Electronic circuits and systems
ELEC271

Parts 10 & 11
Introduction to Feedback 1 and 2

How to make near-to-ideal amplifiers!

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?

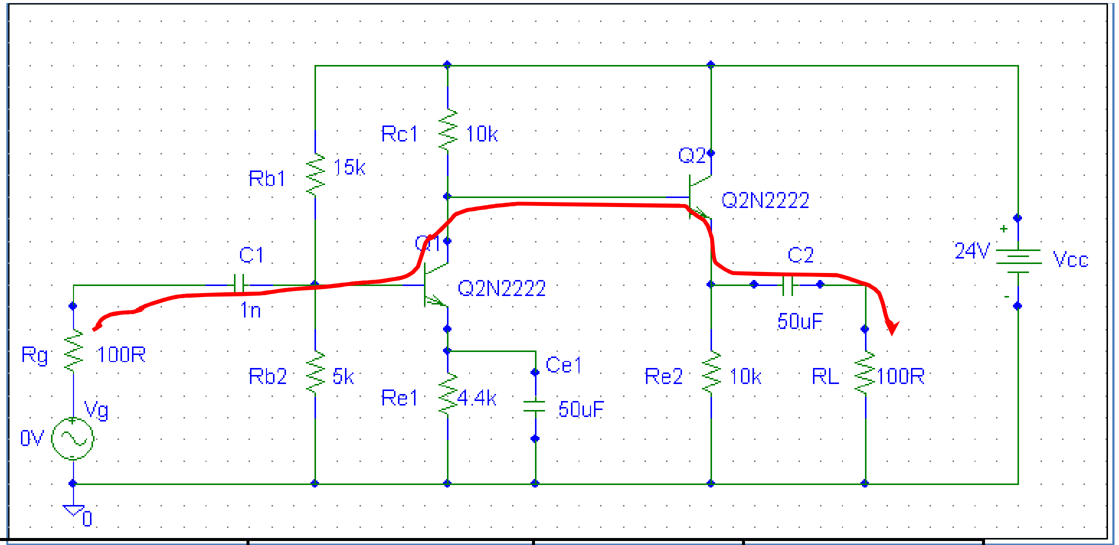
A: Because transistors are such ‘poor’ components’

– what does poor mean??

Negative Feedback allows us to build precision amplifiers using cheap and poor tolerance components

Example of a poor amplifier

Note the forward signal path.



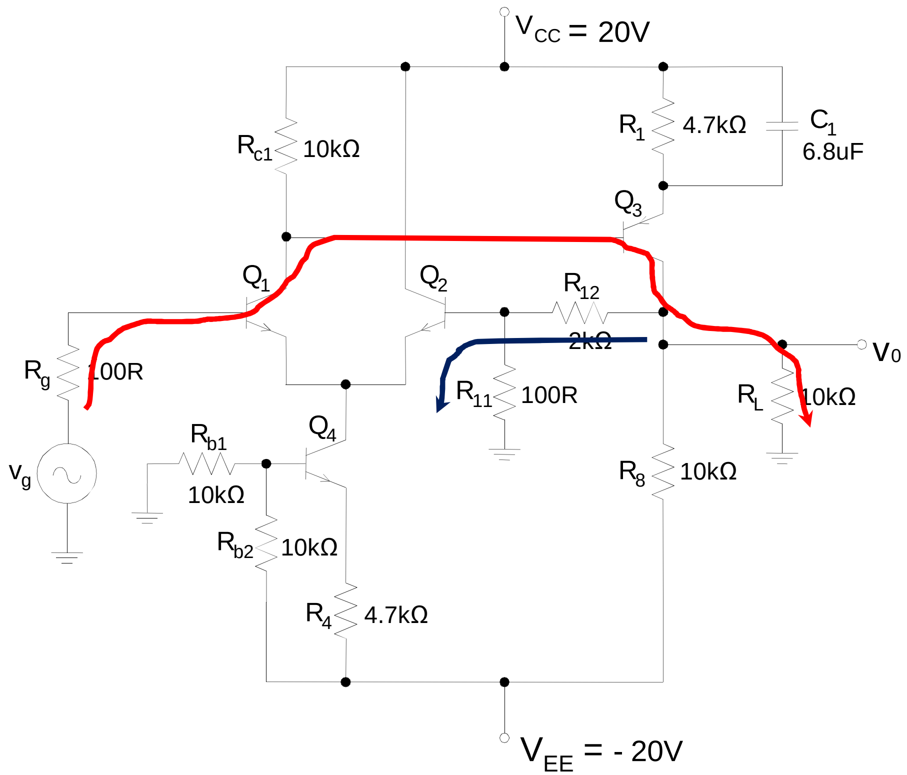
Results in the table indicate unacceptable performance if the circuit parameters are changed (β, R_L, R_g).

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%**

A ‘better’ amplifier

Note 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%***

	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 <u>increases</u> gain of the amplifier and amplifier may be converted to an <u>oscillator</u> – no longer any use as an amplifier

Part 11: Introduction to Feedback - II

2nd example of an Amplifier with feedback

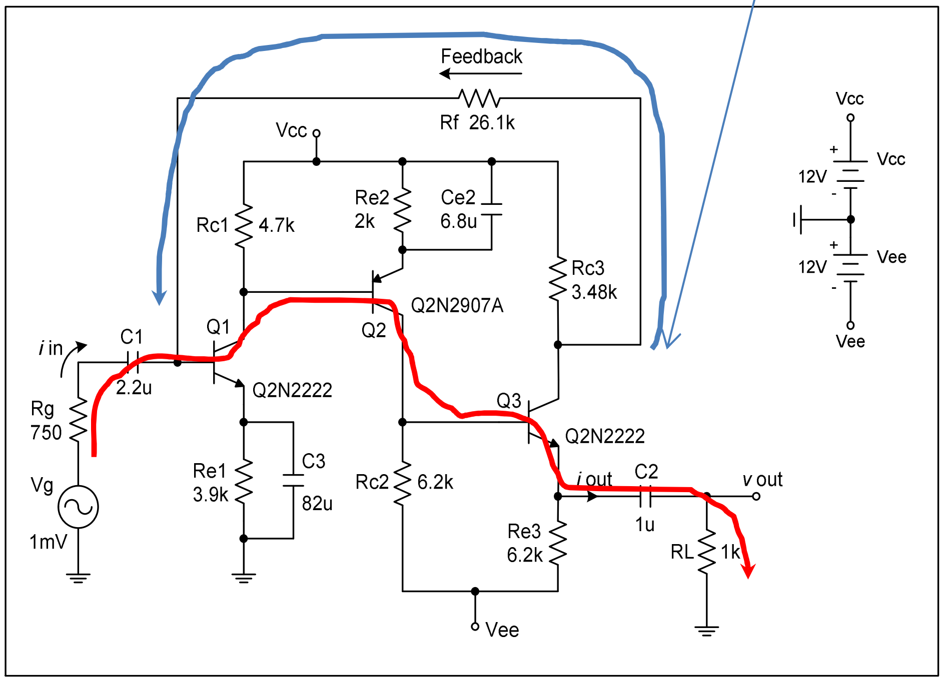
	Initial Values	β doubled	Changing R_g			Changing R_L		
β_1	100	200	11	100	100	100	100	100
β_1	100	200	100	100	100	100	100	100
β_1	100	200	100	100	100	100	100	100
R_g	750	750	1k	2k	10k	750	750	750
R_L	1k	1k	1k	1k	1k	100	6.2k	
A_V	**9.85**	**9.81**	**7.39**	**3.69**	**0.74**	**1.1**	**35.4**	**70.6**

Not from output node!

Results for $A_V = \dfrac{v_O}{v_{in}}$

are **poor** compared with example in previous lecture (part 10)

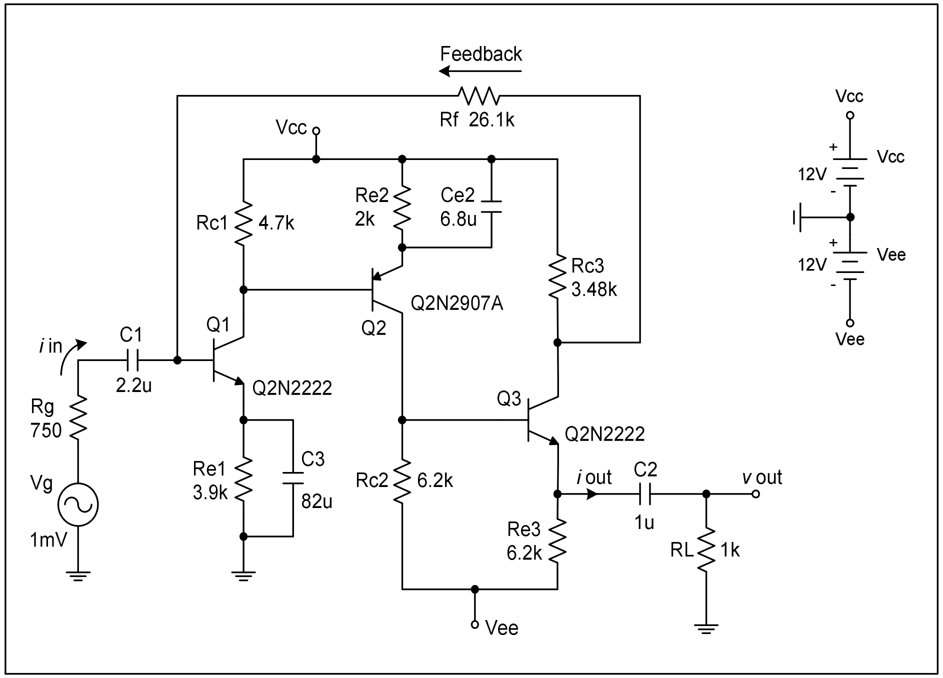
What has gone wrong?!



Part 11: Introduction to Feedback - II

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

	Initial Values	β doubled	Changing R_g			Changing R_L		
β_1	100	200	11	100	100	100	100	100
β_1	100	200	100	100	100	100	100	100
β_1	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_i	**8.85**	**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 <u>good.</u>

Q: what makes this amplifier keep A_i stable while in previous circuit

$A_v = \dfrac{v_o}{v_{in}}$ was stable.

Answer is basically the <u>way</u> in which feedback is applied! To answer the question properly we must look at the **different types** of amplifier

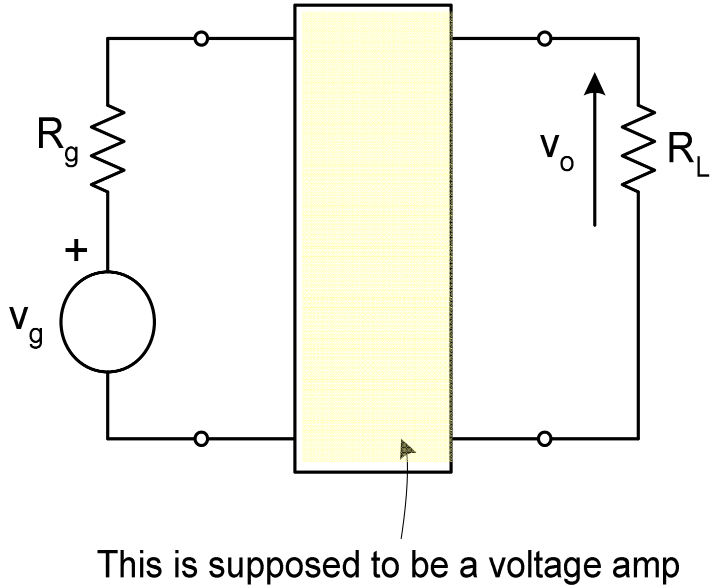
Different types of amplifier

1. Voltage Amp $A_v = \frac{v_o}{v_{in}}$
2. Current Amp $A_i = \frac{i_o}{i_g}$
3. Transresistance Amp (Measured in ohms) $A_r = \frac{v_o}{i_g}$
4. Transconductance Amp (Measured in S) $A_g = \frac{i_o}{v_{in}}$

- **Feedback can only stabilise one of these gains.**

Ideal Amplifiers

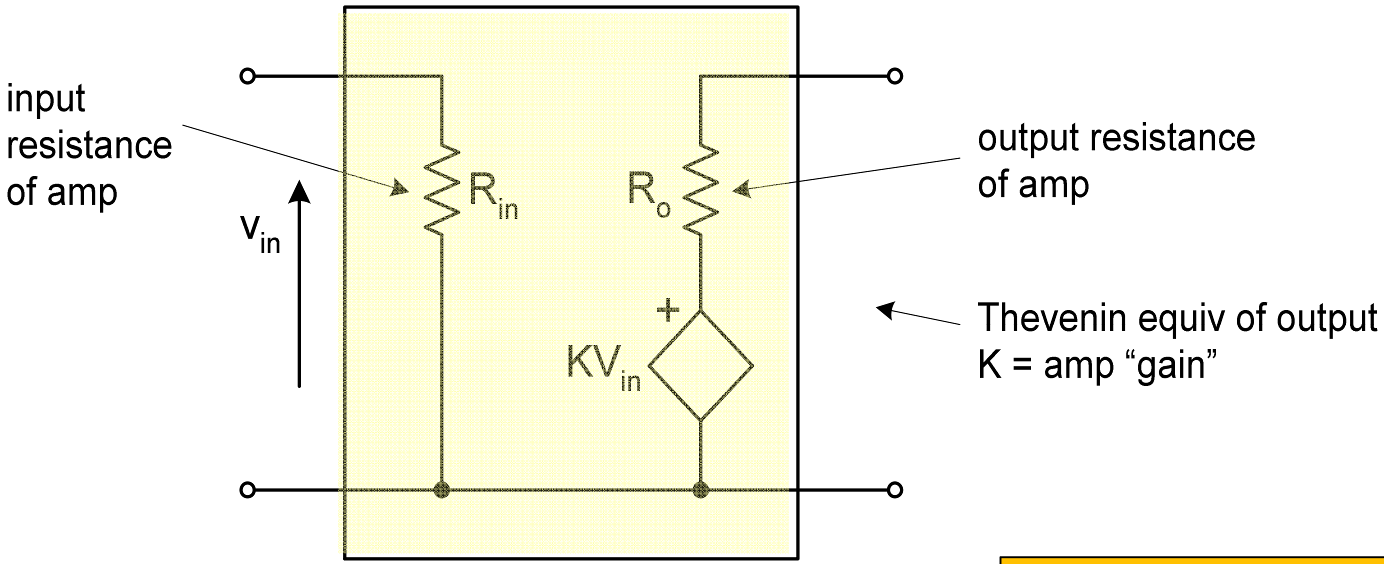
- What makes these amplifiers different? When is it possible to describe an amplifier as a voltage amplifier rather than say a current amplifier?



- What we **expect** from a good voltage amplifier is that the overall voltage gain from source to load **should not vary** too much with changes in - R_g and/or R_L ;   **ideally** not at all.
- So experimentally we could change these resistors and see if voltage gain remains const. **– if it does we have a good voltage amplifier**

Q: What makes a good voltage amplifier?

A: 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.



An equivalent circuit of an amplifier SYSTEM

How can we prove this??

Proof

Connect a load and a source to the amplifier. Then,

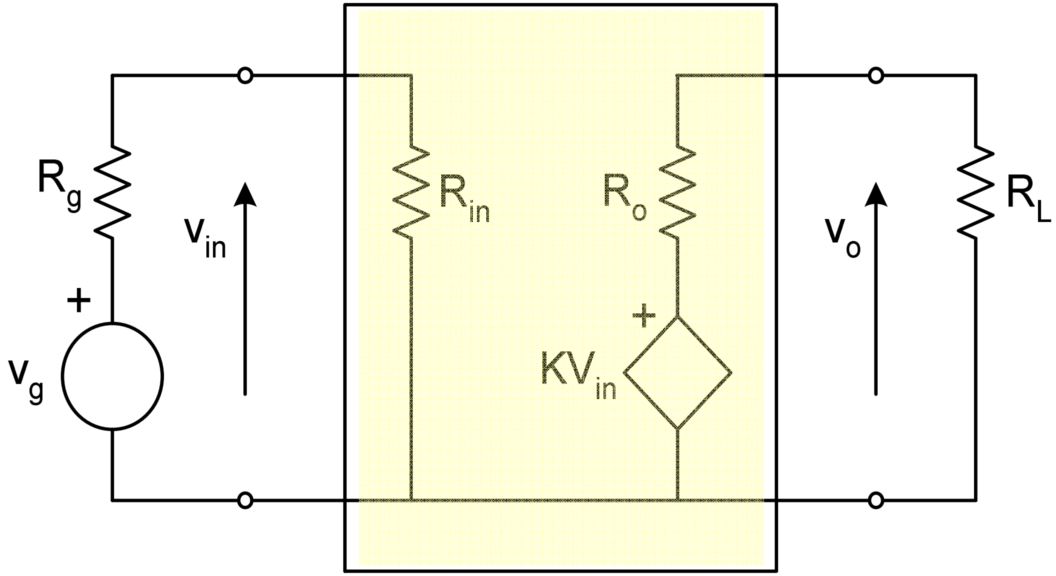
K is the gain (constant)

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

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

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

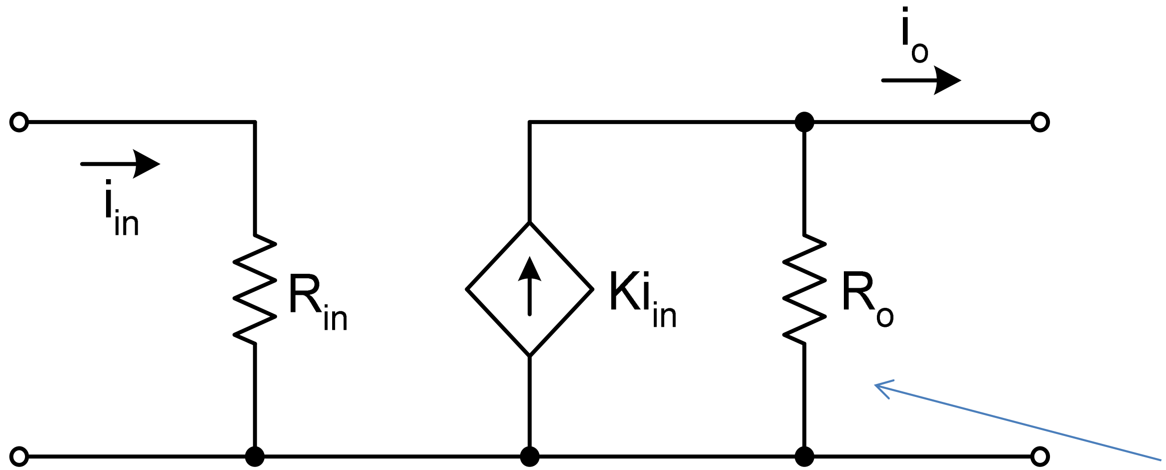
$$\rightarrow K \text{ if } R_o \text{ is small and } R_{in} \text{ is BIG}$$



So A_V doesn't depend on R_g and R_L **- as required!**

Conclusion: Ideal voltage amp. Has R_{in} = ∞ and R_o = 0.

A Current amplifier



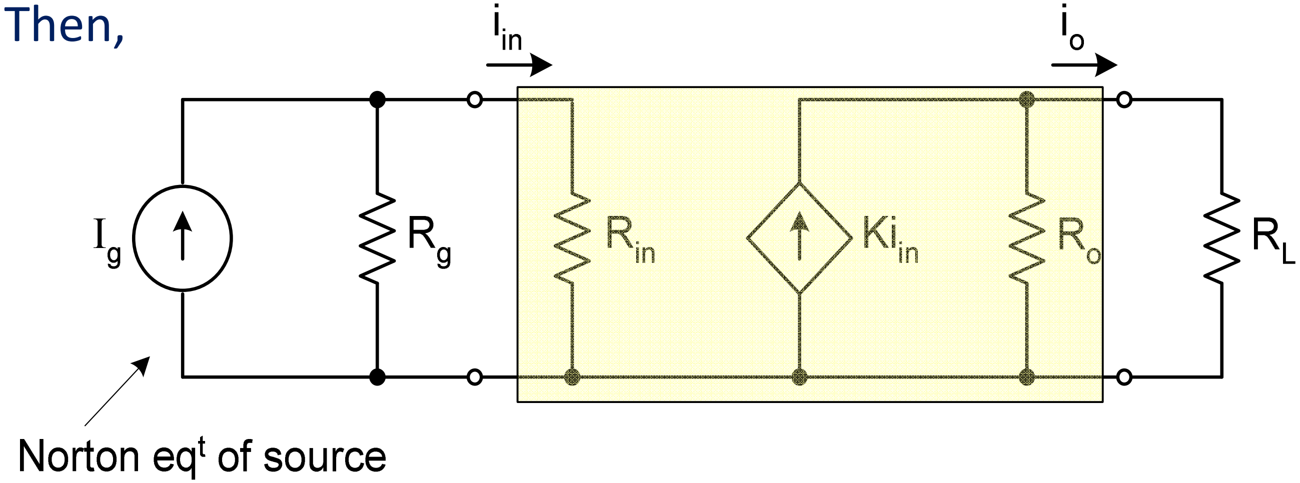
Note we use Norton equivalent now since dealing with **currents.**

- How do we recognise that it is?

$$A_i = \frac{i_o}{i_{in}}$$ should NOT change with changes in R_g, R_L

Proof

Connect a load and a source to the amplifier.
Then,



$$i_o = \frac{R_o}{R_o + R_L} K\, i_{in} \;;$$

$$i_{in} = \frac{R_g}{R_g + R_{in}} i_g$$

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

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

As required!

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

Homework

Can **you** generate the equivalent circuits for a good transresistance amplifier and a good transconductance amplifier?

What values should R_{in} and R_{out} have **ideally** in each case?