Smart choice for power

xantrex

DC Power Supply Basics

Xantrex Technology Inc.

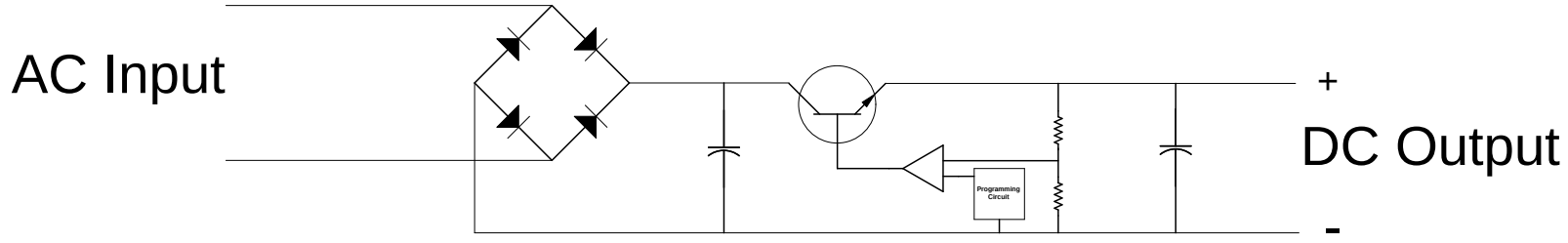
DC Basics Outline

- Basic power supply types
- Key specifications
- Constant voltage / constant current operation
- Remote sensing
- Inductive loads
- Pulsed loads
- Paralleling & series operation
- Analog programming
- Thermal management
- Regulatory
- ATE considerations

Basic Power Supply Types

- Linear
- Switch mode
  - PWM
  - ZVT (a.k.a. ‘soft switching’)

Linear Power Supply (basic design)



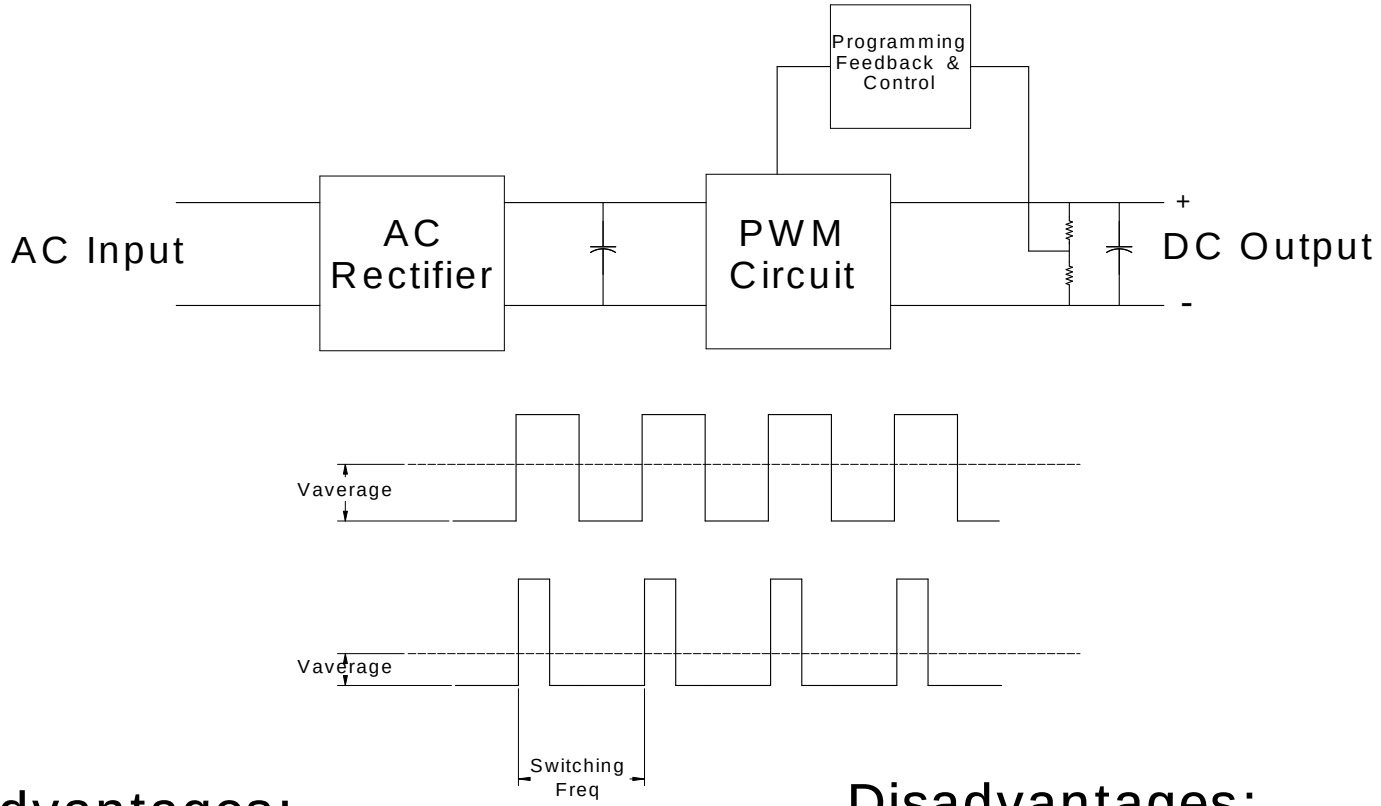
Advantages:

- Low noise
- Fast transient response
- Simple design

Disadvantages:

- Poor efficiency
- Large
- Heavy

Switching Power Supply (basic design)



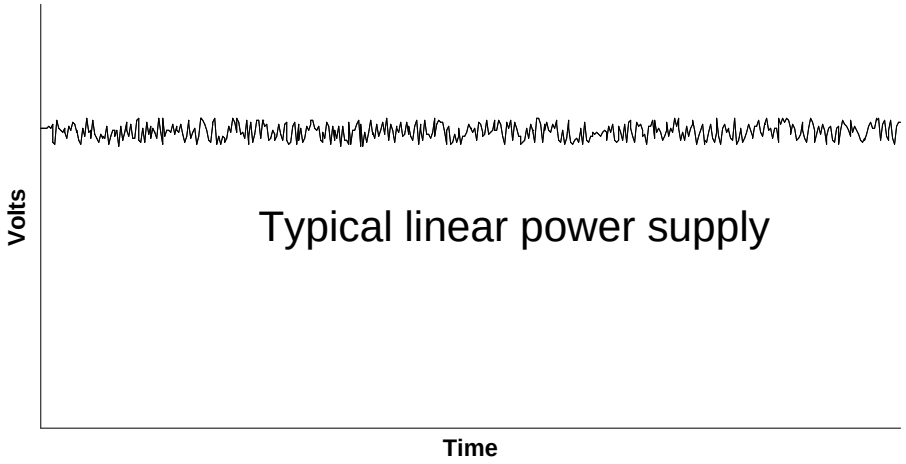
Advantages:

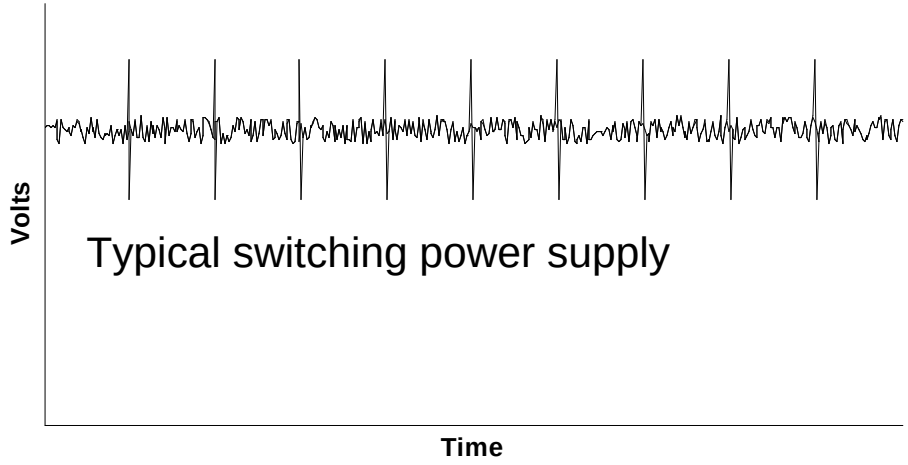
- Higher efficiency
- Smaller size/weight

Disadvantages:

- Higher p-p noise
- Slower transient response (compared to linear)

Noise Profile on Linear vs. Switching





Noise and Ripple Specifications: No Standard

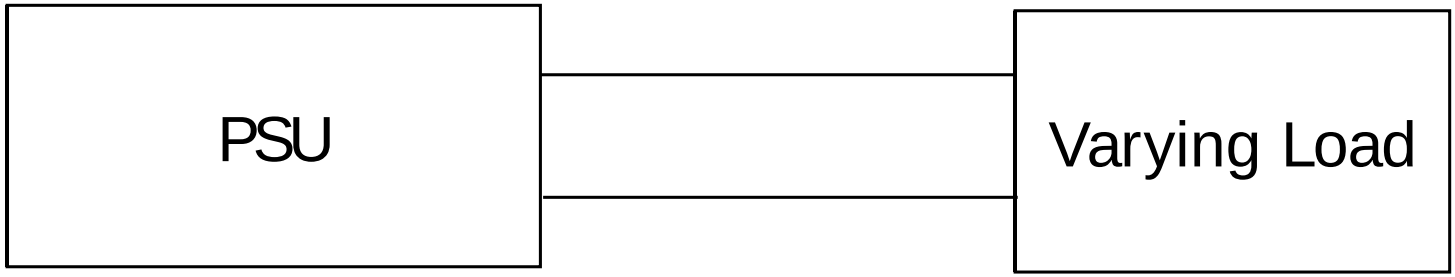
- Different manufacturers use different methods
- ‘Paper’ specifications not always comparable
- Other may measure in 20 Hz – 200 kHz
- Some do not specify bandwidth at all…

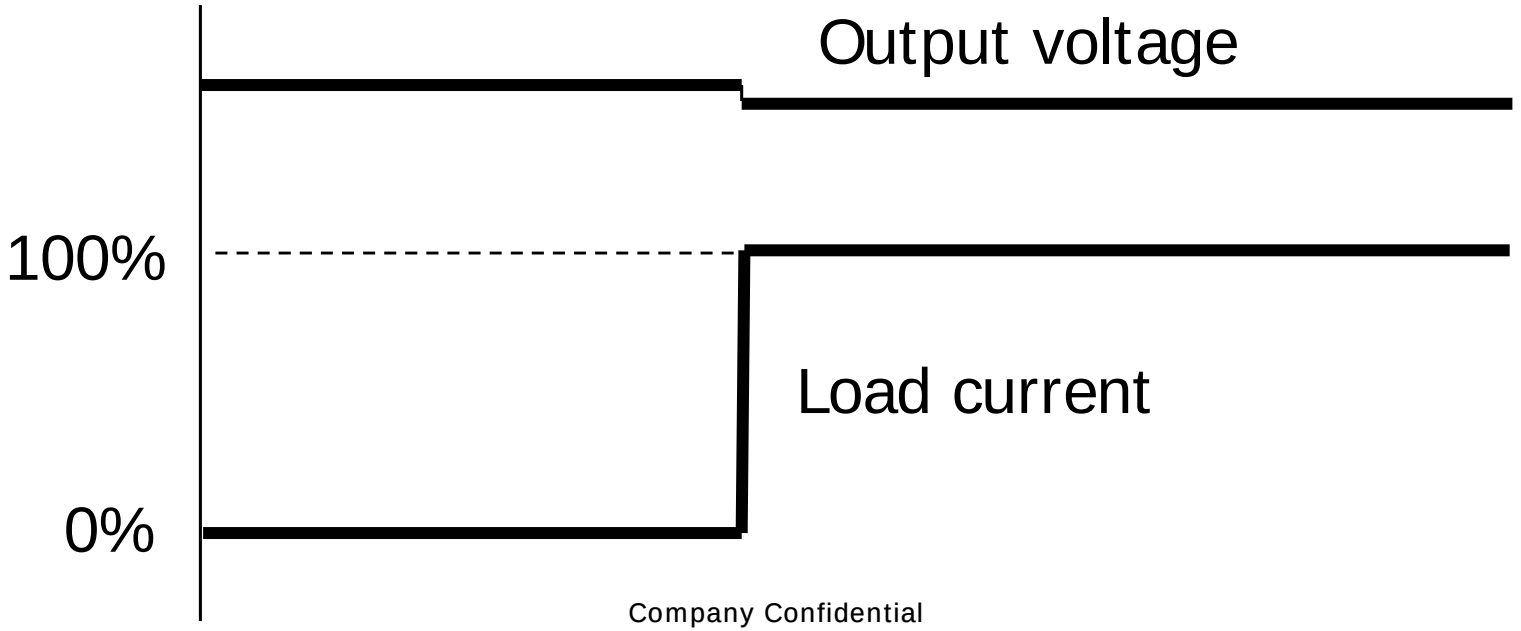
Key Power Supply Specifications

- Load regulation
- Rise time; fall time
- Transient response
- Noise and ripple
- Efficiency
- Input power factor

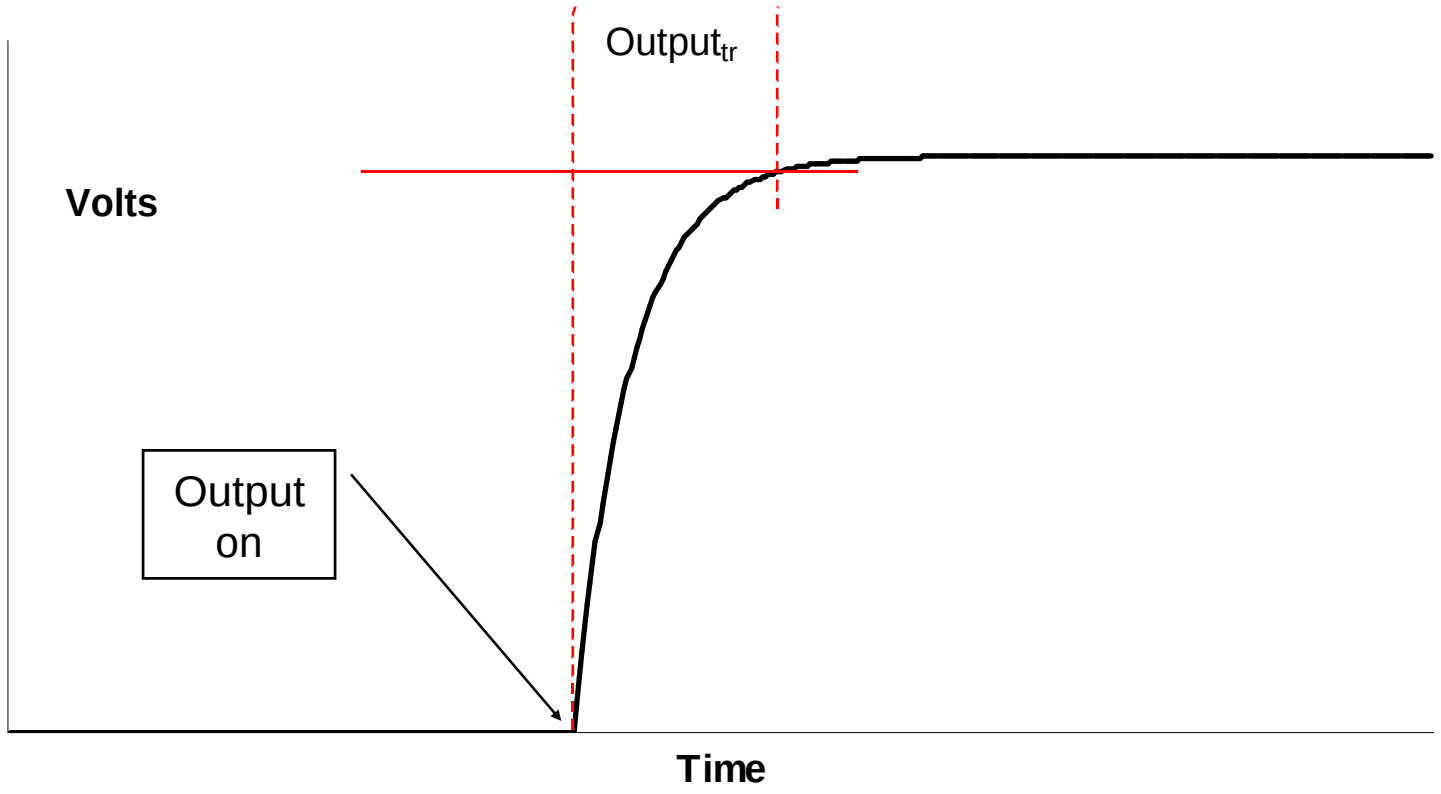
Load Regulation

Percent change of Vout as a function of load change





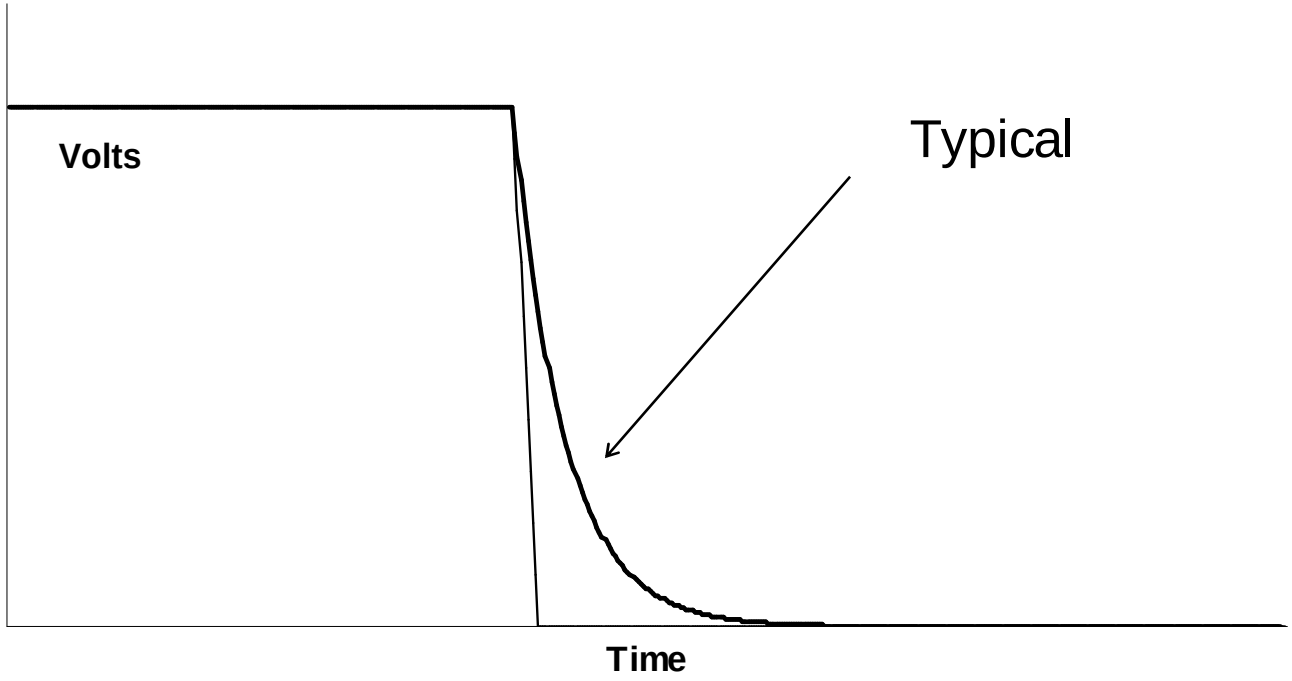
Output Rise Time



Output$_{tr}$ = rise time

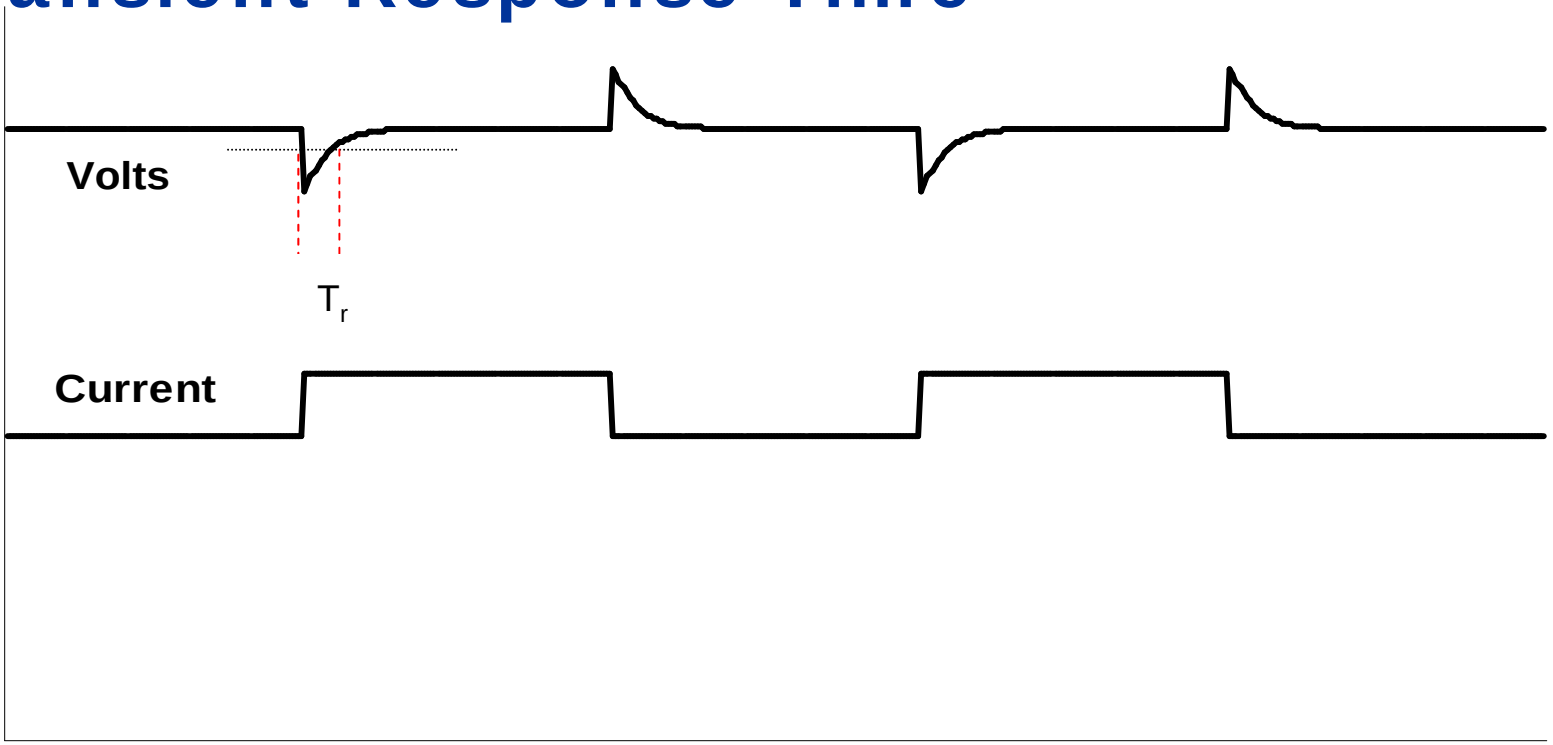
SG Series is 100 ms for 0 to maximum DC output voltage

Output Fall Time



Fast off time is especially critical in production testing and other applications where speed is important

Transient Response Time



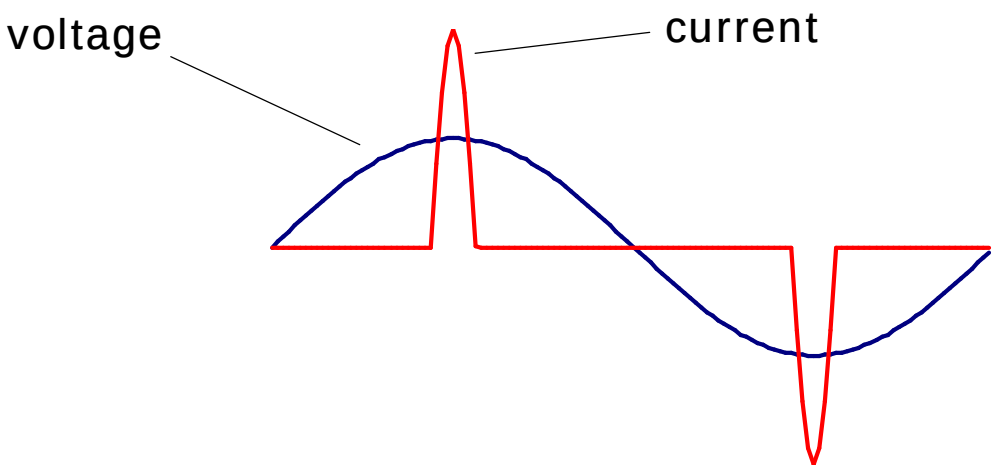
T_r = Transient response time

Typically 1-10 ms

AC Mains Input Power Factor

Bad power factor causes:

- very high peak currents
  - requires thicker wiring and larger breakers
- large harmonic distortion

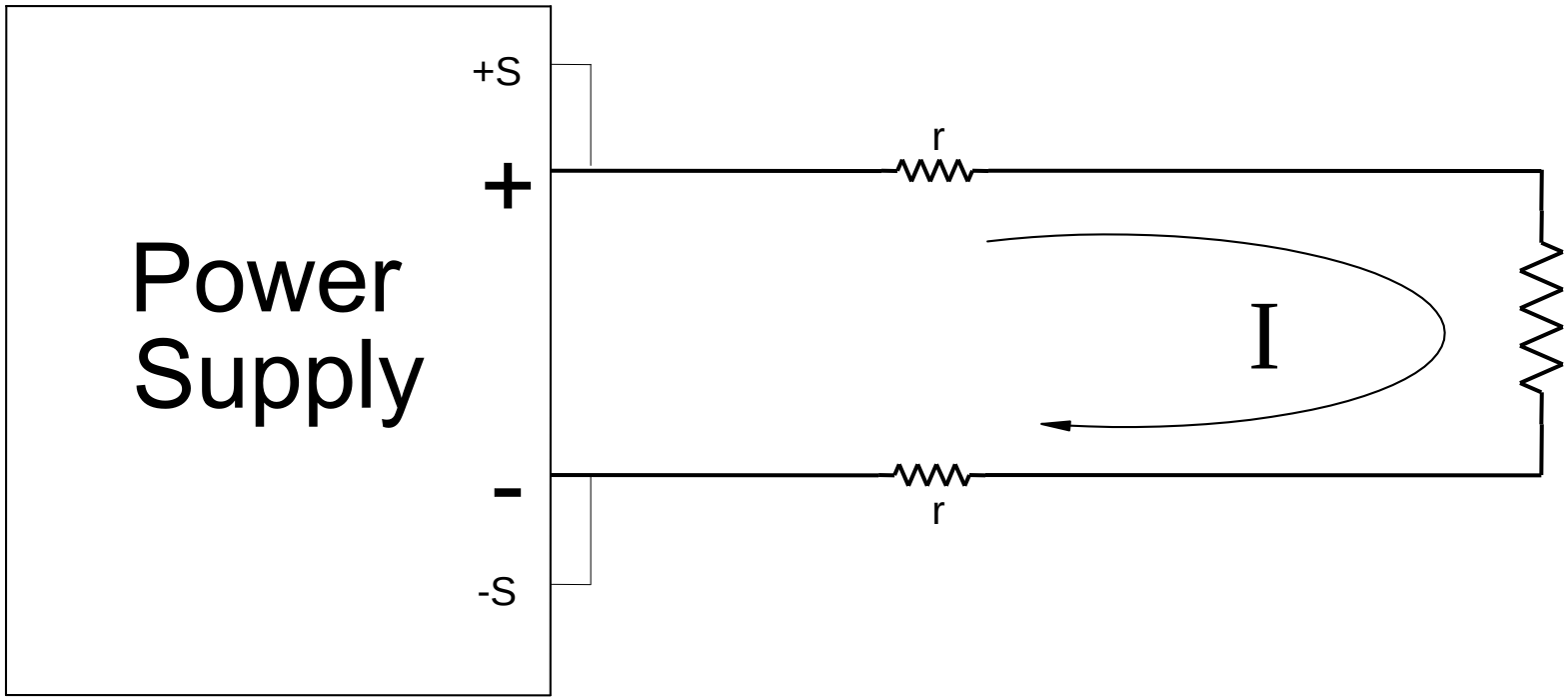


Voltage & Current Mode Operation

- PSU switches between CV and CC automatically based on the load

- If $I_{Load} < I_{SET}$ = constant voltage (CV) mode
- If $I_{Load} > I_{SET}$ = constant current (CC) mode

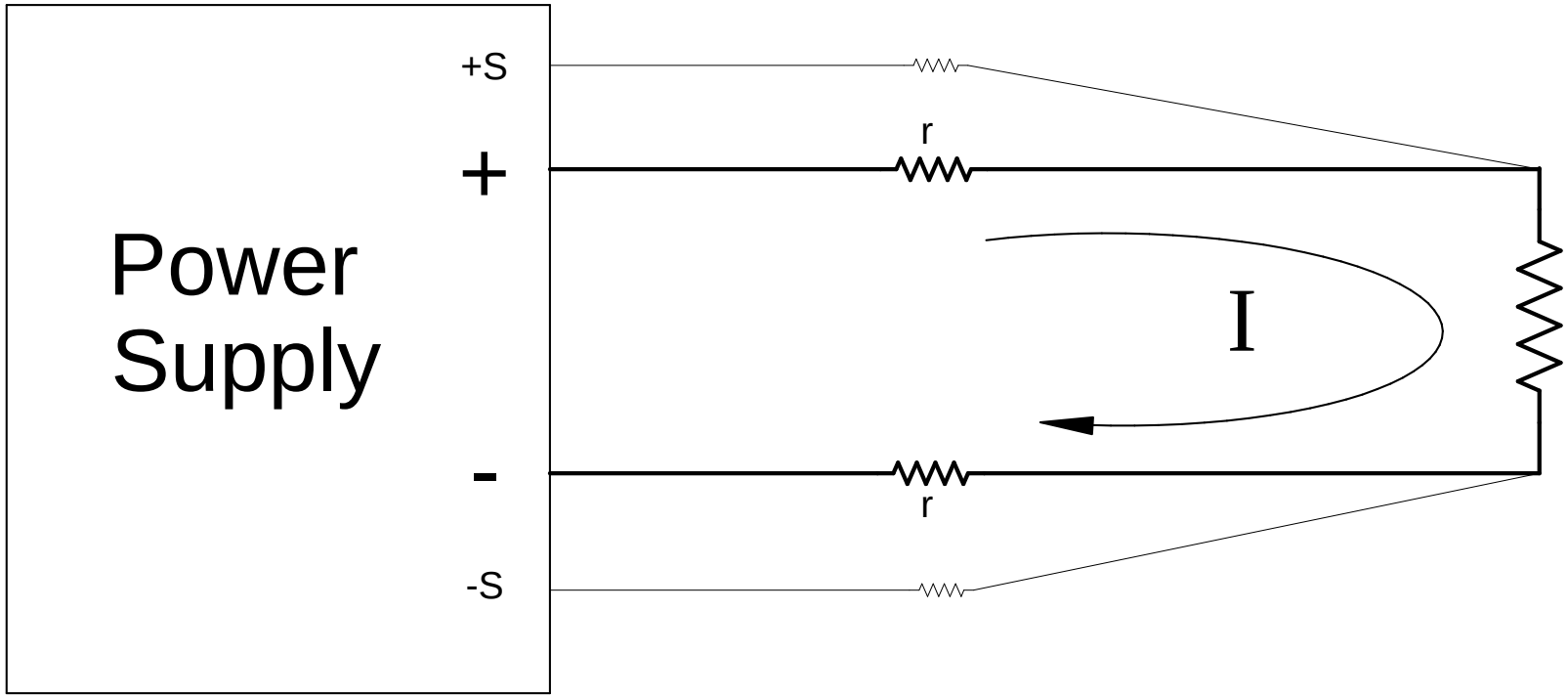
Local Sense Considerations



6 mm^2 wire typically 3 mΩ/m; 10 m = 30 mΩ

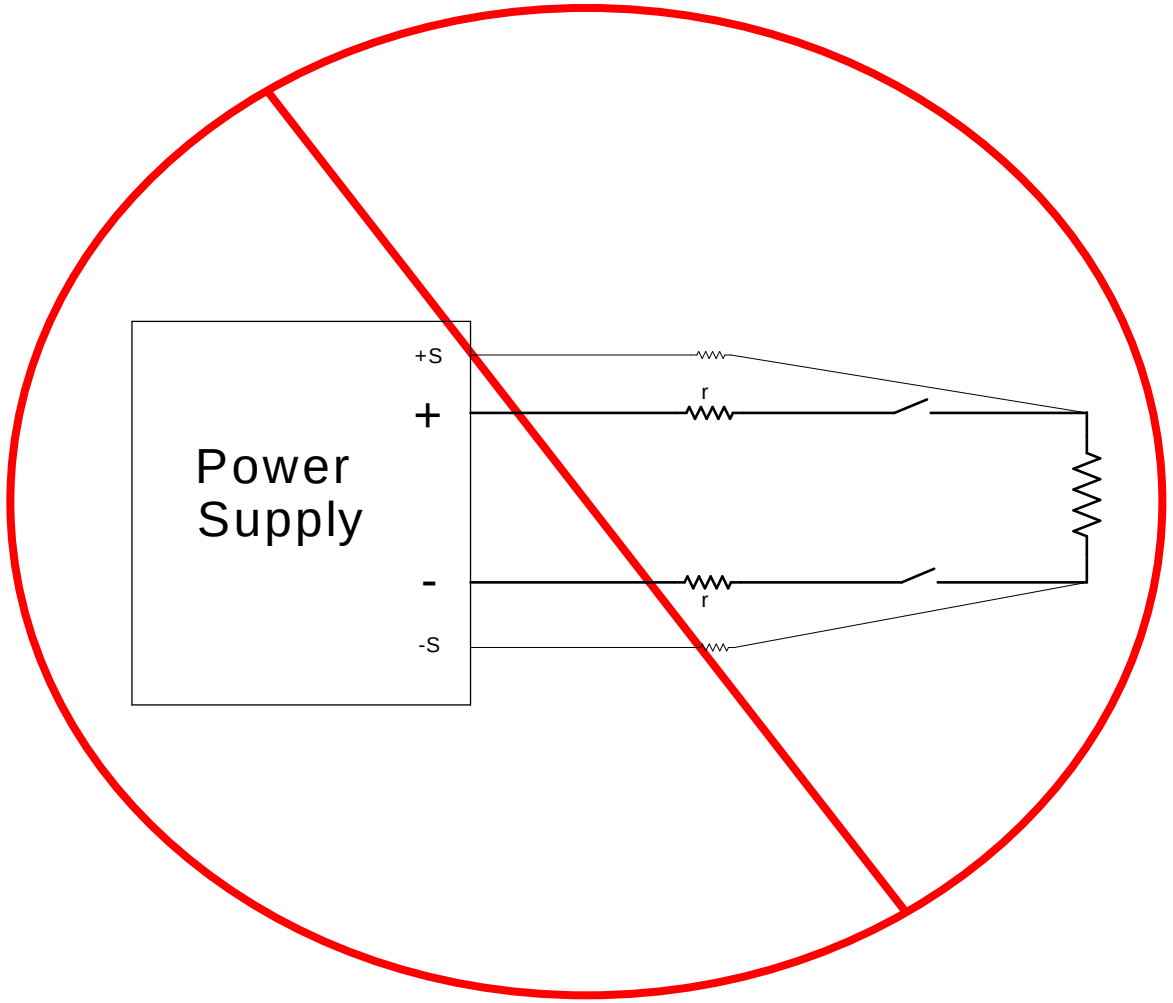
If I = 20 A; V_r = 20 A x 30 mΩ = 600 mV drop per line; total 1.2 V!

Remote Sense Considerations

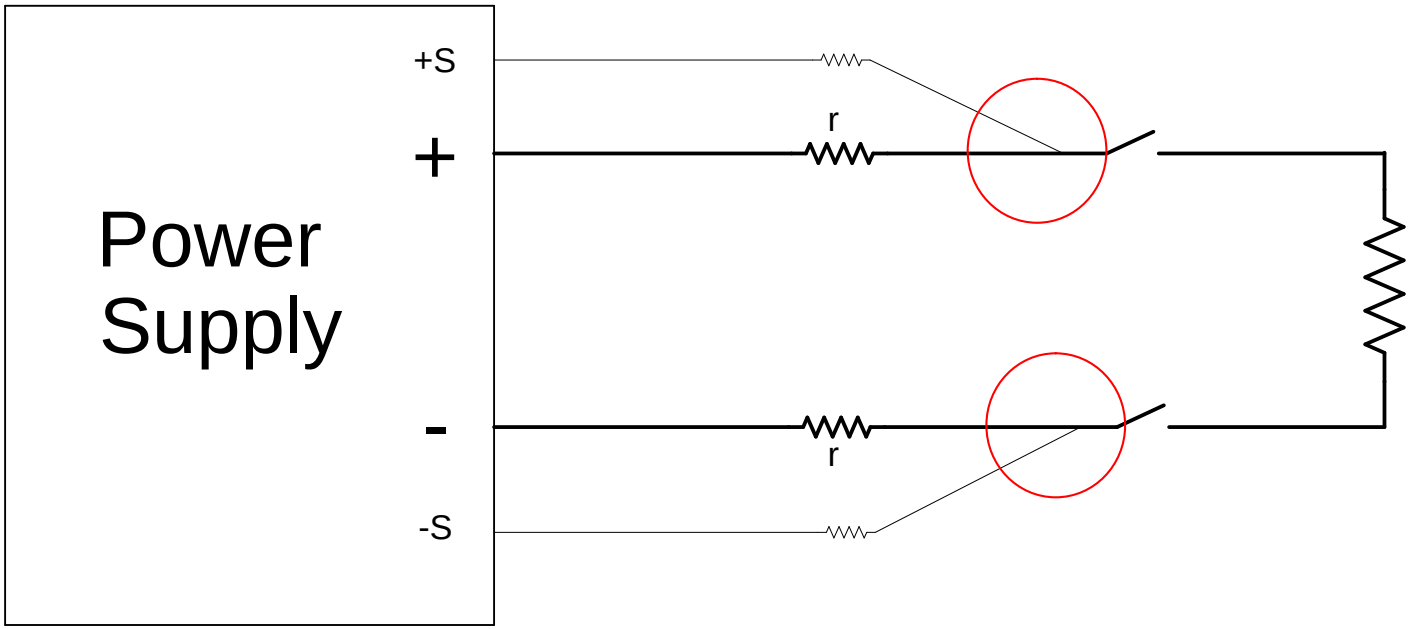


- Advantages:
  - Better regulation at the load
  - Better voltage accuracy

Remote Sense & Load Switching

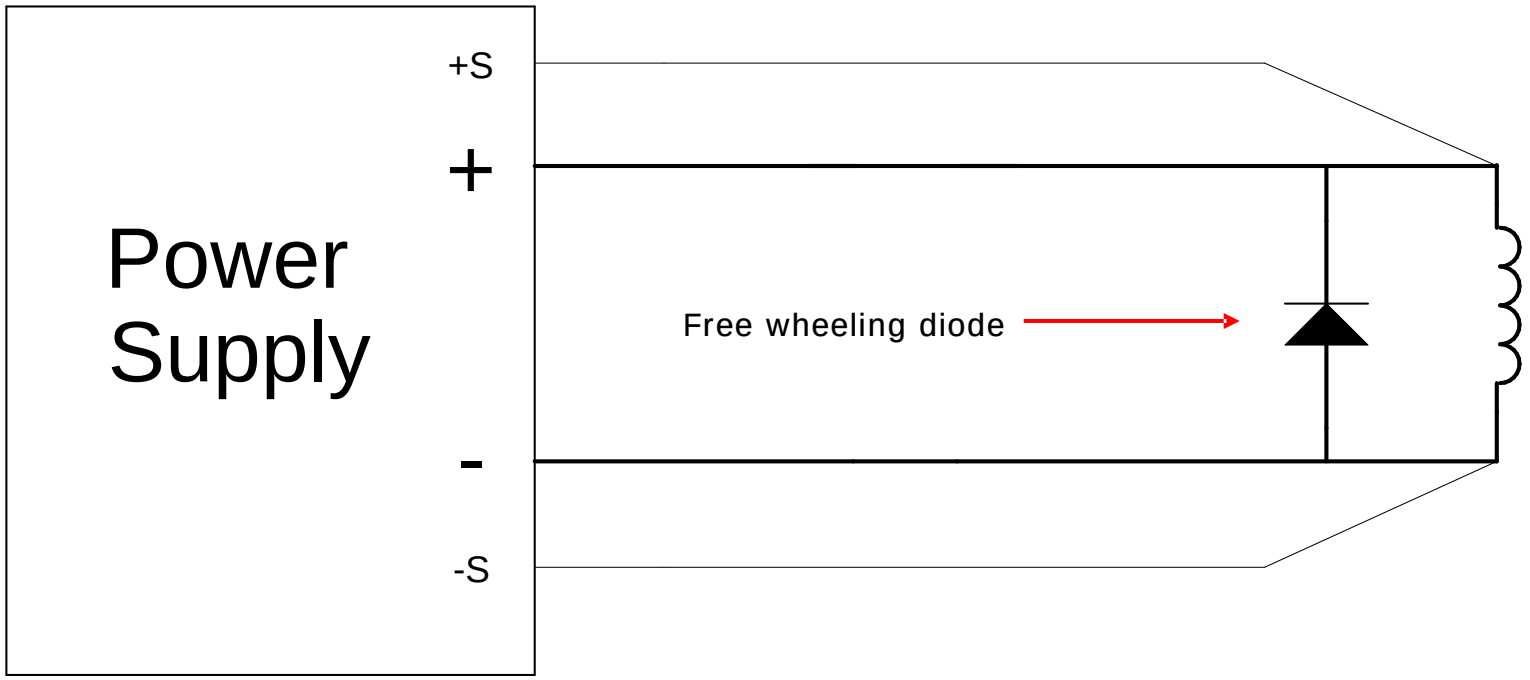


Remote Sense & Load Switching

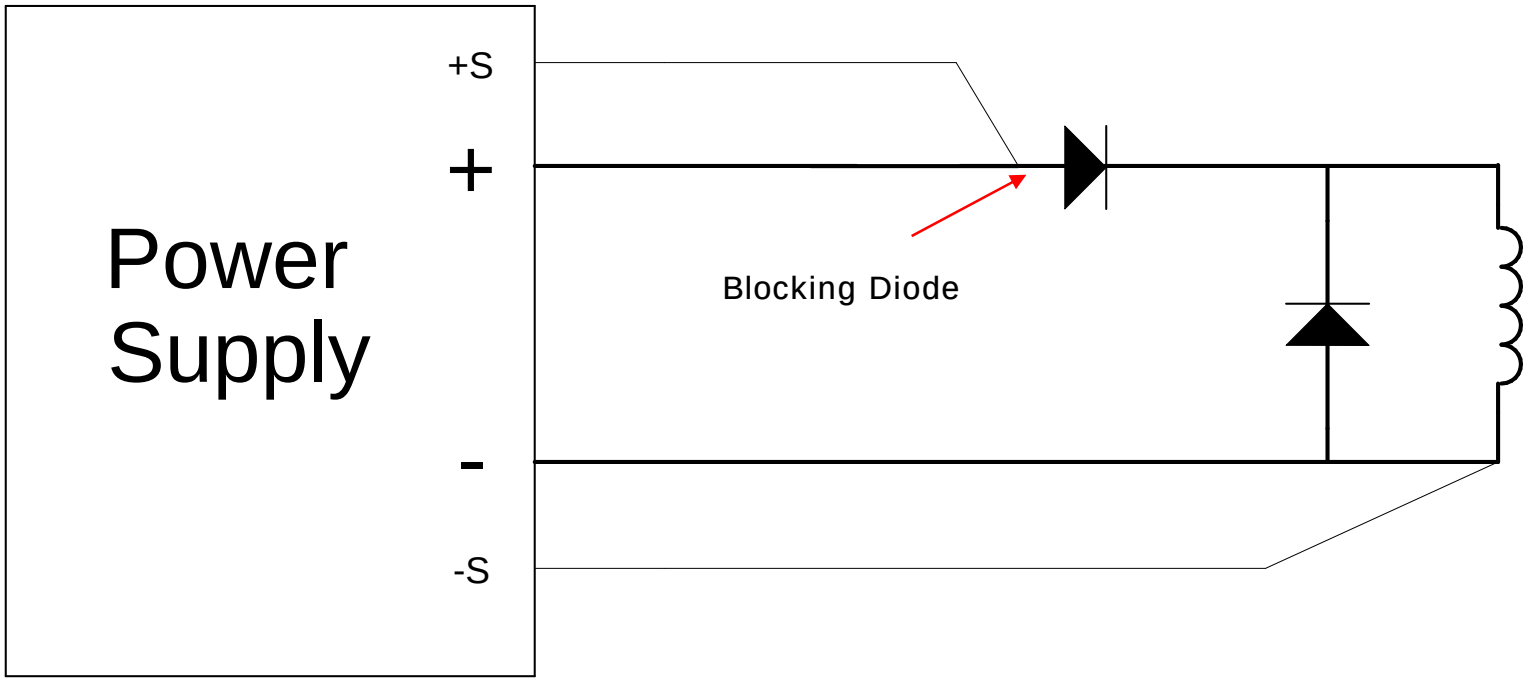


- Correct method:
  - Sense connections on power supply side of switch

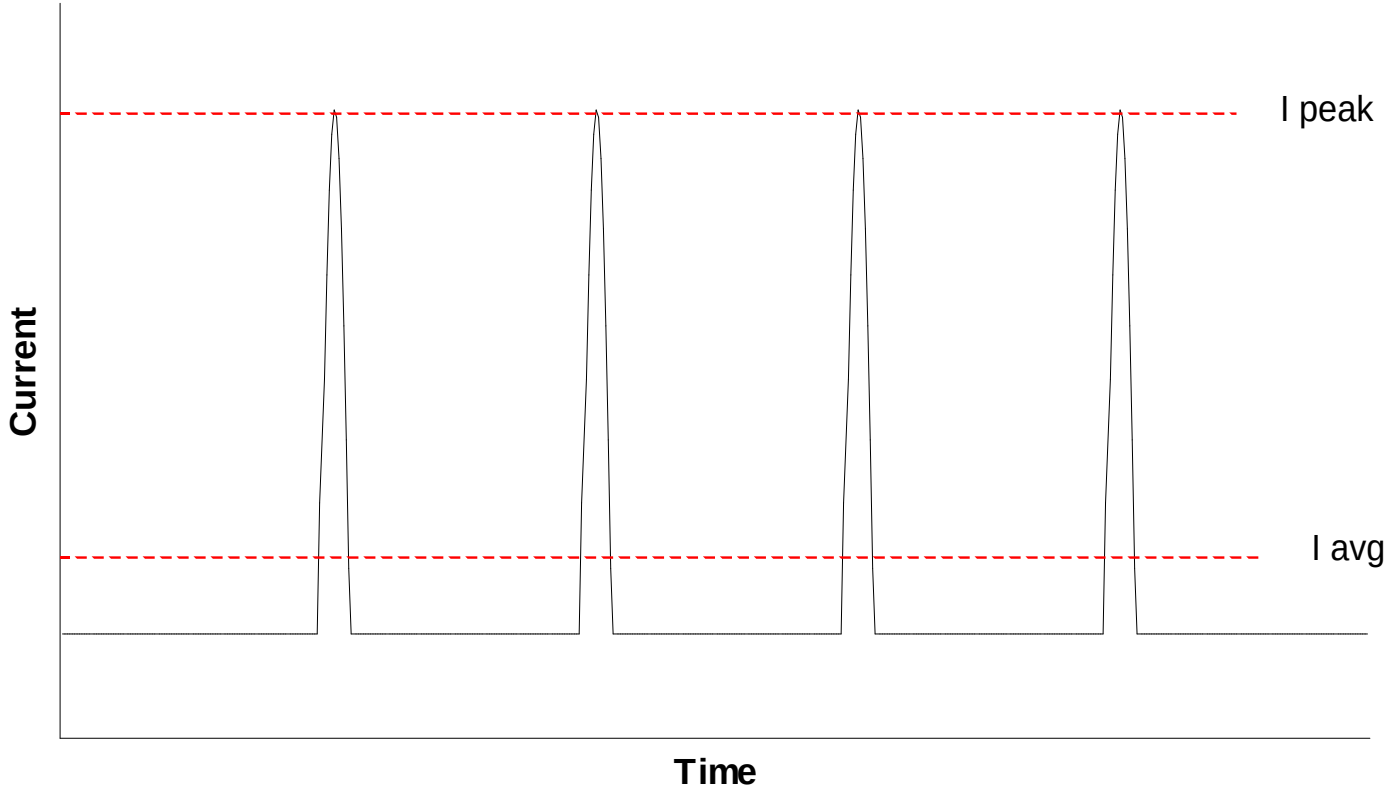
Inductive Load Considerations



Inductive Load Considerations cont'd



Pulsed Loads



Power supply may need to be sized for I peak!

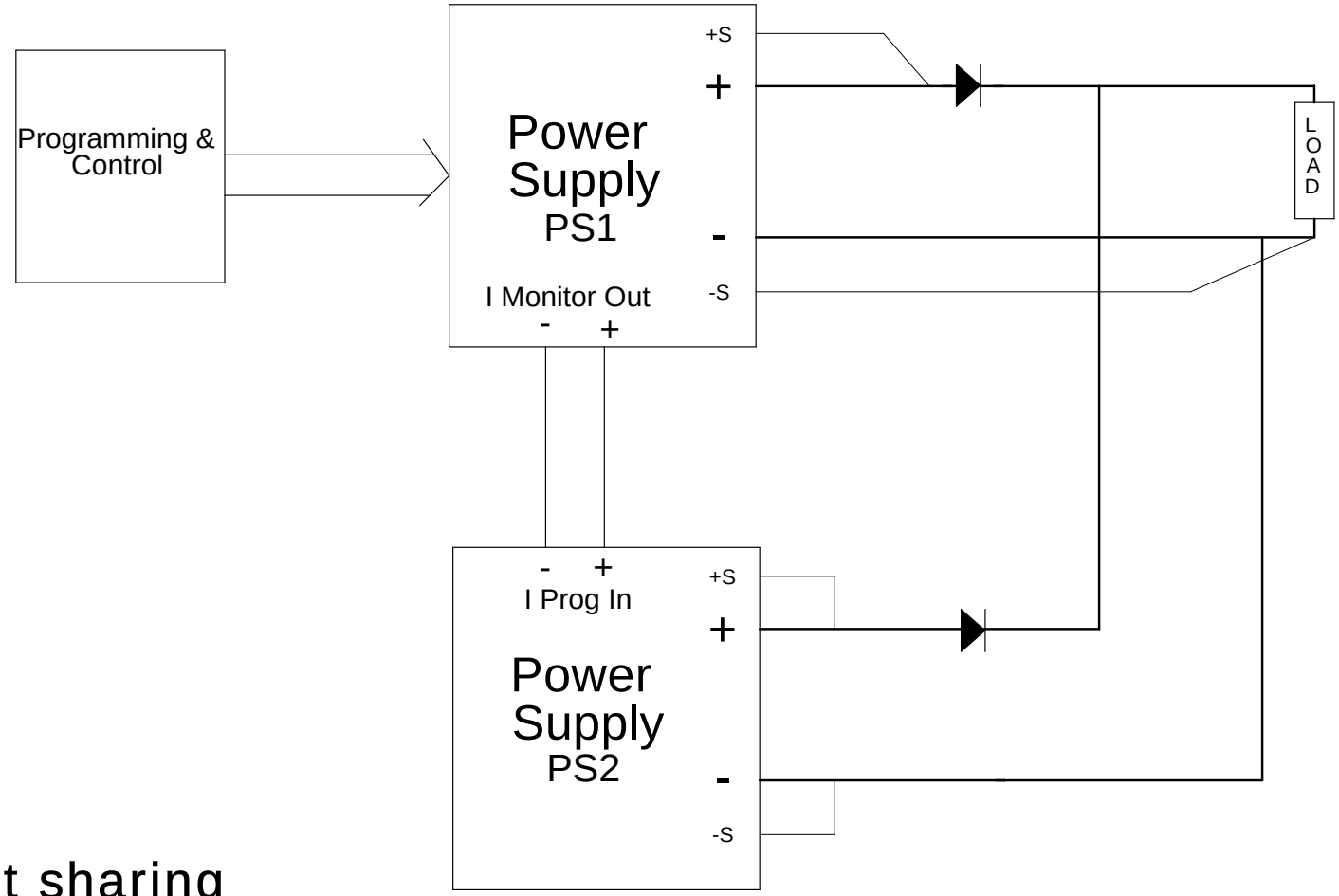
- Typical loads:
  - Inverters (DC →AC)
  - DC to DC converters
  - Audio amplifiers

Parallel Operation

Two methods:

- Manual
  - Both supplies in voltage mode
- Current share
  - Master/slave
  - All in current mode; analog signal split to each supply
  - Dedicated analog paralleling cable
  - Multiple power supplies in parallel
  - Is de-facto extension of the internal control loop
  - Very fast

Parallel Operation



Current sharing

Analog Programming

- Allows you to program the power supply's voltage and current output by providing a 0-10 V external programming voltage
- Allows you to also read back a power supply's status
- Fastest programming possible
- Limited to approx. 4 Hz on most supplies (i.e. can not be used as a power amplifier)

Thermal Management Considerations

- If incorporating power supply's into a cabinet, make sure to:
  - Provide exhaust capabilities to the cabinet
  - Keep the internal operating temperature of the cabinet at or below the operating temperature rating of the power supplies
- Switching power supplies are approx. 90% efficient in most cases; linears are 60%
- That is 10% to 40% of power that is dissipated as heat!

Regulatory

- When using the power as part of a system that will need regulatory approvals it is helpful if the supply meets those approvals too
- Another solution is to have your system approved at the system level
  - Not all components need to be compliant for a system to get approvals, but having compliant components certainly makes it easier

Key Issues with ATE Design

- Mount the power supplies correctly (use rack mount kits and support bars)
- Provide adequate spacing between units (if necessary)
- Provide adequate airflow to the rack (intake and exhaust)
- Provide filtering to air if in a hazardous environment
- Install appropriate AC input breakers
- Provide adequate DC bus (especially if paralleling units) to handle higher currents

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AC Power Supply Basics

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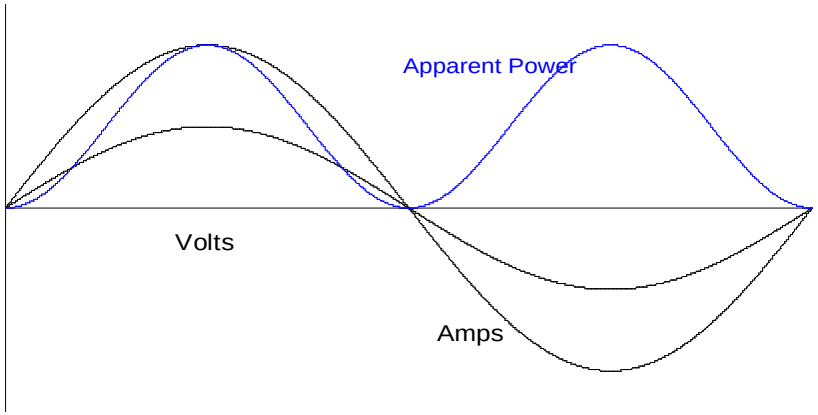
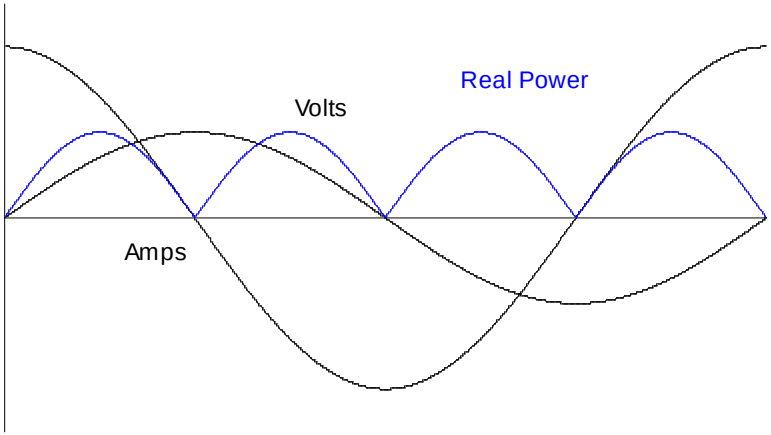
Real vs. Apparent Power



Apparent Power: Measured in **VA** and is the product of RMS voltage and RMS current.

Real Power: Measured in **watts** and is the product of instantaneous voltage and current. Indicates actual power consumption.



Power Factor

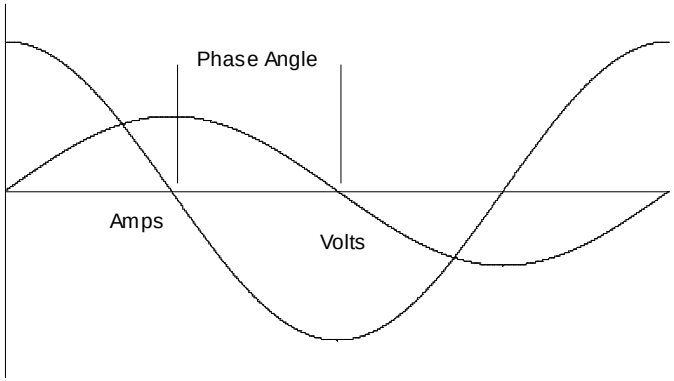
Power Factor (PF) is equal to the ratio of real power to apparent power.

PF = Real Power / Apparent Power

OR

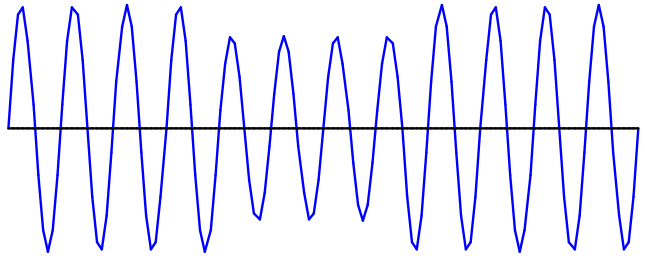
PF = Cosine ∠

Real Power = Apparent Power * Cos ∠

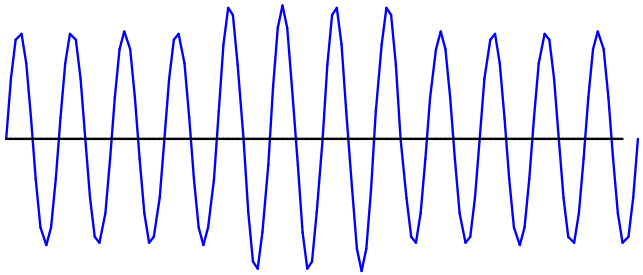


AC Voltage Anomalies

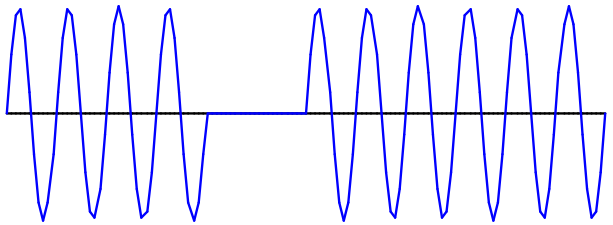
Voltage Sag: Voltage drops below nominal level.



Voltage Surge: Voltage increases above nominal level.



Voltage Drop-out: Voltage goes to zero for a period of time.

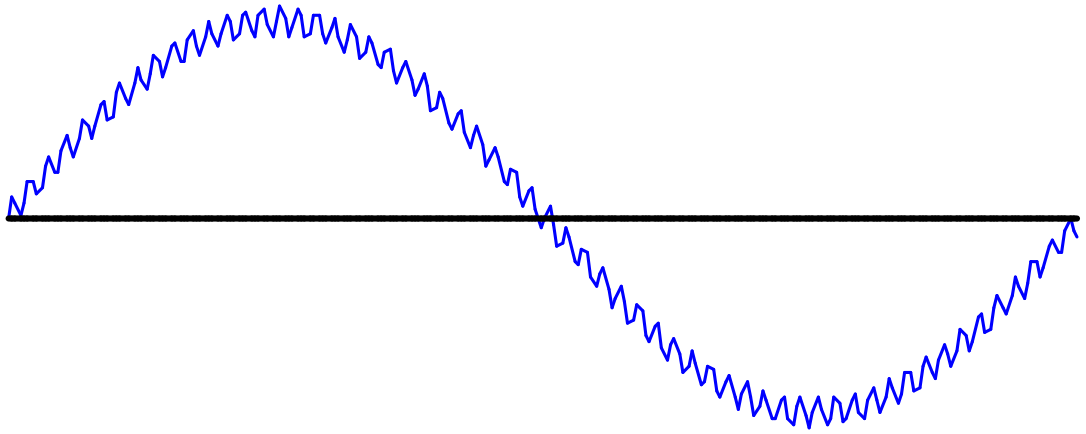


AC Specifications

- Regulation line and load:
  - **Line regulation** is the change in the power supply's output due to a change in the input line voltage.
  - **Load regulation** is the change in the power supply's output voltage due to a change in the load current. The load regulation is a function of the power supply's output impedance; the lower the output impedance the easier it is for a supply to compensate for the change in the load.

AC Specifications

Noise: The undesirable component of the converter output voltage which is usually a byproduct of the conversion process itself. The most common form of noise is the high frequency component remaining after the filtering of the PWM signal.



Power Efficiency

- **Efficiency:** The ratio, specified in percent, of the output power to the input power.

$$\text{Efficiency} = \frac{\text{Output Power}}{\text{Input Power}}$$

AC Loads

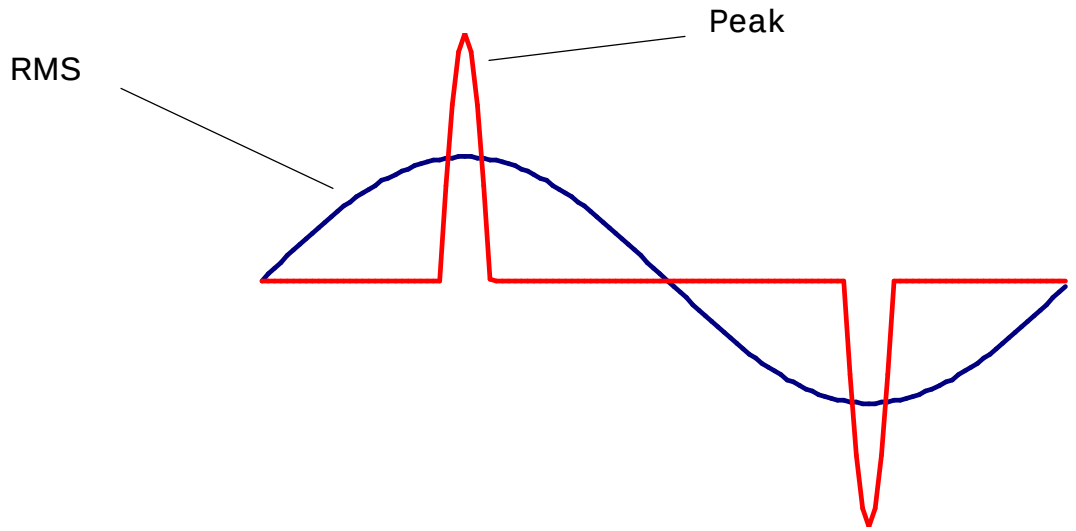
Load Types: Linear and Non-Linear

Linear loads are those that draw current in a sinusoidal fashion. Linear loads can be resistive, inductive or capacitive. In general, linear loads – which include transformers, motors, resistors, and cables – have crest factor of 1.414 (or $\sqrt{2}$).

Non-Linear loads are those that draw current in pulses generally at or very near the peaks of the voltage waveform. Non-linear loads include rectifiers and switching power in general have crest factors in excess of 1.414 (or $\sqrt{2}$).

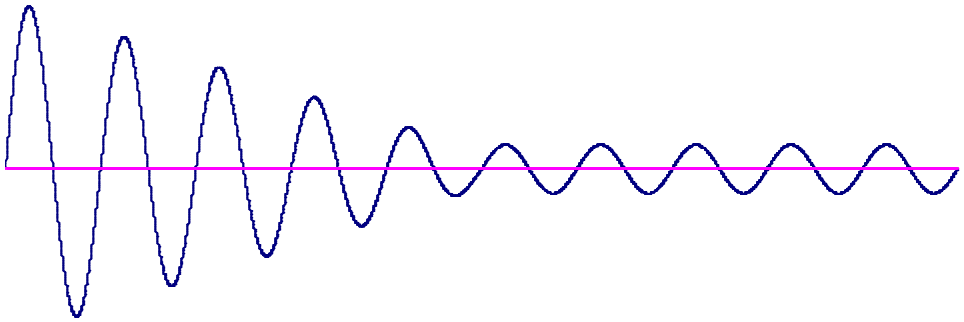
AC Voltage Anomalies

Crest Factor is the ratio of the peak instantaneous current in a load circuit to the RMS current.



In-rush Current

- Inrush Current: The peak current drawn by a device when voltage is first applied, which is generally the result of transformer magnetizing current or the charging of input filter capacitors.



Input Line Currents

Formula for calculating input line currents:

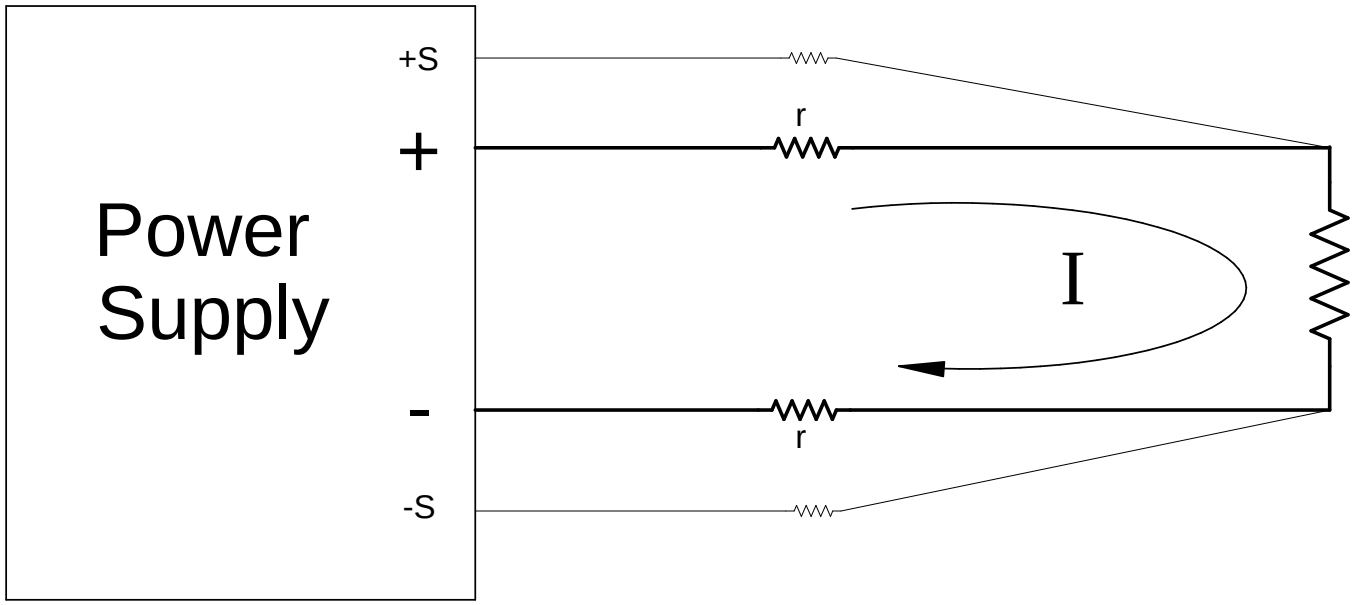
Single-phase input voltage

$$\text{Input Current} = \frac{\text{Power Input}}{\text{V-input} \times \text{Efficiency} \times \text{PF}}$$

Three phase input voltage

$$\text{Input Current} = \frac{\text{Power Input}}{\text{V-input} \times \text{Efficiency} \times \text{PF} \times \sqrt{3}}$$

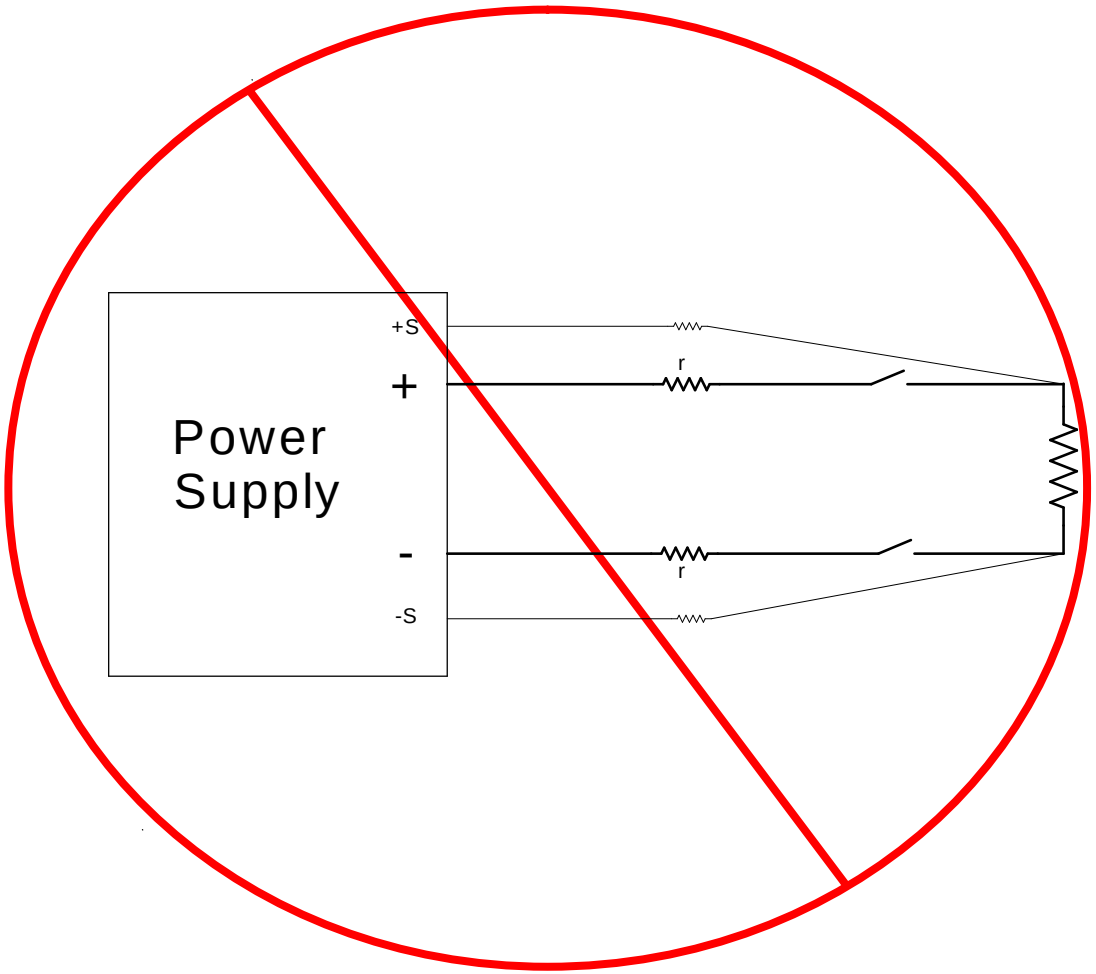
Remote Sense Considerations



Advantages:

- Better regulation at the load
- Better voltage accuracy

Remote Sense & Load Switching



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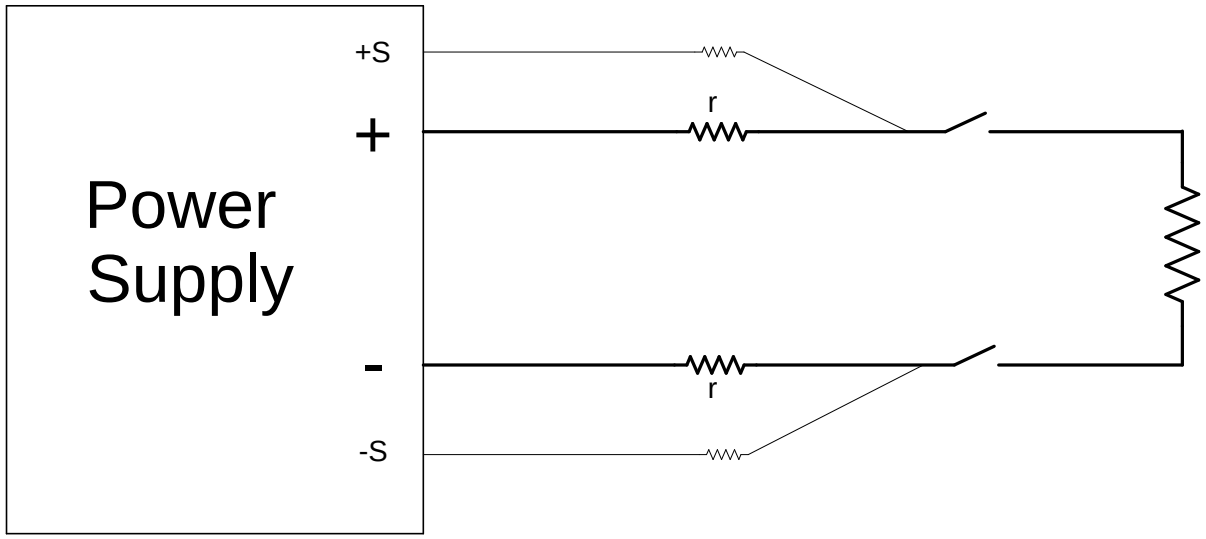

Correct method: Sense connections on power supply side of switch

Questions?

Thank you!