Simple Introduction to Transistor (BJT) Amplifier

Bipolar Junction Transistor

- Made out of n-type and p-type silicon
- There are two "flavors" of BJT's
  - pnp & npn

To Learn More!!
EECE 332 (Semiconductors)
"**Why** do they work?"

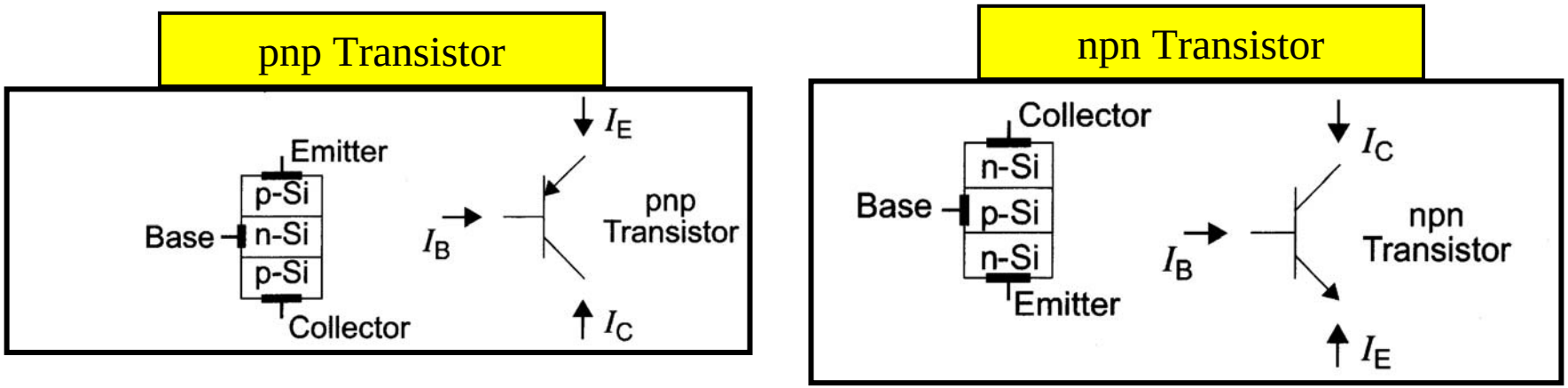


Fig. 28.6 from *Electrical Engineering Uncovered*

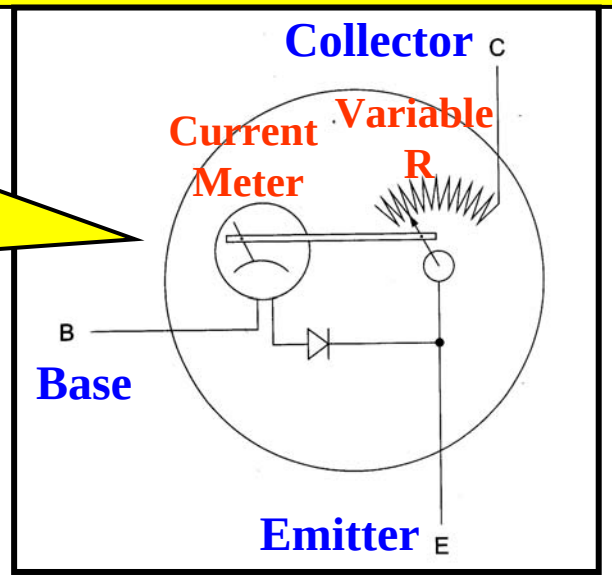
Note: Current Directions Shown are Arbitrary!!

BJT Operation

To Learn More!!
EECE 315 (Electronics)
"**How** do they work?"

- Recall FET: current flow controlled by the gate voltage
- BJT: current flow controlled by the base current
  - Acts like a current amplifier
    - But… with the right circuitry around it can also be a voltage amplifier

Conceptual Model of **npn** Transistor



- Base Current deflects current meter
- Meter linked to variable R
  - Controls the Collector current

➔ Voltage supply between C & E provides large Collector current controlled by small Base current

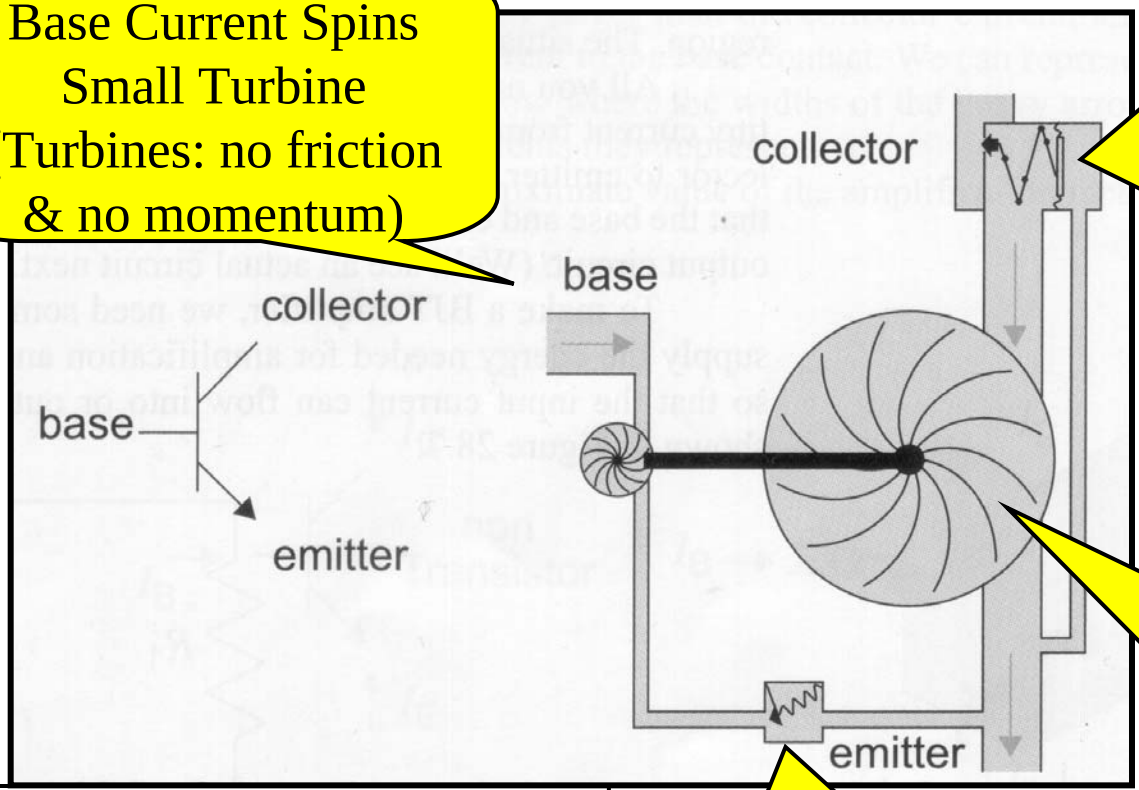
Fig. 28.4 from *Electrical Engineering Uncovered*

BJT Water Model

- While this electrical conceptual model is good… we can also use a water model

Base Current Spins Small Turbine (Turbines: no friction & no momentum)

Regulator (like scuba tank's) ensures that current flows only due to the turbine's "suck"… not the pressure difference between C-E



Large Turbine spins @ same rate as small one… BUT larger size causes more water to flow

Fig. 28.5 from *Electrical Engineering Uncovered*

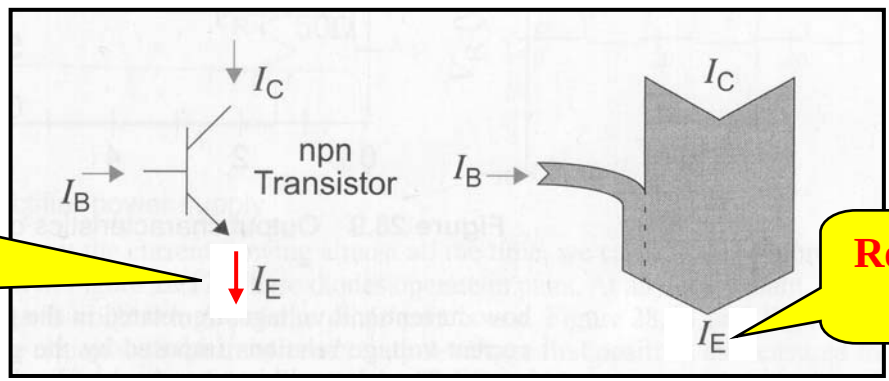
Must exceed Diode "drop" before base current flows

Current Gain of BJT

$I_c = \beta I_B$

- So… the main characteristic of a BJT is its current gain (called β… also called h_{FE}) Typical β: 50 – 200
- In our water model… β is set by the relative size of the two turbines
- Warning… a designer's knowledge of β is almost always imprecise!!!!
  - That seems to limit the usefulness… but can be handled through proper circuit design
- Emitter Current = (Collector Current) + (Base Current)

KCL!!!



Shown opposite book's direction!!

Remove | |

$$I_E = I_B + I_C$$
$$= I_B + \beta I_B$$
$$= (\beta + 1) I_B$$

Main Rules of npn BJT Operation

1. The B-E voltage must be at a "diode drop" of 0.7V
   - If not… no base current flows… and no collector current flows
   - So… if not, the transistor is "cut off"

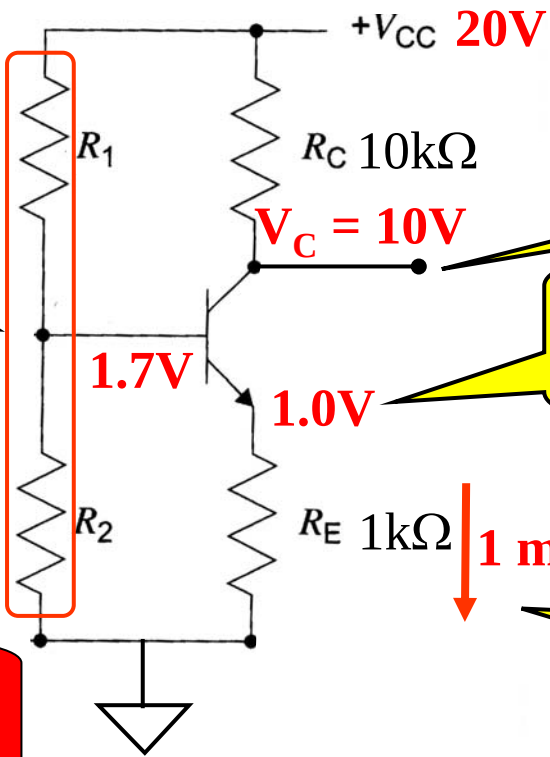
Like an open switch from collector to emitter

2. Collector must be more positive w.r.t. emitter
3. Can't exceed certain maximum values on I_B, I_C, & V_{CE}
4. When rules 1 – 3 are obeyed, $I_C = \beta I_B$

From *The Art of Electronics*, by Horowitz and Hill, Cambridge University Press

Biasing a Typical BJT Amplifier

Before we can use a BJT as an amplifier we need to "**set it up for use**"… called **biasing the transistor**



4. Ohms law says 10V across R_C, putting the collector at V_C = 10 V

1mA × 10k Ω = 10v

1. Voltage Divider makes this 1.7V

20v×[10/(110 + 10)]

= 1.67v

2. Diode drop makes this 1 V

3. Ohms law sets emitter current

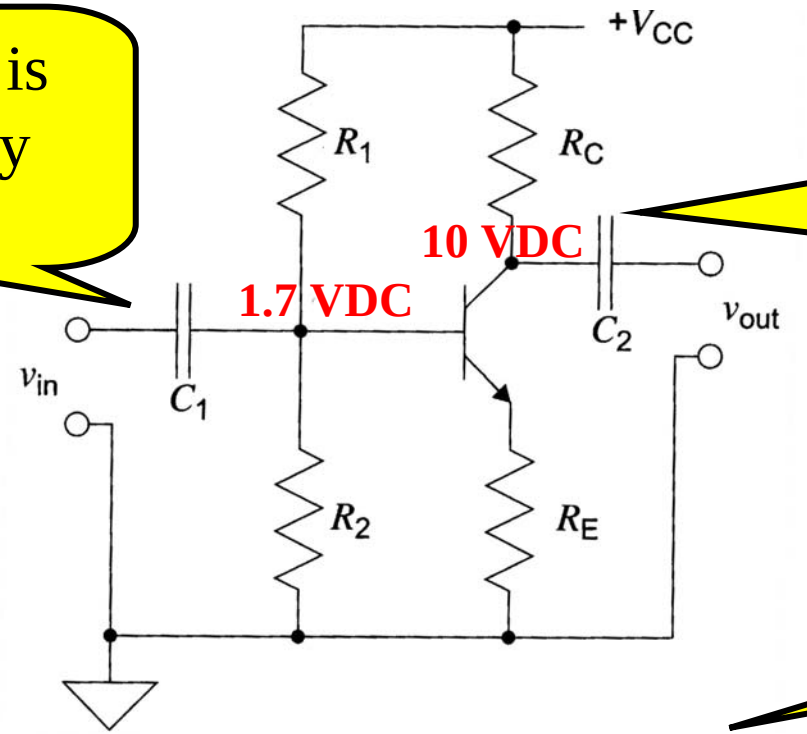
1.0v / 1000Ω = 1mA

Assumes that current into base is negligibly small

Now we can "inject" the signal we want to amplify

Injecting Signal to a BJT Amplifier

Input Signal is "capacitively coupled"



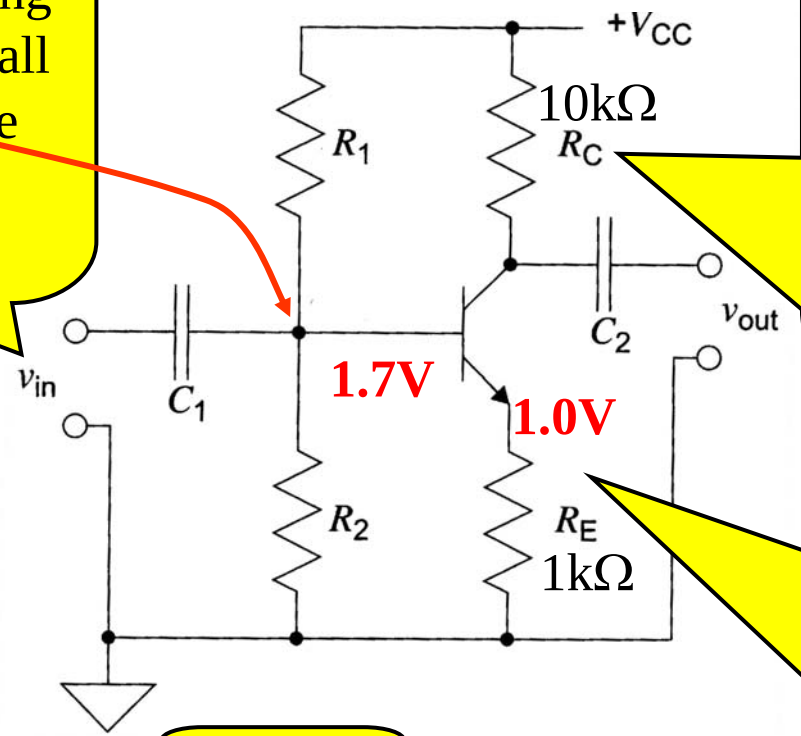
Output Signal is "capacitively coupled" too!

See EECE 260 Circuits to learn methods to analyze this idea

The Input v_{in} typically wiggles around a level of 0 VDC. But we want to make the base voltage wiggle around the 1.7 VDC level. Roughly… Because the cap is like an open circuit to a DC voltage it keeps these two different "DC center values" from "working against" each other… But it passes the input wiggles to the base!!

Gain Analysis of BJT

1. A small wiggling v_{in} causes a small wiggle ΔV_B here in V_B centered around 1.7 V



3. The collector current wiggles about the same amount: $\Delta I_C \approx \Delta I_E$. Causes the collector voltage to wiggle around 10V… But V_C goes down when V_B goes up (inversion!!!)

2. The small wiggle at the base causes the **same amount of wiggle here** around 1V… $\Delta V_E = \Delta V_B$. That **causes a wiggling emitter current ΔI_E** around 1mA

$$\Delta I_E = \frac{\Delta V_B}{R_E}$$

$$\Delta V_{R_C} \approx -R_C \Delta I_E = -R_C \frac{\Delta V_B}{R_E}$$

Inversion

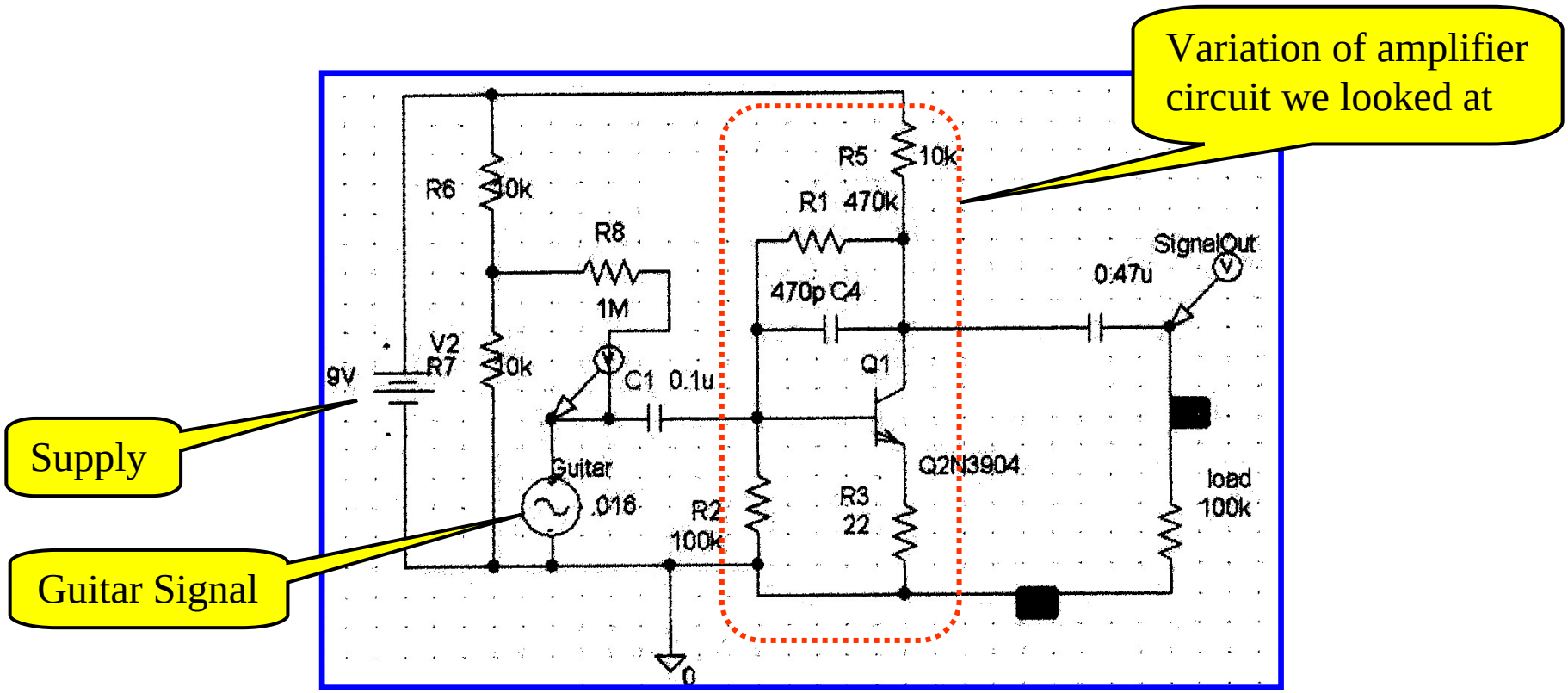
$$\frac{\Delta V_C}{\Delta V_B} = -\frac{R_C}{R_E}$$

Gain!!

Note that the transistor's current gain, β, has no direct effect on the gain… a good design!

BJT Amplifier in Real Life

Guitar distortion boxes work (in part) by amplifying the guitar signal before it reaches the actual amplifier… this overdrives the amplifier to give more distortion than it would otherwise



Partial Circuit for the Boss DS-1 Distortion Box for Guitar

From *Pedal Power Column* by Robert Keeley, in Musician's Hotline Magazine