PHYS225
Lecture 19

Electronic Circuits
Last lecture

• Oscillators and timers
  – Useful for many applications
    • Periodic signals
    • Controls
• Simple RC decay coupled to a comparator can produce many useful oscillations
• 555 IC is very popular and can be used in a variety of ways
  – Use PWM for active controls
Power supplies

• Critical for all active circuits
• Must be stable and reliable
  – Or strange things will happen!
• Batteries are stable and reliable
  – As long as the stored energy persists!
  – Can be expensive and require attention
• Better to use a “power supply”
  – Although depends on what you mean by “better”
Getting DC back out of AC

- AC provides a means for us to **distribute** electrical power, but most devices actually **want** DC
  - bulbs, toasters, heaters, fans don’t care: plug straight in
  - sophisticated devices care because they have diodes and **transistors** that require a certain **polarity**
    - rather than oscillating polarity derived from AC
    - this is why battery orientation matters in most electronics

- **Use diodes to “rectify” AC signal**
- **Simplest (half-wave) rectifier** uses one diode:

![Diagram showing half-wave rectifier with AC source, diode, and load. The diagram illustrates how the diode conducts only when the input voltage is positive, leading to a single polarity output voltage seen by the load.]
Doing Better: Full-wave Diode Bridge

- The diode in the rectifying circuit simply prevented the negative swing of voltage from conducting
  - but this wastes half the available cycle
  - also very irregular (bumpy): far from a “good” DC source
- By using four diodes, you can recover the negative swing:
Full-Wave Dual-Supply

- By grounding the center tap, we have two opposite AC sources
  - the diode bridge now presents + and – voltages relative to ground
  - each can be separately smoothed/regulated
  - cutting out diodes A and D makes a half-wave rectifier

AC source

- load

+ load

can buy pre-packaged diode bridges

voltages seen by loads
Smoothing out the Bumps

- Still a bumpy ride, but we can smooth this out with a capacitor
  - capacitors have capacity for storing charge
  - acts like a reservoir to supply current during low spots
  - voltage regulator smoothes out remaining ripple
How smooth is smooth?

• An RC circuit has a time constant $\tau = RC$
  – because $dV/dt = I/C$, and $I = V/R \rightarrow dV/dt = V/RC$
  – so $V$ is $V_0 \exp(\pm t/\tau)$

• Any exponential function starts out with slope = Amplitude$/\tau$

• So if you want < 10% ripple over 120 Hz (8.3 ms) timescale...
  – must have $\tau = RC > 83$ ms
  – if $R = 100 \, \Omega$, $C > 830$ $\mu$F
Regulating the Voltage

• The unregulated, ripply voltage may not be at the value you want
  – depends on transformer, etc.
  – suppose you want 15.0 V
• You could use a voltage divider to set the voltage
• But it would droop under load
  – output impedance → \( R_1 \parallel R_2 \)
  – need to have very small \( R_1, R_2 \) to make “stiff”
  – the divider will draw a lot of current
  – perhaps straining the source
  – power expended in divider >> power in load
• Not a “real” solution
• Important note: a “big load” means a small resistor value: \( 1 \, \Omega \) demands more current than \( 1 \, \text{M} \Omega \)
The Zener Regulator

- **Zener diodes break down at some reverse voltage**
  - can buy at specific breakdown voltages
  - as long as *some* current goes through zener, it’ll work
  - good for rough regulation

- **Conditions for working:**
  - let’s maintain some minimal current, $I_z$ through zener (say a few mA)
  - then $(V_{in} - V_{out})/R_1 = I_z + V_{out}/R_{load}$ sets the requirement on $R_1$
  - because presumably all else is known
  - if load current increases too much, zener shuts off (node drops below breakdown) and you just have a voltage divider with the load

![Diagram of Zener Regulator](image)
# Example of Zener Diode Voltage Range

<table>
<thead>
<tr>
<th>BZY88...</th>
<th>Working Voltage $V_z$ at $I_z = 1 , mA$</th>
<th>Temperature Coefficient $S_z$ at $I_z = 1 , mA$</th>
<th>Differential Resistance $r_{\text{diff}}$ at $I_z = 1 , mA$</th>
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<td>Min.</td>
<td>Nom.</td>
<td>Max.</td>
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</table>
Voltage Regulator IC

• Can trim down ripply voltage to precise, rock-steady value
• Now things get complicated!
  – We are now in the realm of integrated circuits (ICs)
• ICs are whole circuits in small packages
• ICs contain resistors, capacitors, diodes, transistors, etc.
Voltage Regulators

• The most common voltage regulators are the **LM78XX (+ voltages)** and **LM79XX (− voltages)**
  
  — XX represents the voltage
  
  — 7815 is +15; 7915 is −15; 7805 is +5, etc
  
  — typically needs input > 3 volts above output (reg.)

• A versatile regulator is the **LM317 (+)** or **LM337 (−)**
  
  — 1.2–37 V output
  
  — \( V_{\text{out}} = 1.25(1+R_2/R_1) + I_{\text{adj}}R_2 \)
  
  — Up to 1.5 A
  
  — picture at right can go to 25 V
  
  — datasheetcatalog.com for details
Switched Mode Power Supplies

Linear

1. Stepped down,
2. Rectified,
3. Filtered,
4. Regulated

Loss
Costly

Switched

1. The unregulated DC is chopped at a high frequency (using transistor / MOSFET / IGBT)
2. The chopped waveform is then rectified and filtered to get the desired DC voltage.