Battery and Power Supply Considerations

ECE2799 Lecture
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Batteries and Power Supplies

• The function of a power supply is to provide power to the components of an electric circuit.

• Power supplies are typically characterized by their:
  – Input voltage (and possibly frequency)
  – Output Voltage
  – Output Current
  – Ripple
  – Regulation
  – Efficiency
Basics of Power Conversion

• One of the simplest types of power supply is the half-wave rectifier.

• In this case, the peak output voltage is $1.4 \times E_{\text{RMS}}$, where $E_{\text{RMS}}$ is the AC output of the transformer.

• The average output voltage is $\text{RAVG} = 0.45 \ E_{\text{RMS}}$.

• Ripple is too high to make this useful in DC applications without filtering.

Full-Wave Rectifier

- In this case, the peak output voltage is still 1.4 \( E_{\text{RMS}} \), but average voltage is now 0.9 \( E_{\text{RMS}} \).
- Ripple is improved, but filtering is still required.
- A center-tapped transformer is required.

Bridge Rectifier

- In this case, the peak output voltage is still $1.4 \times E_{RMS}$, but average voltage is now $0.9 \times E_{RMS}$.
- Similar characteristics to a full-wave rectifier, but the transformer only needs a single winding.

Power Supply Filtering

• Smoothing out the ripple of a power supply is done using a filter.
• In this example, a capacitor is used to hold charge between peaks – this acts to smooth out the ripple.
• Raising the frequency results in less ripple for a given filter.

Power Supply Filters

• While power supply filter circuits are generally simple, adding capacitors and inductors increases the order of the filter.
• Higher order filters aid in reducing ripple.
• Basically we’re designing a low-pass for DC.
• Too much ripple can result in “AC Hum.”
Ripple

- Ripple is the variation around the average DC output of the power supply.
- Ripple is the AC component that lies on top of the desired DC signal:
  - Measured in % of nominal.
  - Measured in Vpp
- A 10V supply with 1% ripple would output voltages between 9.95 and 10.05 Volts.
- \( C \times V_r = I \times t \) is a good approximation.
  - \( C \) = Capacitance of filter \( \mu F \)
  - \( V_r \) = Peak-to-Peak Ripple voltage
  - \( I \) = load current in milliamps
  - \( t \) = time between half cycles

Source: Radio Amateurs Handbook, SGS-Thompson Application Note AN253/1088
Power Supply Example

• Suppose we want a 10 Volt supply that has 1% ripple with a load current of 1 Amp.

• Use a 7.5V transformer and bridge rectifier to get about 10.5 volts peak output.

• What filter capacitance do we need:
  – $C = \frac{(It)}{Vr} = \frac{(1000mA \times 7.5mS)}{0.1}$
  – $= 75000\mu F$!

• Output will be “close” to 10V.
Problems With Our Example

- Problem 1 – 75000μF (with a voltage rating of at least 25V) is a BIG capacitor!
  - 3”x4 ½”
  - $91

- Problem 2 – Even if we build this supply, it might not work the way we hope.
Improving Our Power Supply

• While our example power supply will work, it is an “unregulated” power supply.

• That means the DC voltage output can, and will, change somewhat with changes in the load current.

• A “regulated” supply attempts to maintain constant output regardless of changes in the load:
  • % Regulation = [(V_{OC} − V_{FL}) / V_{FL}] * 100
The Effect of Poor Regulation

- In an unregulated supply, the DC output voltage can drop significantly with increases in load current.
- The amount of ripple will increase with load.
- For applications, with a constant load, this might be fine.
- For applications with variable current requirements this can be a problem.

Source: SGS-Thompson Application Note AN253/1088
Improving Regulation

• Improving regulation can be done in a number of ways.
• In general, you’ll start with a voltage that will always be at least a little higher than you need.
• Then you’ll “regulate” that voltage down to exactly what you need.
• While the input voltage to the regulator might vary with load, the output of the regulator will remain constant.
A Really Simple Regulator

- About the simplest regulator circuit is a Zener diode.
- This approach is fine for up to about 100mA.
- Resistor R must be sized to ensure that the Zener always draws current.
- Note resistor and Zener power dissipation!

Source: SGS-Thompson Application Note AN253/1088
Series Regulators

- Another approach that does not pass all of the current through a series resistor is the use of a “pass transistor”.
- Most “3-terminal” regulators use this approach.
- Be careful of power dissipation in the regulator!

Source: SGS-Thompson Application Note AN253/1088
Generic 12V Power Supply

Source: SGS-Thompson Application Note AN253/1088
Increasing Efficiency

- DC-to-DC converters provide an efficient way to generate higher, or lower, voltages than the input voltage.
- Some controller devices generate multiple voltages.
- Positive and/or negative outputs are possible.

Source: http://www.maxim-ic.com/appnotes.cfm/appnote_number/2031/
DC-to-DC Converters

• Efficiencies of 90% are not uncommon in DC-to-DC converters.
• Much higher parts count than 3-terminal regulators.
• Be careful of
  – Saturation of inductors
  – ESR of filter capacitors
  – Ratings of switch and output diode.

Source: http://www.maxim-ic.com/appnotes.cfm/appnote_number/2031/
Batteries

• We started this discussion talking about AC powered DC supplies.
• Next, we shifted to DC-to-DC converters, with the assumption that the converter was powered from an AC-to-DC supply.
• There is no reason that the power source cannot be a DC source, such as a battery.
• Virtually all portable electronic devices use battery powered DC-to-DC converters.
How Long Does a Battery Last?

• Batteries come in a variety of shapes, sizes, and voltages.
• Batteries are most commonly rated with a “capacity.”
  – Capacity is rated in milliamp-hours (mAh)
  – Capacity also assumes a nominal discharge rate – this rate varies from battery to battery
• Some batteries may be damaged if they are discharged too far!
The Common “D” Cell

ENERGIZER NO. EN95

Chemical System: Alkaline
Zinc-Manganese Dioxide (Zn/MnO₂)
(No Added Mercury or Cadmium)

Designation: ANSI-13A, IEC-LR20

Battery Voltage: 1.5 Volts

Internal Resistance: 173 Milliohms (Fresh)

Operating Temp: -18°C to 55°C (0°F to 130°F)

Average Capacity: 20,500 mAh (to 0.8 volts)
(Rated capacity at 25 mA continuous dis
141.9 grams (5.03 oz.)

Average Weight:

Volume: 55.9 cubic centimeters (3.4 cubic inch)

Cell: One No. 3-350 (size ‘D’)

Jacket: Plastic Label

Shelf Life: 7 years (80% of rated capacity)

CONSTANT CURRENT DISCHARGE
Typical Service

Service, Hours

Discharge Current, mA

0.8 Cutoff Voltage
1.0 Cutoff Voltage
1.2 Cutoff Voltage
The A76 Coin Cell

ENERGIZER A76

**Typical Discharge Characteristics**
Typical Performance at 21°C (70°F)

- Load: 7.5K ohms - Continuous
- Typical Drain @ 1.25V: 0.17 mA
- Hours to 0.9V: 900

### Chemical System:
Manganese Dioxide (MnO₂)

### Designation:
ANSI/NEDA 1166A, IEC-LR44

### Nominal Voltage:
1.5 Volts

### Typical Capacity:
150 mAh* (to 0.9 volts)

### Capacity Test:
7.5K ohm continuous drain at 21°C (70°F)

### Typical Weight:
2.4 grams (0.08 oz.)

### Typical Volume:
0.54 cubic centimeters (0.03 cubic inch)

### Impedance (40 Hz):
3 to 9 ohms

### Max Bulge:
This battery will bulge as it is discharged, but will not exceed the maximum height shown on the battery drawing.
The 392 Coin Cell

ENERGIZER 392/384

**Specifications**

- **Chemical System:** Silver Oxide (Zn/Ag₂O)
- **Designation:** ANSI-1135SO/1134SO, IEC-SR41
- **Nominal Voltage:** 1.55 Volts
- **Typical Capacity:** 41 mAh* (to 1.3 volts)
- **Capacity Test:** 15K ohm continuous drain at 21°C
- **Typical Weight:** 0.57 grams (0.023 oz.)
- **Typical Volume:** 0.18 cubic centimeters (0.011 cubic inch)
- **Impedance (40 Hz):** 10 to 20 ohms

**Typical Discharge Characteristics**

Typical Performance at 21°C (70°F)

- **Schedule:** Continuous
- **Typical Drain @1.55V:**
  - 0.103 milliamperes
- **Load:** 15K ohm

![Graph showing typical discharge characteristics](image-url)
Rechargeable Batteries

ENERGIZER NH50-2500

**Specifications**

- **Classification:** Rechargeable
- **Chemical System:** Nickel-Metal Hydride (NiMH)
- **Designation:** ANSI-1.2H4
- **Nominal Voltage:** 1.2 Volts
- **Rated Capacity:** 2500 mAh* at 21°C (70°F)
- **Typical Weight:** 73.0 grams (2.6 oz.)
- **Typical Volume:** 57.0 cubic centimeters (3.5 cubic inch)
- **Terminals:** Flat Contact
- **Jacket:** Plastic

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* Based on 500 mA (0.2C rate) continuous discharge to 1.0 volts.
Battery Charging Circuits

- Charging a battery is not as simple as connecting a power supply to the terminals of the battery!
- Different battery technologies have different charging requirements (NiCd, NiMH, Li-Ion, Lead-Acid, etc.)
- Many suppliers provide controllers specifically for recharging different battery technologies.
- **Not all batteries are considered rechargeable!**
An Example Charging Circuit

R_TR PROVIDES TRICKLE CHARGE CURRENT WHEN THE LM2576 IS OFF. SELECT VALUE USING:

\[ R_{TR} = \frac{(V_{IN} - 15)}{I_{TR}} \]

**FIGURE 1. 2.6A NI-CD/NI-MH CHARGER**

Resources

• The following companies make several power management devices (and many other useful components):
  – http://www.maxim-ic.com/
  – http://www.national.com/
  – http://ti.com/
  – http://www.fairchildsemi.com/