

SO FAR:

- COMPLEX IMPEDANCE
- PASSIVE & ACTIVE FILTERS
- SPECTRAL (FOURIER) ANALYSIS

TODAY:

POWER SUPPLIES

- TRANSFORMERS
- RECTIFIERS
- FILTERING
- LINEAR REGULATORS

NEXT TIME: START DIGITAL ELECTRONICS!

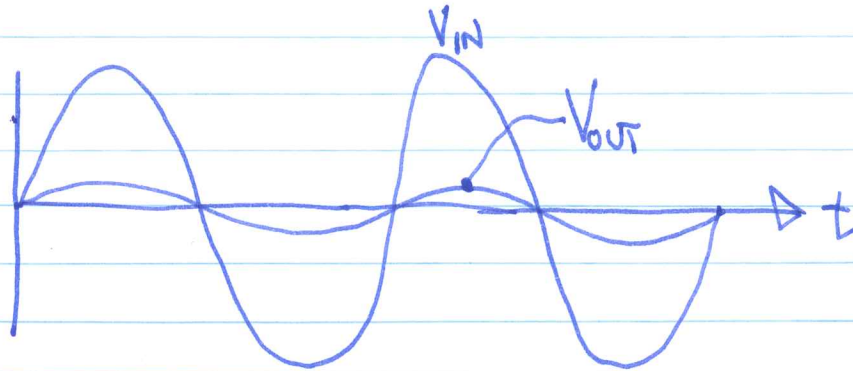
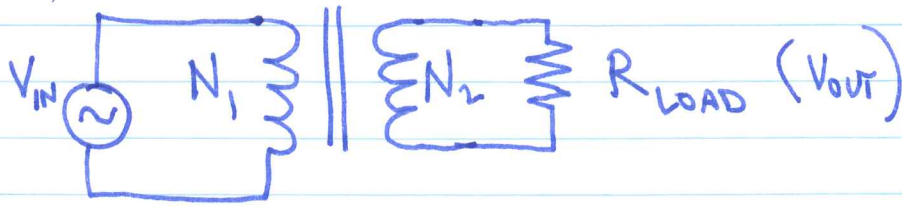


TODAY'S OBJECTIVE IS TO START WITH 120 V AC FROM THE WALL AND END UP WITH A WELL-REGULATED DC POWER SOURCE.

IT IS NOT UNUSUAL IN PHYSICS EXPERIMENTS FOR POWER SUPPLY STABILITY TO BE THE LIMITING FACTOR IN A PRECISION MEASUREMENT.

FIRST, STEP VOLTAGE DOWN.

TRANSFORMER — TURN RATIO $N_2:N_1$



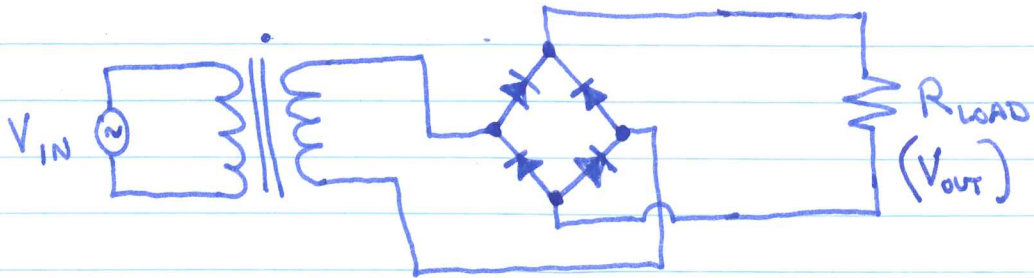
$$V_{OUT} = \frac{N_2}{N_1} V_{IN}$$

$$i_{OUT} = \frac{N_1}{N_2} i_{IN}$$

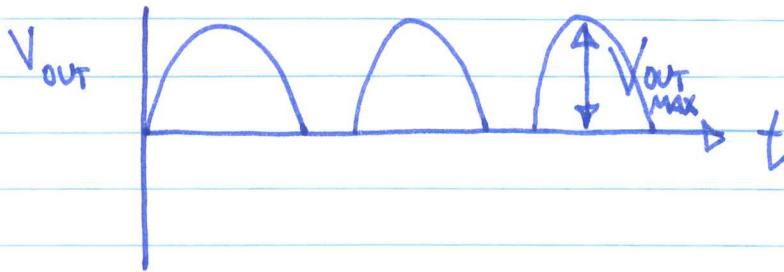
$$P_{OUT} = P_{IN} \text{ (IDEALLY)}$$

SECOND, CONVERT FROM AC TO DC.

BRIDGE RECTIFIER



$$\text{DIODE DROP} = V_t$$



$$V_{OUT} = H \left[\left| \frac{N_2}{N_1} V_{IN} \right| - V_t \right]$$

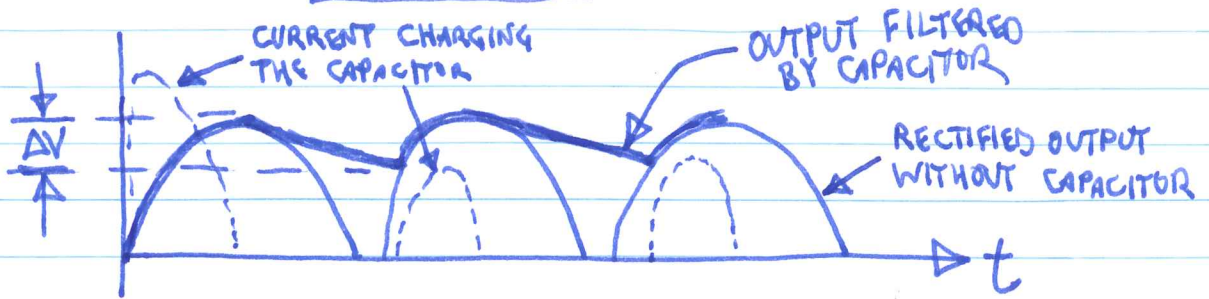
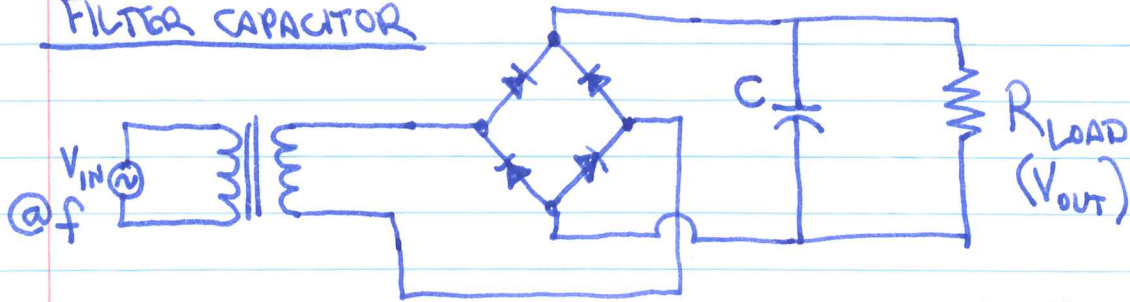
HEAVISIDE FUNCTION

$$H(x) = \begin{cases} 1, & x \geq 0 \\ 0, & x < 0 \end{cases}$$

$$V_{OUT\ MAX} = \frac{N_2}{N_1} V_{IN\ MAX} - 2V_t$$

THIRD STEP: SMOOTH OUT THE BUMPS

FILTER CAPACITOR



WE CALL THIS A BRUTE FORCE POWER SUPPLY.

SIMILAR SUPPLIES ARE COMMON FOR MODEL RAILROAD EQUIPMENT AND OTHER APPLICATIONS THAT ARE INSENSITIVE TO NOISE.

RIPPLE VOLTAGE:

$$q = CV$$

$$V = iR$$

$$i = \frac{dq}{dt} = \frac{V}{R} = C \frac{dV}{dt}$$

$$\text{SO } \frac{dV}{dt} = \frac{V}{RC} \quad (\text{THIS SHOULD LOOK FAMILIAR})$$

NOW, THE CAPACITOR DISCHARGES FROM V_{OUT_MAX} FOR A TIME OF $\Delta t = T/2 = 1/2f$.

ASSUMING $\Delta t \ll RC$,

$$\Delta V \approx \frac{dV}{dt} \Delta t = \frac{V_{OUT_MAX}}{2fRC}$$

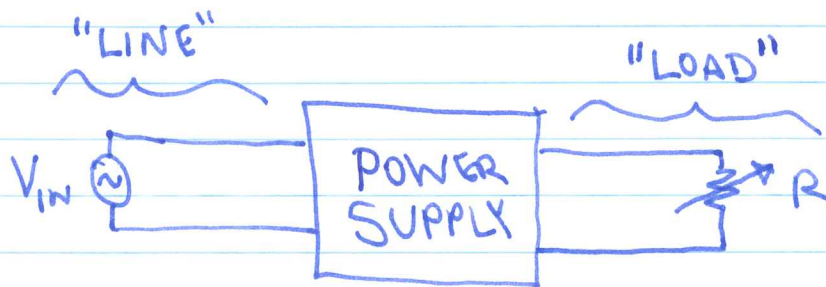
LOAD AND LINE REGULATION

LOAD REGULATION:

"CHANGE IN OUTPUT VOLTAGE OR CURRENT FOR ANY LOAD CHANGE WITHIN RATINGS"

LINE REGULATION:

"CHANGE IN OUTPUT VOLTAGE OR CURRENT FOR ANY LINE CHANGE WITHIN RATINGS"



Q: WHAT ARE THE LOAD AND LINE REGULATION CHARACTERISTICS OF THE BFPS ?

BFPS LOAD REGULATION:

$$\Delta V = \frac{V_{OUT\ MAX}}{2f R_{LOAD} C}$$

THE SMALLER R_{LOAD} , THE GREATER THE CURRENT LOADING THE SUPPLY, AND THE GREATER THE RIPPLE VOLTAGE. THE MEAN OUTPUT VOLTAGE IS ROUGHLY

$$\bar{V}_{OUT} = \left(1 - \frac{1}{4f R_{LOAD} C} \right) V_{OUT\ MAX}$$

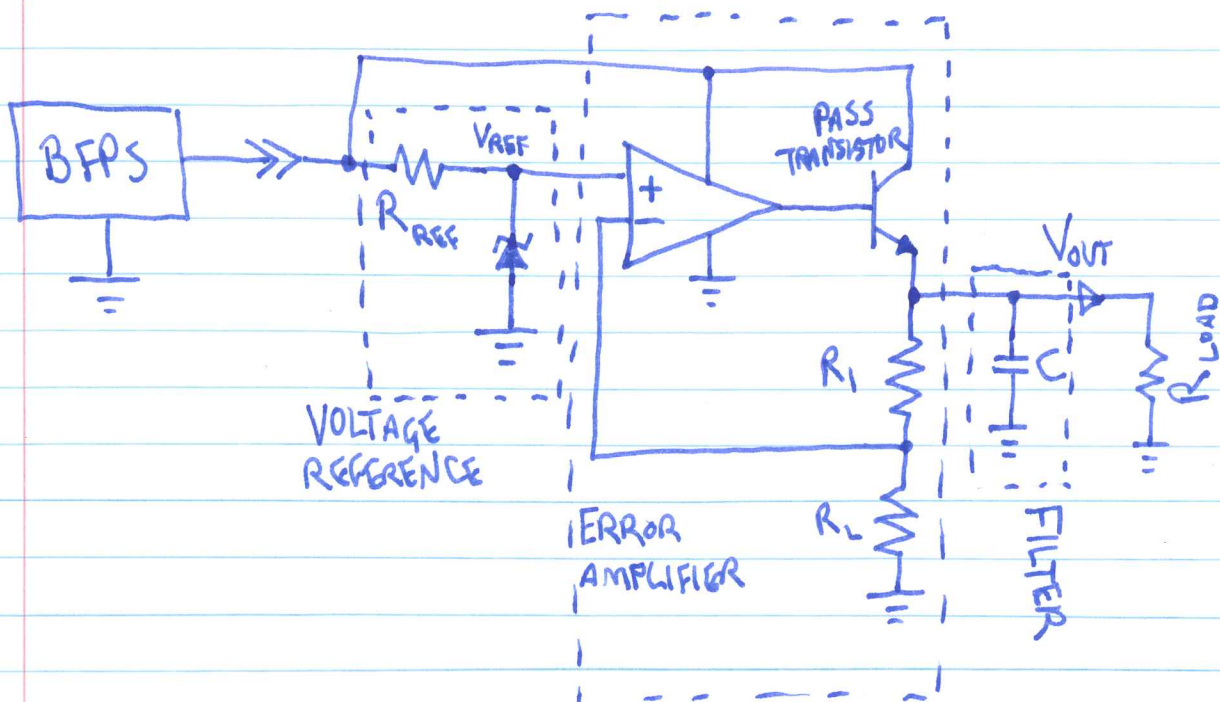
BFPS LINE REGULATION:

$$V_{OUT\ MAX} = \frac{N_2}{N_1} V_{IN\ MAX} - V_t$$

$$\Delta V_{OUT} = \frac{N_2}{N_1} \Delta V_{IN}$$

SO, THE BFPS HAS ESSENTIALLY NO LINE REGULATION. THE OUTPUT VOLTAGE IS ESSENTIALLY PROPORTIONAL TO LINE VOLTAGE.

SIMPLIFIED LINEAR REGULATOR



HOW IT WORKS:

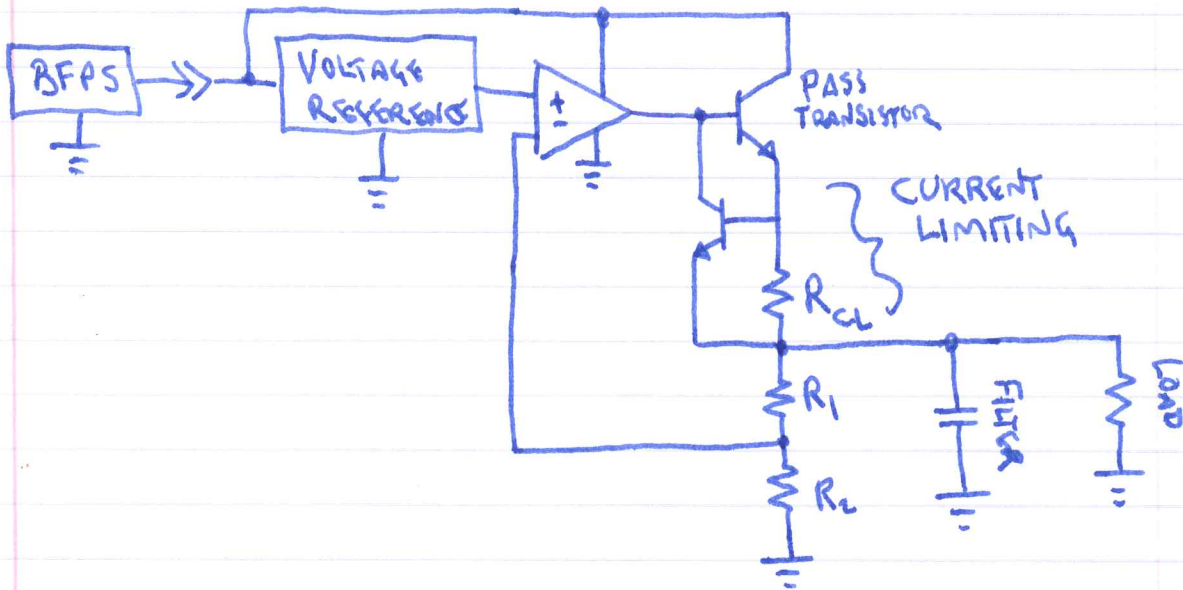
- ZENER DIODE PROVIDES A VOLTAGE REFERENCE.
- OP AMP STABILIZES OUTPUT VOLTAGE AT $\left[\frac{R_1 + R_2}{R_2} \right] V_{REF}$.
- PASS TRANSISTOR CAN SOURCE LOTS OF CURRENT, SO IT ACTS AS A LINE DRIVER FOR THE OP AMP.
- FILTER CAPACITOR SMOOTHS OUT REMAINING RIPPLE.

ISSUES:

- INRUSH* AT TURN-ON TIME CAN DAMAGE PASS TRANSISTOR.
- VARYING CURRENT THROUGH ZENER CAUSES SMALL FLUCTUATIONS OF REFERENCE VOLTAGE.

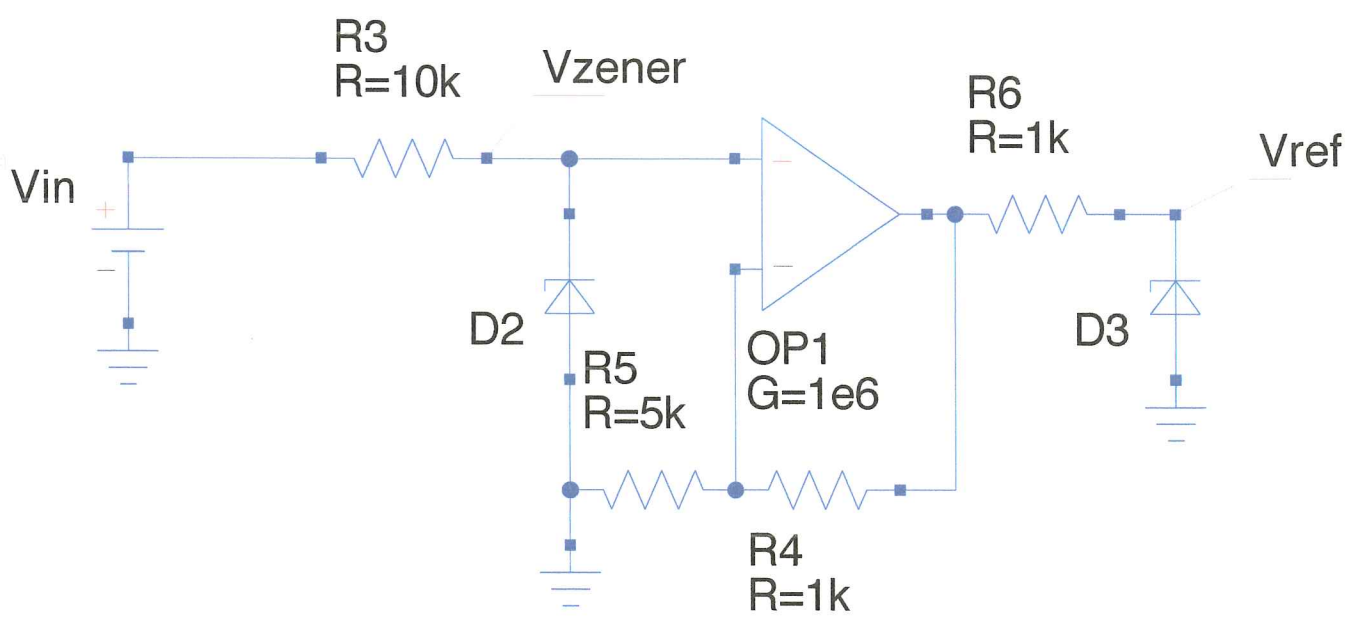
* I.E., WHILE CAPACITOR IS CHARGING INITIALLY.

CURRENT LIMITING (PROTECTS THE PASS TRANSISTOR)



- R_{CL} IS A SMALL VALUE, CHOSEN SO THAT $V = iR_{CL} = 0.7V$ FOR SOME MAXIMUM DESIRED CURRENT. WHEN THIS THRESHOLD IS EXCEEDED, THE LOWER TRANSISTOR TURNS ON AND REDUCES THE BASE CURRENT TO THE PASS TRANSISTOR.

(CRIBBED FROM THE LM723 DATA SHEET)



PRECISION VOLTAGE REFERENCE

- THIS IS INTENDED TO IMPROVE LINE REGULATION.
- THE 723 REGULATOR USES AN AMPLIFIER AND A CURRENT SOURCE TO ACCOMPLISH THE SAME THING.

