

# ECE 214 – Electrical Circuits Lab

## Lecture 10

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# Announcements

- Midterm next week during class (April 21st)
- Final writeup due last day of classes (Friday May 1st 5pm)
- Final on Tuesday May 5th, 8am
- Lab notebooks will be collected immediately after the final.

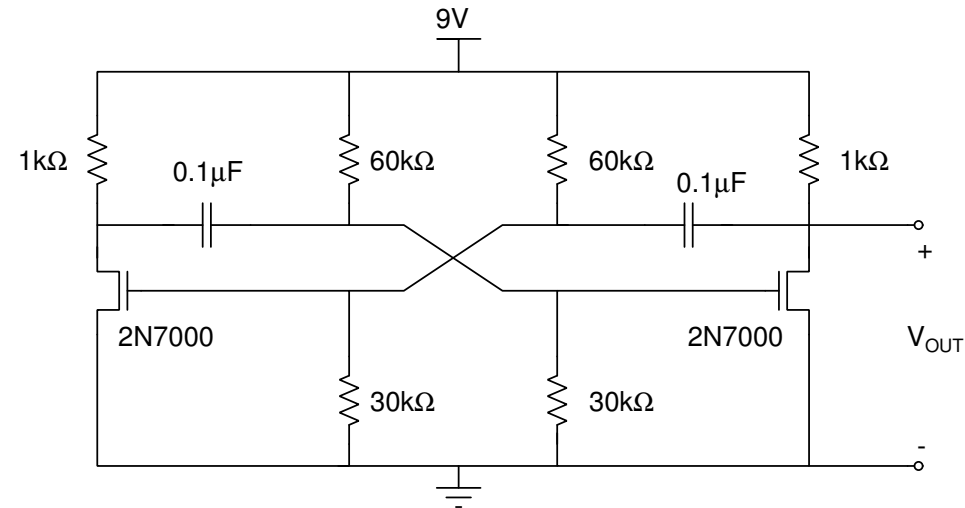
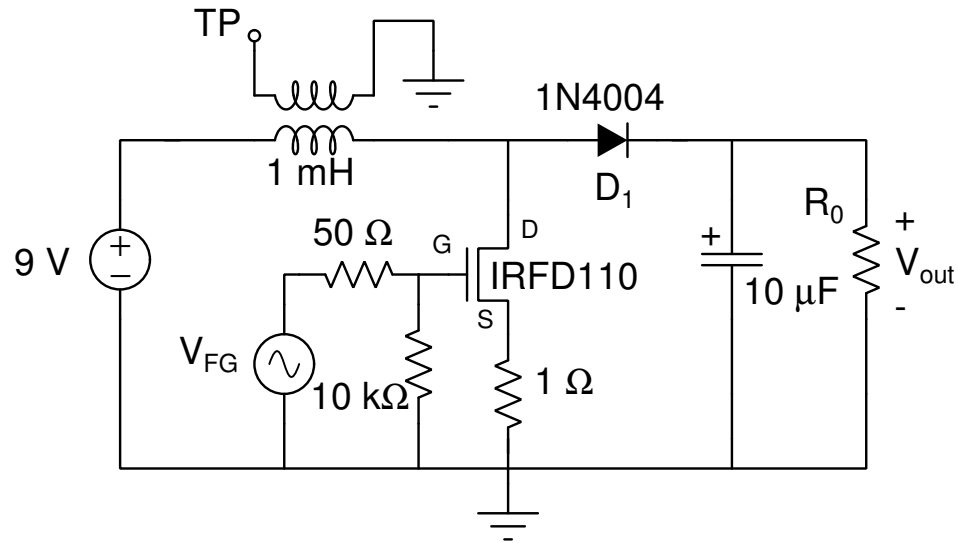


# Lab #10 – DC-DC Power Supply

- Take 9V in, output 45V, with less than  $1V_{P-P}$  of ripple.
- Add a second stage of your boost converter.
- Conveniently, the Duty Cycle for pulse input for each stage is  $1 - \frac{V_i}{V_o}$ . Note that  $9/20$  is very close to  $20/45$ .
- Once you get the first stage outputting 20V with relatively low ripple, I'd attach the second circuit and then mostly fiddle with the output load values.



# Circuit review



# Circuit theory review

- Voltage boost based on the duty cycle, roughly  $1 - \frac{V_i}{V_o}$
- Ripple based on various things. Partly based on the frequency of your multivibrator.  
What happens if you have too low frequency?  
Saturate the inductor, short to ground, high current.
- Ripple also affected by the load. Higher resistance affects the time constant; the capacitor voltage drains less before being recharged.



# Estimating Manufacturing Costs

- Pretend you are going to be manufacturing the DC-DC converters.
- How much would it cost to make 10,000 of them?



# Non-recurring costs

- One-time costs independent of the number you produce
  - Design time
  - Simulation / Verification
  - Prototype build, test, and verification
  - PCB design time
  - Packaging design
  - Reliability engineering
  - Temperature testing
  - Accelerated lifetime testing



- UL Listing
- Marketing / Advertising / Kickstarter?
- Engineering costs based on man-month rate, or hourly rate
  - Salary – \$60-70k/year?    \$30-\$35/hr (roughly 2000 hours/year)
  - Benefits
    - \* Social Security / Medicare (17%, half paid by employer)  
\$2.70/hr





- \* Health care: dental, vision. \$12-24k/year (employer pays 80%) \$5-\$10/hr
- \* Sick leave, holidays, 3 weeks vacation, roughly 10%, \$3-\$4/hour
- Let's estimate \$35/hr + \$15/hr benefits is roughly \$50/hr

- Overhead

- Office (or cube) \$1.50/sqft month
- Internet connection / Phone
- Electricity/Heat/AC



- Admin support
- IT/computer/laptop/backups
- Usually calculated as percentage of salary, let's estimate 100%
- **Total now \$100/hr for engineering cost**



# Recurring costs



# Bill of Material (BOM)

- Interesting reference:  
<http://www.bunniestudios.com/blog/?p=2776>
- Quantity, Value, and Price
- Value
  - Be specific! Factory will want to substitute to use cheapest part possible.
  - Don't just say 1k resistor. Say 1k 5% 1/4 Watt through-hole resistor (axial)



- How many parameters can something simple like a resistor have?  
Size. Tolerance. Wattage. Through hole vs SMT, Type (carbon film vs wire-wound)
- Capacitor?  
Size. Voltage rating. Type (ceramic, tantalum, electrolytic, etc). Q value? Surface mount?  
Manufacturer (bad days with exploding caps)
- Inductor: size, core material, Q factor, max current, etc.



# Price Breaks

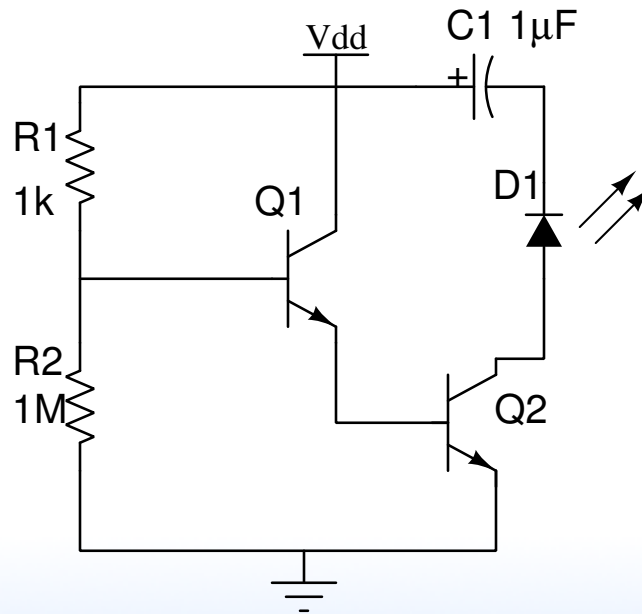
Be sure you look at price in quantity, often goes down the more you buy. An example on LEDs on digikey:

| Quantity | Unit Price | Extended Price |
|----------|------------|----------------|
| 1        | 0.33000    | 0.33           |
| 10       | 0.23900    | 2.39           |
| 100      | 0.12600    | 12.60          |
| 250      | 0.08568    | 21.42          |
| 500      | 0.07560    | 37.80          |
| 1,000    | 0.05922    | 59.22          |
| 2,500    | 0.05796    | 144.90         |
| 5,000    | 0.05040    | 252.00         |
| 10,000   | 0.04536    | 453.60         |



# Sample BOM

| Qty | Value                        | Package | Designation | Manufacturer | Part                    | Cost    |
|-----|------------------------------|---------|-------------|--------------|-------------------------|---------|
| 1   | 1K, 5%, 1/4 W                | axial   | R1          | Stackpole    | DigiKey CF14JT1K00TR-ND | 0.00475 |
| 1   | 1M, 5%, 1/4 W                | axial   | R2          | Stackpole    | DigiKey CF14JT1M00TR-ND | 0.00475 |
| 1   | 1 $\mu$ F, 50V, electrolytic | radial  | C1          | Nichicon     | DigiKey 493-12567-3-ND  | 0.046   |
| 2   | 2N2222 NPN transistor        | TO-92   | Q1, Q2      | ON Semi      | DigiKey P2N2222AGOS-ND  | 0.064   |
| 1   | Red 635nm LED 3mm            | T-1     | D1          | LiteON       | DigiKey 160-1139-ND     | 0.04536 |



# Printed Circuit Board and Assembly

- 3x4 inch board, 2-sided, silkscreen, soldermask, purchased in panels, estimate \$6.60/board
- Assembly. Large orders. Overseas? Pick-and-place robots? Surface mount stencils? Oddly can be cheaper to pay people to hand-assemble.  
1/3 cent per connection or pin. Each resistor is 2/3 cent, each transistor 1 cent.
- Yield. Not all boards work first try! Need testing





strategy.

Assume 95% will work first try, add 5% to cover rework

- Final test – can be automated, but if done by hand, 15 seconds per board, 42 hours. Done by technician at rate of \$40-\$50/hr, so 20 cents a board.



# Other costs

- Support (e-mail, 1-800 number, etc)
- Sales?
- Marketing?
- Legal?
- Shipping?



# Profit

- Usually a percentage over cost
- Too high, no one will buy
- Too low, you run risk of not having enough left over, bankruptcy



# For your final writeup

- Include BOM
- Estimated total cost
  1. Non-recurring engineering cost (use the \$100/hr estimate, pick and justify how many engineers and how long it would take to develop the board)
  2. Manufacturing cost for 10,000 units, including parts, PCB, assembly, and testing. Be sure to factor in yield.
  3. Be sure to explain the decisions you make. Simply



putting something like  $Total = 10000 * 25.00 + 500 * 3 + 100 * 40$  is not enough.

- Final selling price per unit

