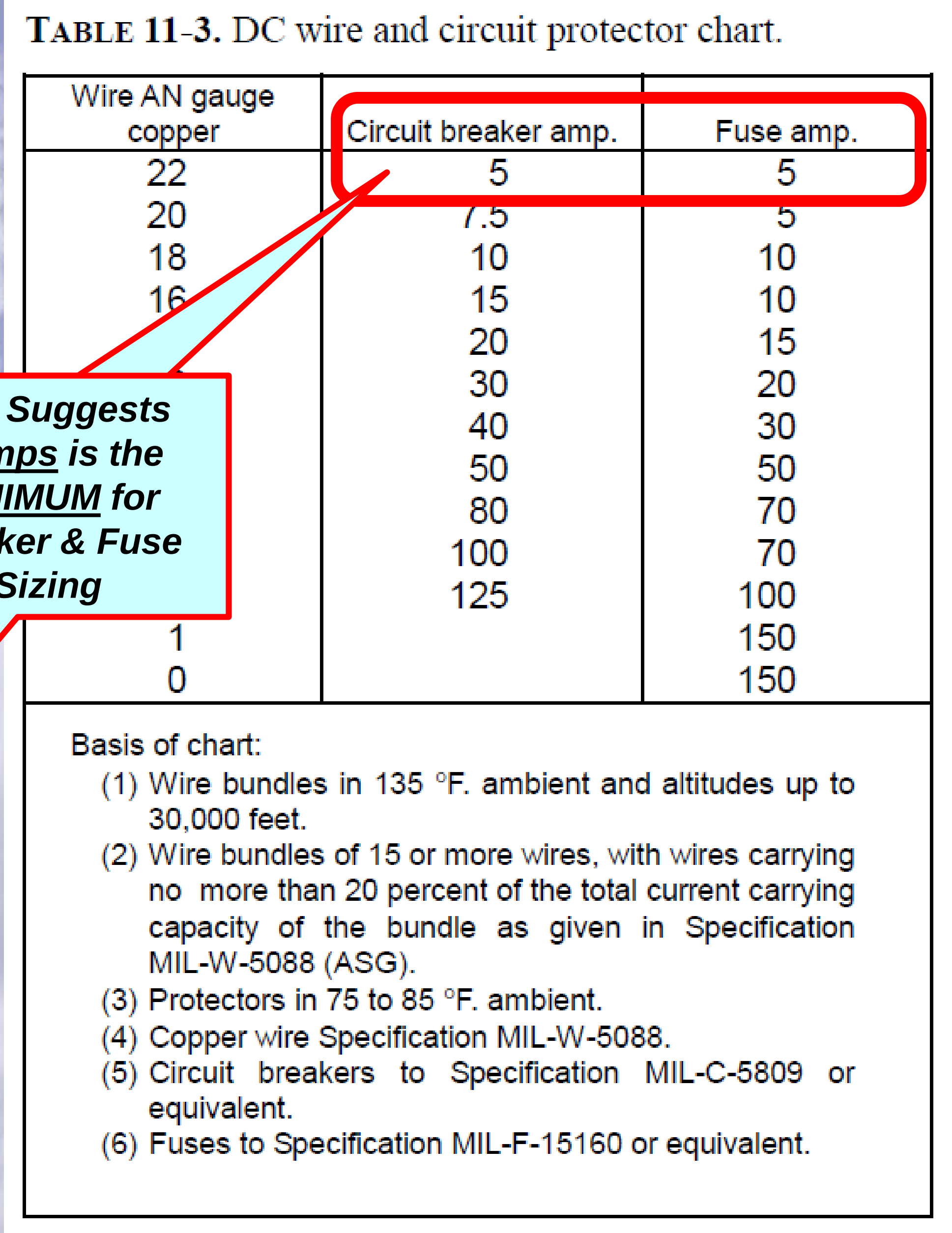


TABLE 11-3. DC wire and circuit protector chart.

Wire AN gauge copper	Circuit breaker amp.	Fuse amp.
22	5	5
20	7.5	5
18	10	10
16	15	10
	20	15
	30	20
	40	30
	50	50
	80	70
	100	70
	125	100
1		150
0		150

Basis of chart:

(1) Wire bundles in 135 °F. ambient and altitudes up to 30,000 feet.

(2) Wire bundles of 15 or more wires, with wires carrying no more than 20 percent of the total current carrying capacity of the bundle as given in Specification MIL-W-5088 (ASG).

(3) Protectors in 75 to 85 °F. ambient.

(4) Copper wire Specification MIL-W-5088.

(5) Circuit breakers to Specification MIL-C-5809 or equivalent.

(6) Fuses to Specification MIL-F-15160 or equivalent.

Loosing Volts - Fuses

Example: Common Eaton/Bussman AGC Fuse

Specification Source: http://www.cooperindustries.com/content/dam/public/bussmann/Electronics/Resources/product-datasheets/Bus_Elx_DS_OC-2543_AGC_Series.pdf

Fuse Size (Model)	**Typical DC Cold Resistance**	**Typical Voltage Drop** (at 1A load)
1 amp (AGC-1-R)	0.190Ω	0.190 Vdc
2 amp (AGC-2-R)	0.078Ω	0.078 Vdc
3 amp (AGC-3-R)	0.045Ω	0.045 Vdc
4 amp (AGC-4-R)	0.030Ω	0.030 Vdc
5 amp (AGC-5-R)	0.024Ω	0.024 Vdc
10 amp (AGC-10-R)	0.008Ω	0.008 Vdc

Avoid

OK to Use

Loosing Volts - Breakers

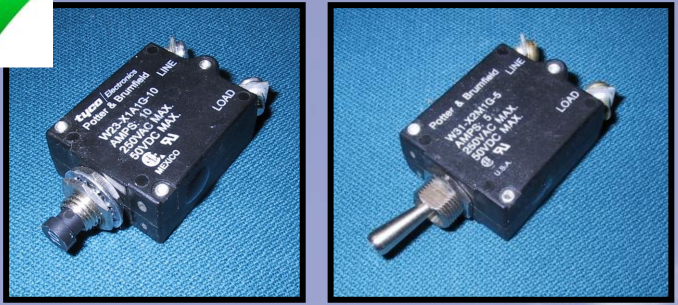
Klixon 7277/7274 Breakers Voltage Drop

Rating	Max. Voltage Drop
½	2.00Vdc
¾	1.45Vdc
1	1.10Vdc
1½	0.75Vdc
2	0.70Vdc
2½	0.50Vdc
3	0.33Vdc
4	0.30Vdc
5	0.25Vdc
7½	0.20Vdc
10	0.15Vdc
15	0.15Vdc
20	0.15Vdc

Do Not Use

OK to Use

✓



Tyco W23 & W31 Breakers Voltage Drop

Rating	Max. Voltage Drop	Resistance
1	0.61 Vdc	0.61
5	0.15 Vdc	0.03
10	0.1 Vdc	0.01
15	0.09 Vdc	0.006
20	0.08 Vdc	0.004
30	0.09 Vdc	0.003
40	0.08 Vdc	0.002
50	0.1 Vdc	0.002

Loosing Volts - Breakers

All Electronic Breakers

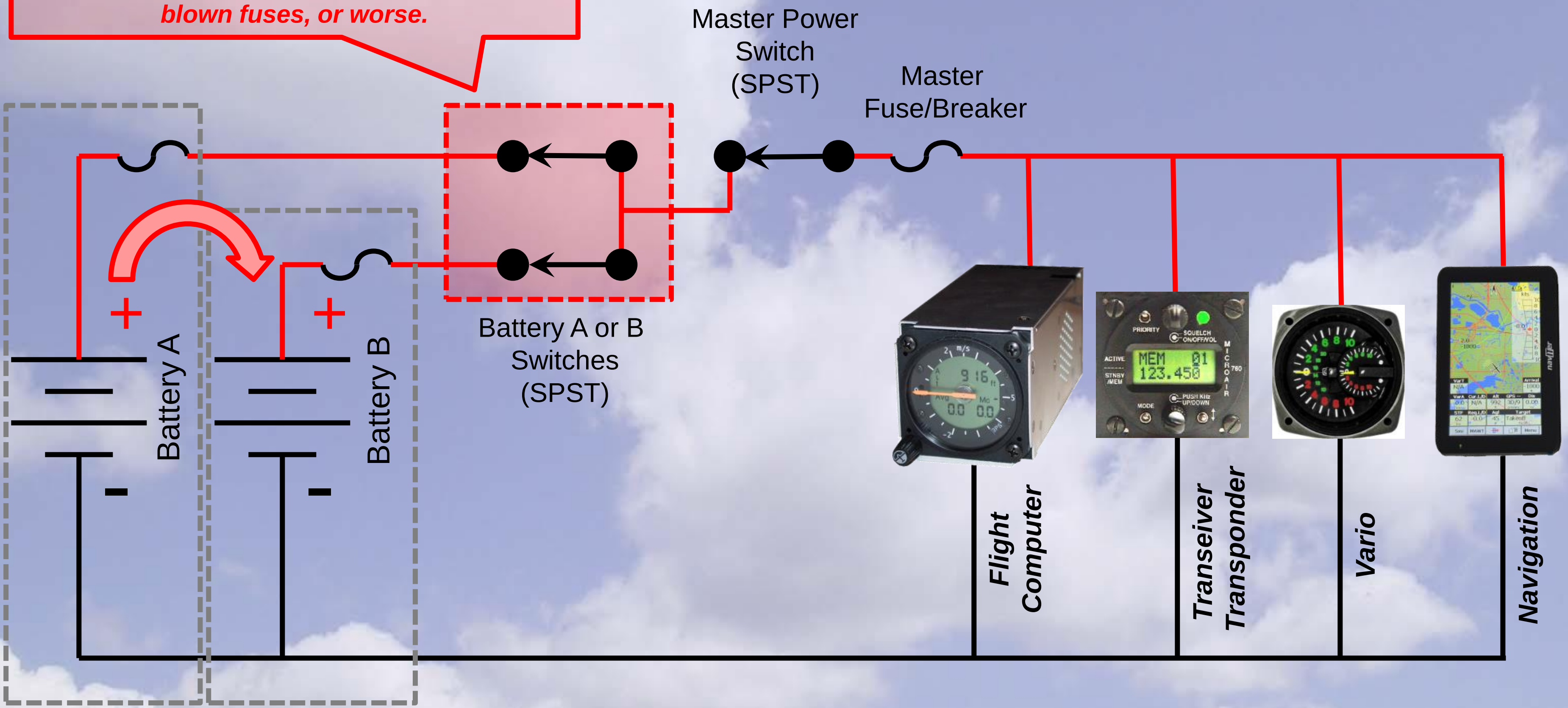
Source: http://www.bridgingworlds.com/

- **Pros**
  - *0.1Vdc Voltage Drop*
  - *Over Current*
  - *Under & Over Voltage*
- **Cons**
  - *Large*
  - *Expensive $$$*

Sample Power Distribution Circuits

Dual Battery Switching

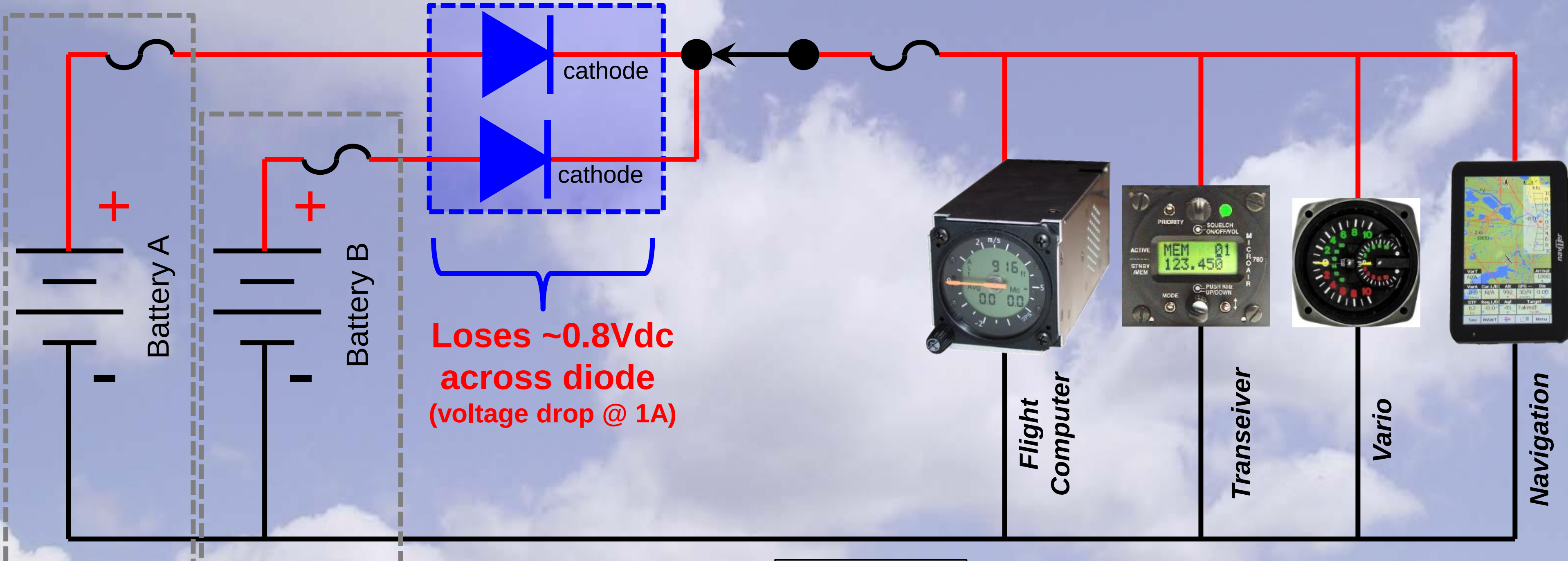
When both switches are closed the batteries are "bridged" and can cross-charge one another if they are at a different state of charge. This may cause a current surge, blown fuses, or worse.



Sample Power Distribution Circuits

Prevent Dual Battery Cross Charging

Silicon Diodes – 1N4001



Loses ~0.8Vdc across diode
(voltage drop @ 1A)

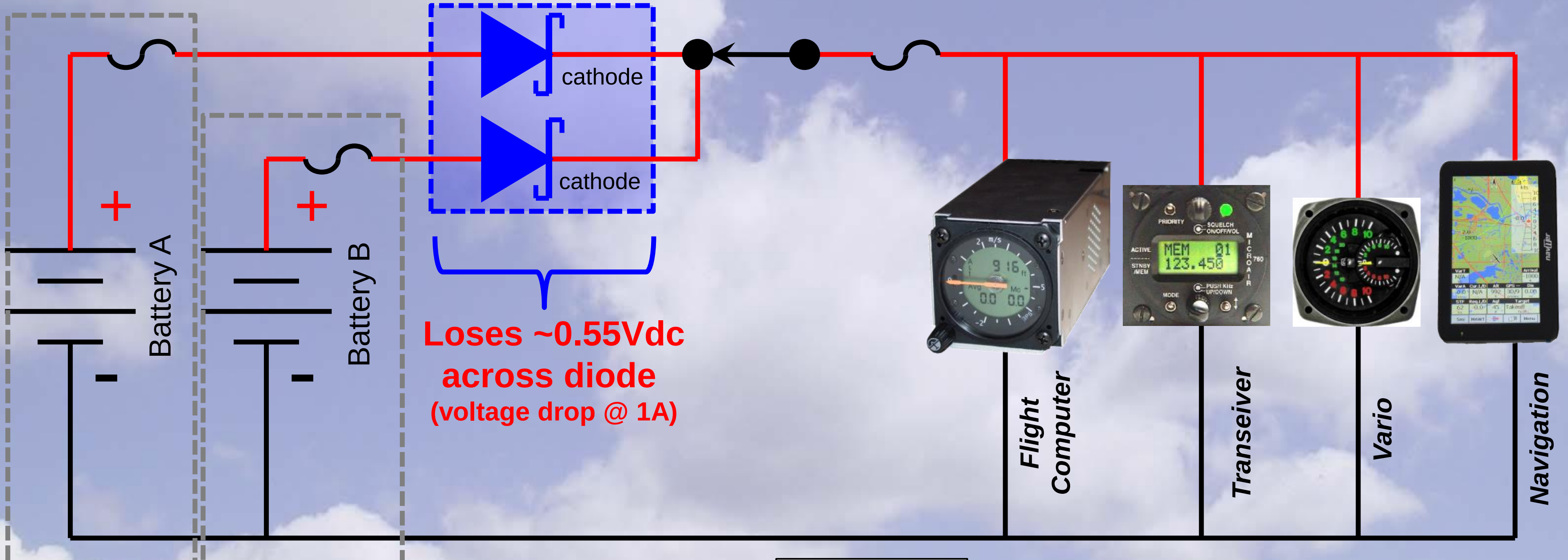
Source: Search eBay for "1N4001 Diode"
Cost: $0.20 per diode

🡐 Note the silver band on the diode. This represents the cathode end which helps indicate the direction of current flow. The cathode silver band should be at the correct end of the diode as shown above.

Sample Power Distribution Circuits

Prevent Dual Battery Cross Charging

Schottky 5A Diodes - 1N5824 (5A 21V)



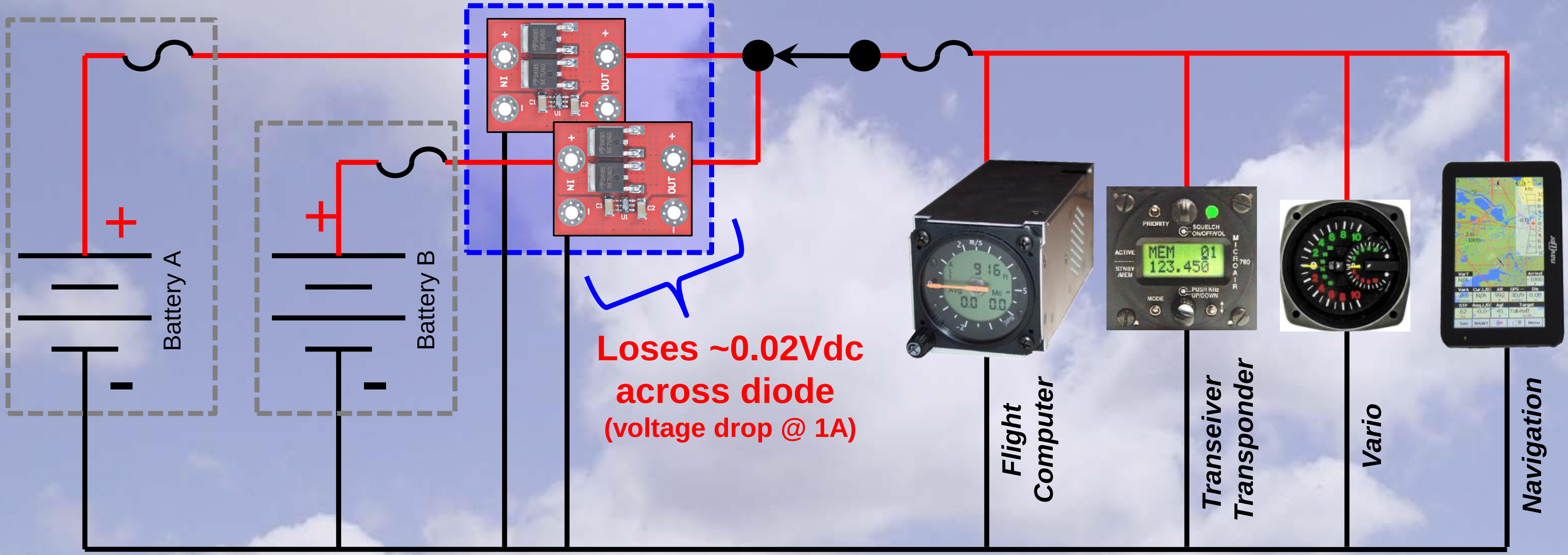
Loses ~0.55Vdc across diode
(voltage drop @ 1A)

Source: Search eBay for "1N5824 Diode"
Cost: ~$1.00 per diode

🡐 Note the silver band on the diode. This represents the cathode end which helps indicate the direction of current flow. The cathode silver band should be at the correct end of the diode as shown above.

Sample Power Distribution Circuits

Prevent Dual Battery Cross Charging



"Ideal Diodes"

(Loses ~0.02Vdc across diode)

Loses ~0.02Vdc across diode

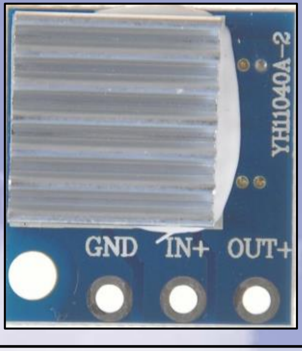
(voltage drop @ 1A)

Source: eBay - Search for "Ideal Diode"
Cost: $6 to $25 per diode

Sample Power Distribution Circuits

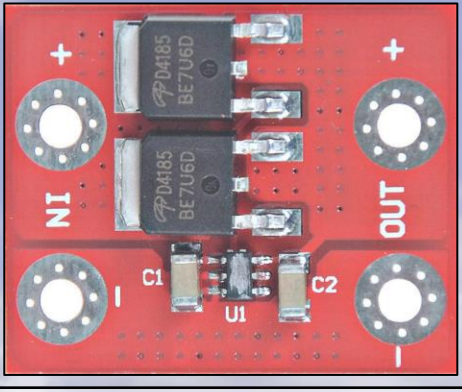
Idea Diode – Various Styles

Voltage Drop = 0.029Vdc

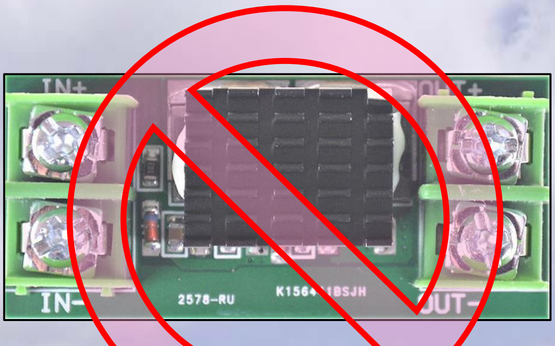


Voltage Drop = 0.005Vdc

Measured Voltage
Drop Across
Terminals from
12Vdc Source
at 1A Load



Voltage Drop = 0.018Vdc

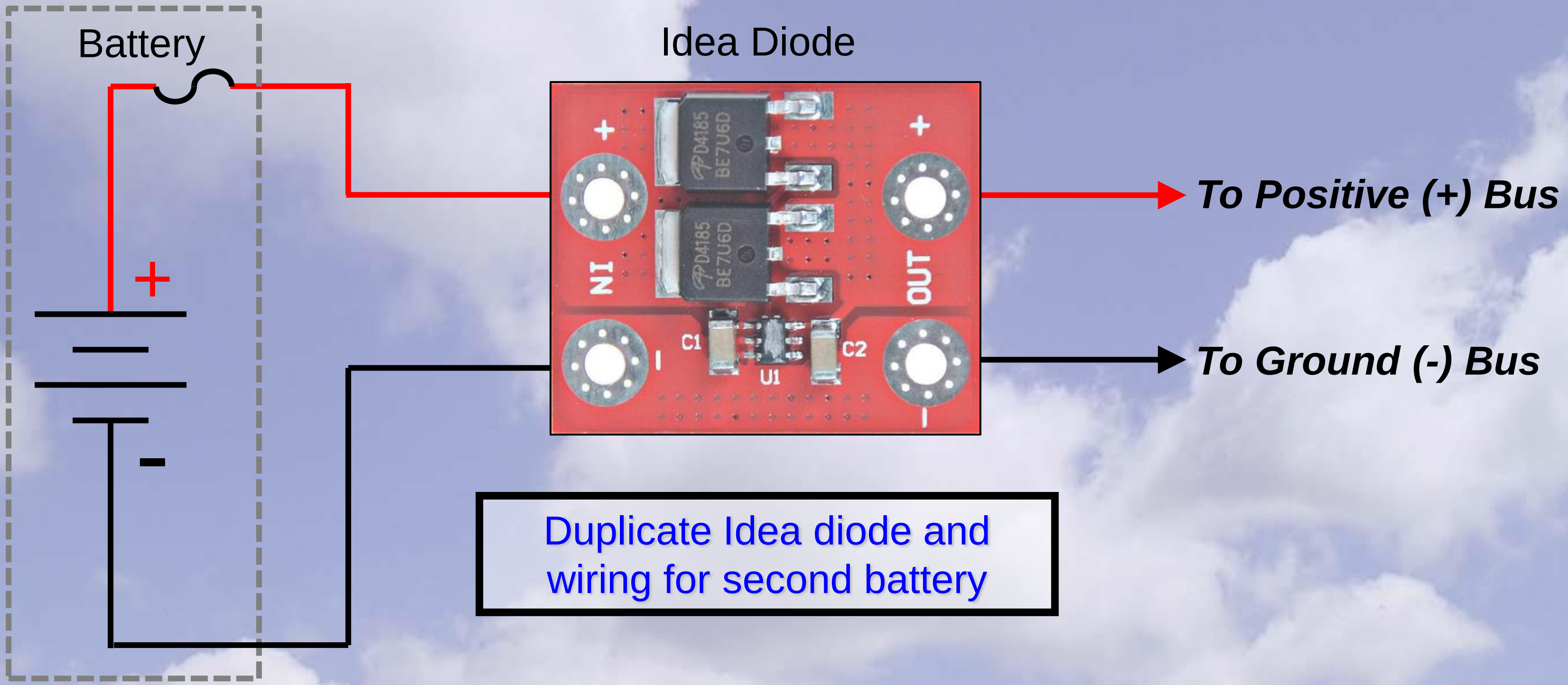


Voltage Drop = 0.66vVdc

Source: Search eBay
for “Ideal Diode”
Price: $6 to $25
per diode
(2 devices required)

Sample Power Distribution Circuits

Idea Diode – Example Wiring



Duplicate Idea diode and wiring for second battery

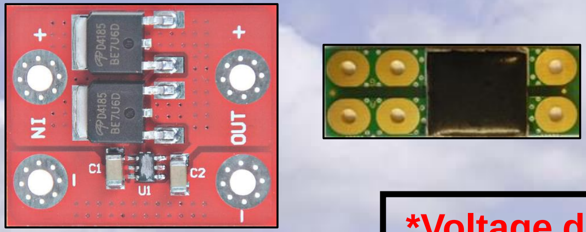
Loosing Volts – Diodes Recap

Diodes should be used when cross connecting two batteries …

- **Pro** – Prevents high amperage cross-charging
- **Con** - Can lose volts across its terminals

Silicon Diodes – Loses ~0.8Vdc*

Schottky Diodes – Loses ~0.4Vdc*



“Ideal” Diodes – Loses ~0.02Vdc*

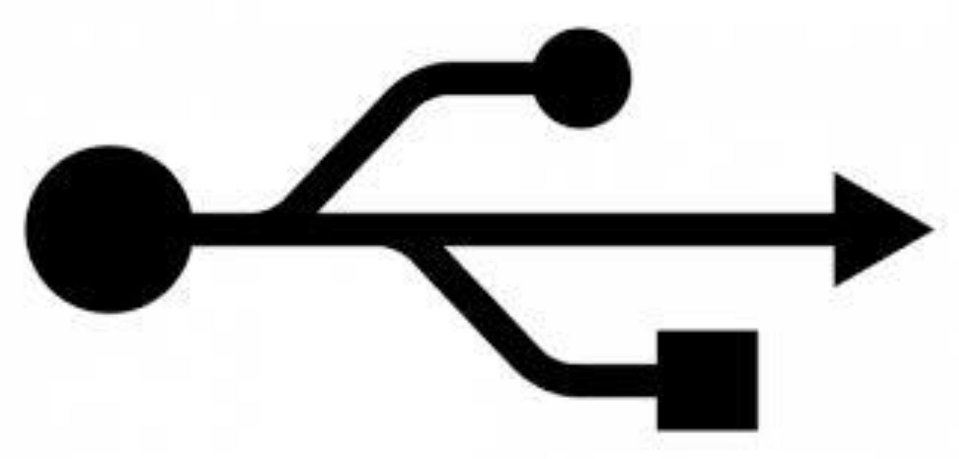
***Voltage drop across diode at 1A current flow**

Loosing Volts - Recap

- **Wiring**
  - **Problem:** Can lose ~1.0Vdc due to resistance of small gauge wiring
  - **Solution:** Use Larger Gauge Wiring
- **Circuit Protection**
  - **Problem:** Can lose ~1.0Vdc due to small amp rated breakers
  - **Solution:** Use 5A and Larger Rated Breakers
- **Batteries**
  - **Problem:** Discharge voltage droop causing more current to flow which, in turn, causes more voltage drop in the wiring
  - **Solution:** Use Lithium Batteries (flat discharge profile)
- **Connections**
  - **Problem:** Poor connections causing resistance
  - **Solutions:** Use the best products, best crimping practices, eliminate corrosion, and minimize the number of electrical connections
- **Diodes**
  - **Problem:** Can lose up to 0.8Vdc
  - **Solution:** Use Schottky or “Ideal” Diodes

Chapter 9

Proving USB Power



Proving USB Power

It has become an important ingredient in our cockpits to provide reliable USB (Universal Serial Bus) power to be used by our removable electronics devices such as cell phones, flight loggers, tablets, etc.

There are VERY IMPORTANT considerations when adding a USB outlet to your cockpit. The most important of which is providing clean power without interfering with other critical avionics onboard your glider.

Providing USB Power

Commonly Found Types of USB connections

Output Power Jack


Type A

Input Power Plugs


Type B Mini


Type B Mico

Output/Input Power Jack/Plug


Type C

Proving USB Power

USB charging adapters come in many forms (see later slide) but they all convert 12Vdc input voltage (and sometimes other voltages) to 5Vdc used by all USB powered devices.

Again, the fatal flaw of many chargers, especially the commonly sold cheap units, is causing RF noise (due to the use of “switching” power supplies) which can easily cause interference in your avionics instrumentation.

TESTING ➔ Be sure to test a USB charger before permanent installation. Temporarily connect the charger to 12Vdc and then to a USB powered device.
Then make several test flights. Just because it charges a device does **not** mean that it will not cause interference.

Providing USB Power

These USB chargers are made by the aviation industry and <u>should</u> be interference free*.

As you might imagine they cost $200-$400 each

Garmin

Stratus

True Blue

Electronics International

*** NOTE: I have tested <u>none</u> of these chargers**

Electrical Parts Sources

http://aircraftspruce.com

http://wagaero.com

http://www.wicksaircraft.com

http://cumulus-soaring.com

http://www.airsuppliers.com

http://www.hi-line.com

http://wingsandwheels

http://craggyaero.com

http://www.steinair.com

http://waytekwire.com

See My Other Presentations

- Transceiver Troubleshooting
- Oxygen Systems
- Working with Glider Air Lines
- Sailplane Wiring
- Trailer Wiring & LED Lights
- Pilot Relief Systems
- Battery Testing
- Open Glider Network (OGN)
- Spar Alignment Tool
- L’Hotellier Fittings
- Carbon Fiber Panels
- IGC Filename Decoding
- Blanik L-23 Strut Work
- Landout Survival Kits
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