PART 10: Introduction to Feedback

Summary

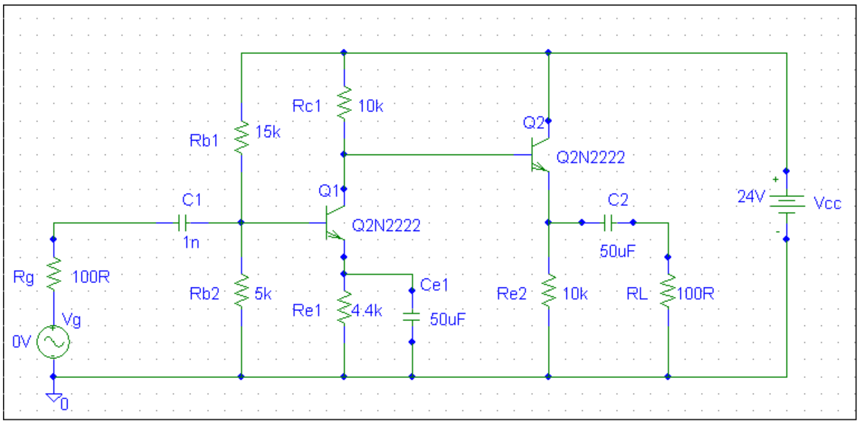
- We have developed a device electrical 'model' (hybrid-pi)
- Used this to analyse amplifier configurations: CE, CC, CB, CE-ED, Diff. Amp
- Looked at dc biasing techniques for IC based circuits – current mirrors, current sources
- Analysed the frequency response of amplifiers using equivalent circuits
  - f_T
  - $A_V(f)$
  - High-bandwidth configurations: CB, Cascode
- Field effect transistors – can use similar approaches but the model is different!
- Step response of an amplifier (time response)

Second half is concerned with **FEEDBACK**

- What is negative feedback?
  - What happens when it is applied to an amplifier: (Also covered in Control Systems!)

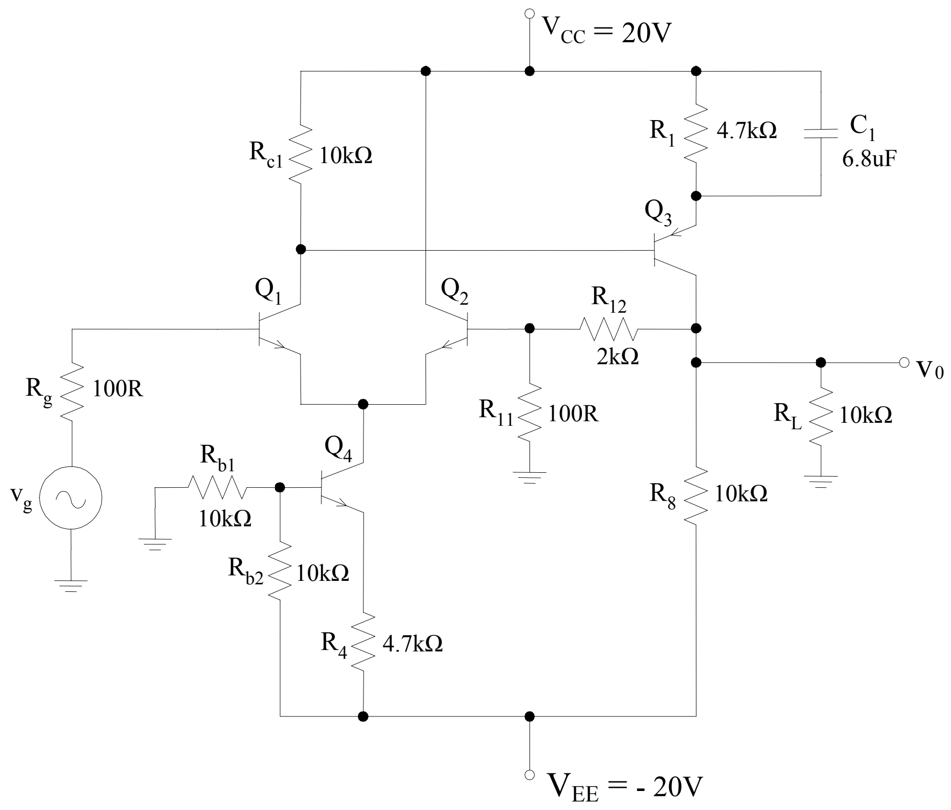
Q: Why is NF important?
A: Because transistors are such 'poor' components'
– what does poor mean??

Negative Feedback allows us to build precision amplifiers using cheap components
An example of a poor amplifier is shown below. Note the forward signal path. The results in the table indicate unacceptable performance if the circuit parameters are changed (β, R_L, R_g).



Circuit Parameters		Initial Values	β doubled	β halved	R_L up	R_g up
	β_1	100	200	50	100	100
	β_2	100	200	50	100	100
	R_L	100	100	100	1k	100
	R_g	100	100	100	100	1k
Results	$A_v = v_o/v_g$	**- 161**	**- 214**	**-106**	**-312**	**-105**
	% change in A_v	-	+33%	-34%	+94%	-35%

An example of a better amplifier is shown below.



Note again the forward signal path and FEEDBACK path via feedback resistors R_{f1}, R_{f2}. (Don't worry about the details of the circuit operation at the moment – we will look at this later – just note the improvement in performance…).

	Initial Value	**β x2**	**β /2**	**Altered R_g Values**			**Altered R_L Values**		
β_1	100	200	50	100	100	100	100	100	100
β_2	100	200	50	100	100	100	100	100	100
β_3	100	200	50	100	100	100	100	100	100
R_g	100	100	100	***1k***	***10k***	***100k***	100	100	100
R_L	10k	10k	10k	10k	10k	10k	***100M***	***1k***	***100***
A_V	**20.81**	**20.90**	**20.63**	**20.78**	**20.44**	**15.74**	**20.84**	**20.57**	**18.41**
% change	-	+0.43%	-0.86%	-0.14%	-1.78%	***-24.4%***	+0.14%	-1.15%	***-11.5%***

As you can see, changing the β values has now, little effect on the gain and as long as the source, R_g doesn't get too big (larger than 10k), or the load, R_L too small, then the gain is nearly constant at 20.8 (±2% say). Note that this is quite a small gain however, compared to the previous example. This is the **trade-off** we have made – better **stability** has been achieved at the expense of gain.

BUT, changing the feedback resistors R_{f1}, R_{f2} DOES alter the gain.

Conclusion: using negative feedback makes gain more stable to changes of components in the FORWARD signal path and allows us to set gain to any required value (within reason!) by altering components in the FEEDBACK path.

Advantages of Negative Feedback

1. Negative feedback reduces the sensitivity of the gain on parameters of amplifier such as transistor current gain.

2. Negative feedback allows us to set gain to any value we want.

3. Negative feedback increases the bandwidth of the amplifier.

4. Negative feedback reduces distortion

5. Negative feedback allows us to adjust the input and output impedances of an amplifier.

BUT these advantages do not come FREE!

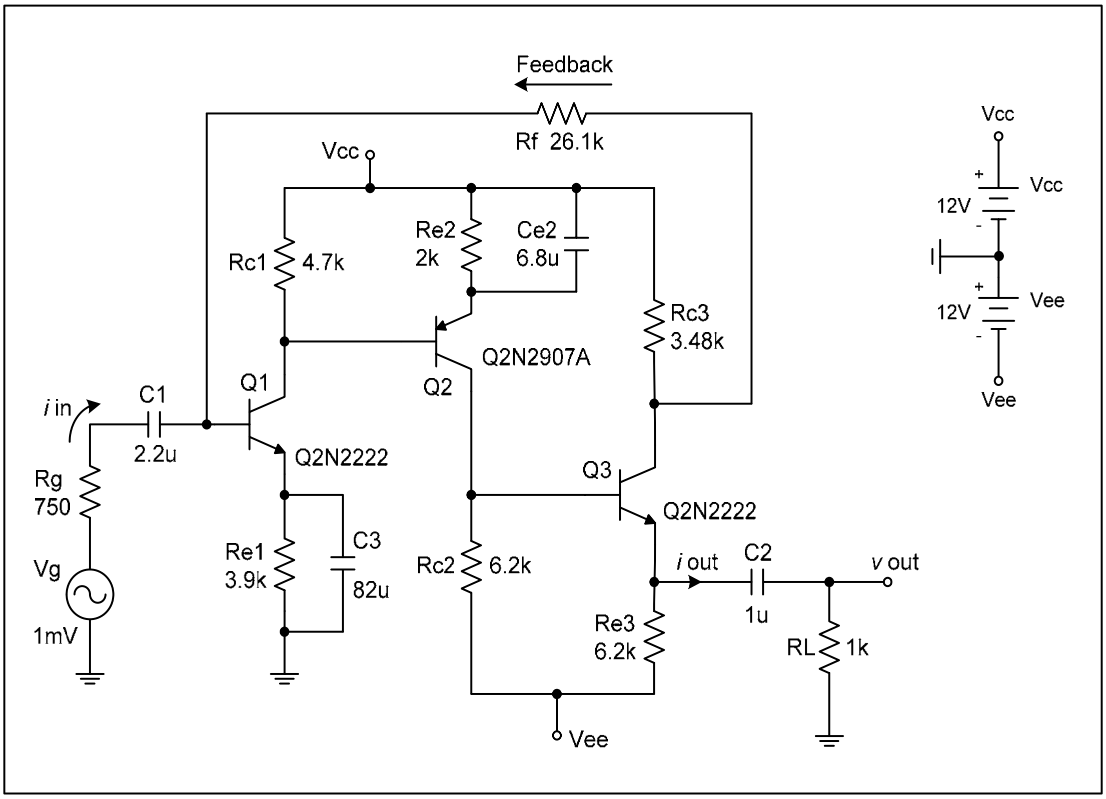
Disadvantages of Negative Feedback

1. Negative feedback always reduces the gain of an amplifier.

2. Over certain frequency ranges, it can be that negative feedback changes from negative to Positive with catastrophic results. Positive feedback increases gain of the amplifier and amplifier may be converted to an oscillator – no longer any use as an amplifier

Part 11: Introduction to Feedback - II

2[nd] example of an Amplifier with feedback – consider the circuit below.



Another Example: Current Amp

	Initial Values	βs doubled	Changing R_g			Changing R_L		
β_1	100	200	11	100	100	100	100	100
B_2	100	200	100	100	100	100	100	100
B_3	100	200	100	100	100	100	100	100
R_g	750	750	1k	2k	10k	750	750	750
R_L	1k	1k	1k	1k	1k	100	6.2k	∞
$A_v = v_o / v_{in}$	9.85	9.81	7.39	3.69	0.74	1.1	35.4	70.6

Results for $A_v = \frac{v_o}{v_{in}}$ are poor compared with example in previous lecture (part 10).

What has gone wrong?!

Consider a different type of gain – the current gain of the amplifier defined as $A_i = \frac{i_o}{i_{in}}$

$A_i = i_o / i_{in}$	8.58	8.54	8.58	8.58	8.58	8.58	8.58	8.57

The results show that for this type of gain, the stability to changes in parameters is good.

Q: what makes this amplifier keep A_i stable while in previous circuit $A_V = \frac{v_O}{v_{in}}$ = was kept stable??

Answer is basically the way in which feedback is applied! To answer the question properly we must look at:

Different types of amplifier

1) Voltage Amp $A_V = \frac{v_O}{v_{in}}$

2. Current Amp $A_i = \frac{i_o}{i_g}$

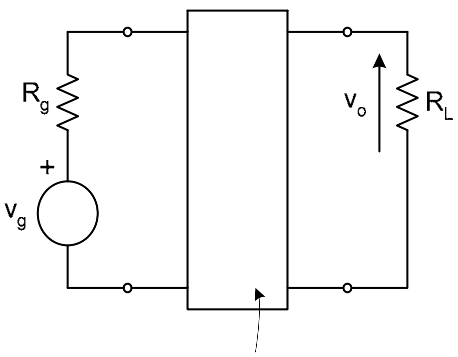
3. Transresistance Amp $A_r = \frac{v_o}{i_g}$ (Measured in ohms)

4. Transconductance Amp $A_g = \frac{i_o}{v_{in}}$ (Measured in Siemens)

Feedback can only stabilise one of these gains.

Ideal Amplifiers

What makes these amplifiers different? When is it possible to describe an amplifier as a voltage amplifier rather than say a current amplifier?

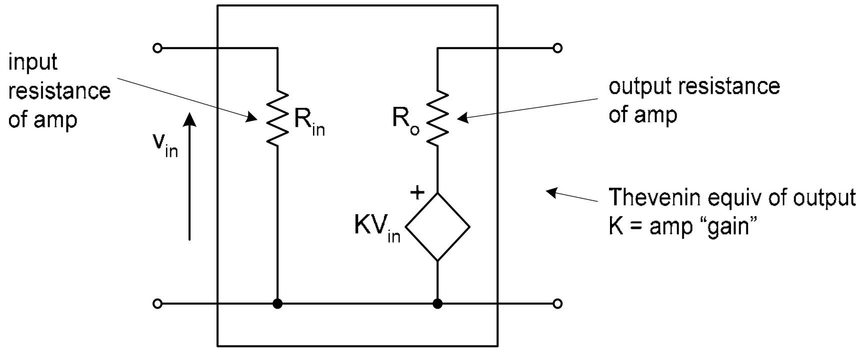


This is supposed to be a voltage amp

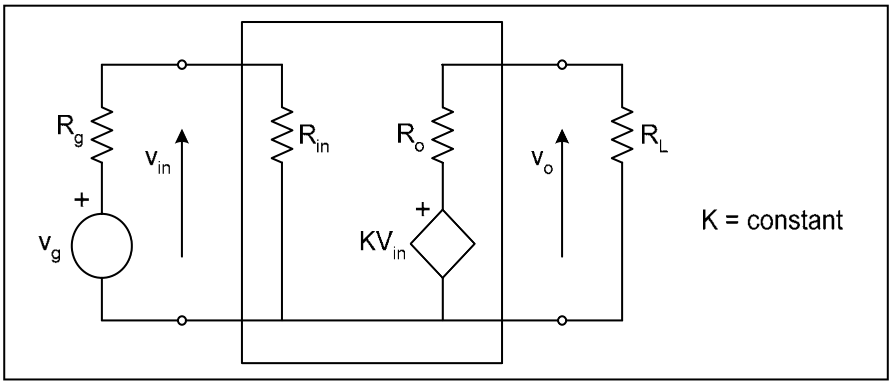
This is supposed to be a voltage amp but how do I tell? What we expect from a good voltage amplifier is that the overall voltage gain $\frac{v_o}{v_g}$ from source to load should not vary too much with changes in R_g and R_L - ideally not at all. So experimentally we could change R_g and R_L and see if voltage gain remains const. – if it does we have a good voltage amplifier

Q: What makes a good voltage amplifier?

Ans: An amplifier will be a good voltage amplifier if its equivalent circuit looks like the model below, with R_{in} BIG and R_o SMALL.



Proof:



$$v_o = \frac{R_L}{R_o + R_L} K v_{in}$$

$$v_{in} = \frac{R_{in}}{R_{in} + R_g} \quad v_g$$

$$\therefore \frac{v_o}{v_g} = A_v = \frac{R_L}{R_o + R_L} \quad K \quad \frac{R_{in}}{R_{in} + R_g}$$

$$\rightarrow K \text{ if } R_o \text{ is small and } R_{in} \text{ is BIG}$$

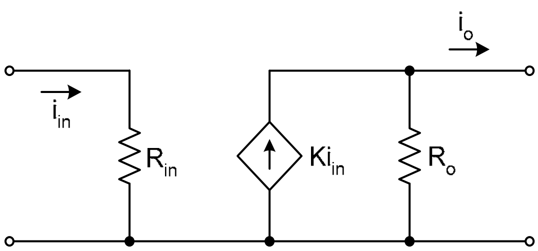
So A_v doesn't depend on R_g *and* R_L as required.

Conclusion: Ideal voltage Amp has $R_{in} = \infty$, and $R_o = 0$.

Current amps

How do we recognise? - $\frac{i_o}{i_{in}}$ should NOT change with changes in R_g *and* R_L

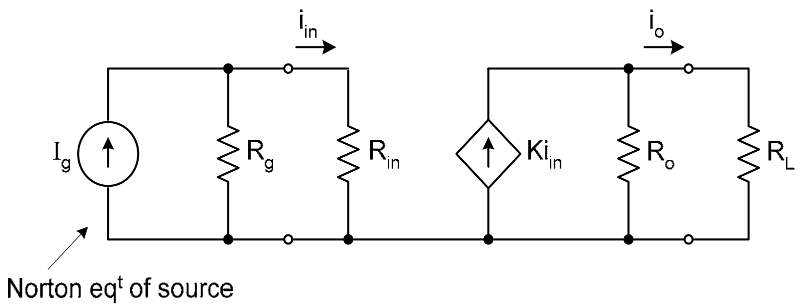
Equivalent circuit:



Note we use Norton equivalent now since dealing with **currents.**

To make a good current amp: R_{in} should be **small** and R_o should be **big**

Let's look at the model:



$$i_o + \frac{R_o}{R_o + R_L} K\, i_{in} \; ; \quad i_{in} \; = \frac{R_g}{R_g + R_{in}} i_g$$

$$\therefore\; i_o = \frac{R_o}{R_o + R_L} \; K \; \frac{R_g}{R_g + R_{in}} \; i_g$$

$$\therefore \text{ current gain } \; \frac{i_o}{i_g} = \frac{R_o}{R_o + R_L} \;\; K \;\; \frac{R_g}{R_g + R_{in}} \;\; \rightarrow \; K$$

If $R_{in} = 0$ and $R_o = \infty$

Homework

Can <u>you</u> generate the equivalent circuits for a good transresistance amplifier and a good transconductance amplifier? What values should R_{in} and R_{out} have <u>ideally?</u>