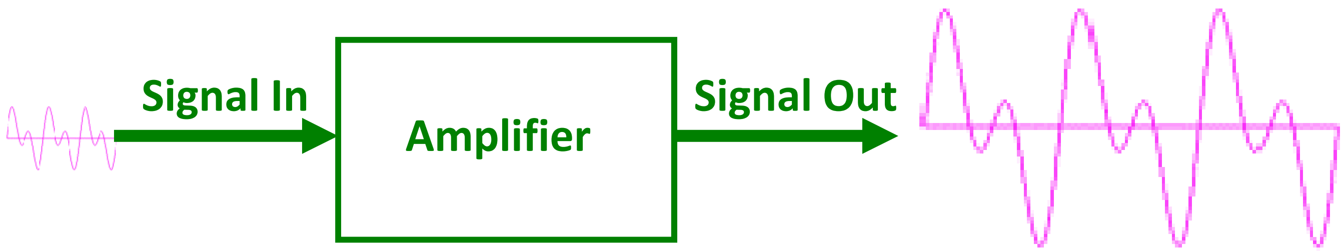
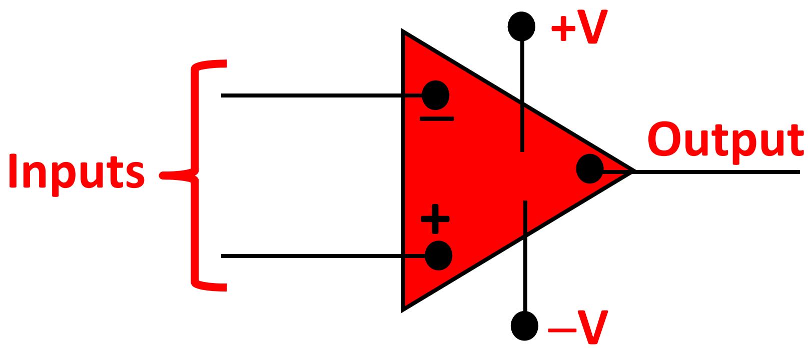
# Amplifiers




- **An amplifier increases the power (amplitude) of an electronic signal, as shown in the figure above.**
- **Amplifiers are found everywhere – in TV's, radios. MP3 players, small appliances, cars, etc.**
- **A new automotive amplifier application…**
- **Most amplifiers are <u>linear</u>. That is, the output is a constant (*K*, called the <u>gain</u>) times the input (K>>1).**

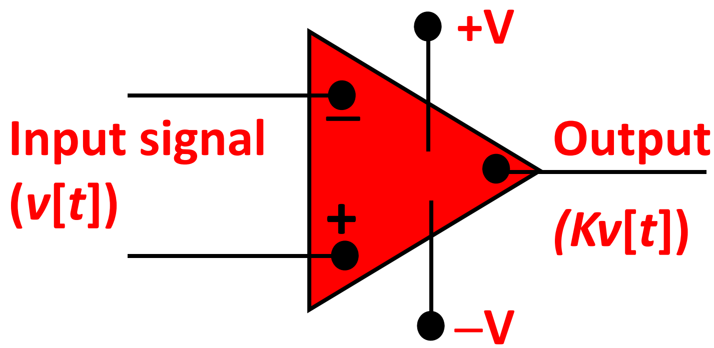
# The Operational Amplifier




- The “op amp” typically has 5 inputs: ±V (normally equal-magnitude + and – voltages; the power inputs), two inputs, with the polarity as indicated, and an output.
- There is no ground or common terminal, although one is usually supplied by the input power supply.

# Amplifier Gain *K*

- **The op amp (as most amplifiers) has a linear gain, i.e., the output is a constant K times the input.**
- **This linearity means <u>the output signal of the op amp has exactly the same form as the input signal</u>; it is just of greater amplitude.**
- **If the amplification of the op amp was <u>not</u> linear, the output signal would not match the input; it would be <u>distorted</u>.**
- **All high-quality amplifiers have linear amplification.**

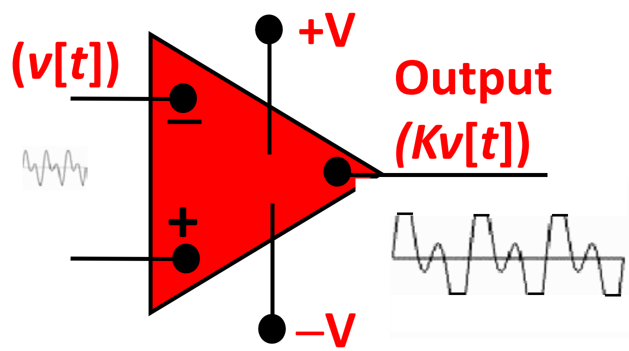


# Characteristics of the "Op Amp"

- **The op amp has some unique characteristics that make it very useful for many amplifying applications:**
  - **Very high "open loop" gain (*K* ~ 100,000+)**
  - **Very low output impedance (≤ a few hundred Ω)**
  - **Very high input impedance (100,000 to 1,000,000 Ω)**
- **Since useful amplifiers do not often have such large *K*, the practical gain can be reduced using negative feedback (covered shortly).**
- **The high input impedance and low output impedance make it relatively easy to design an amplifier circuit with a usable range of amplification.**

# Amplifier Range and "Clipping"

- **For an operational amplifier with DC power inputs +V and –V, the output signal cannot possibly be > ± V .**
- **In practice, problems begin to appear when the output signal amplitude → 0.6-0.7V.**
- **When the signal approaches this limit (which is different for different amplifiers), the output is clipped.**
- **This means that the output cannot produce the full swing in amplitude so that $v_{out} = K(v_{in})$. The amplification is no longer linear.**

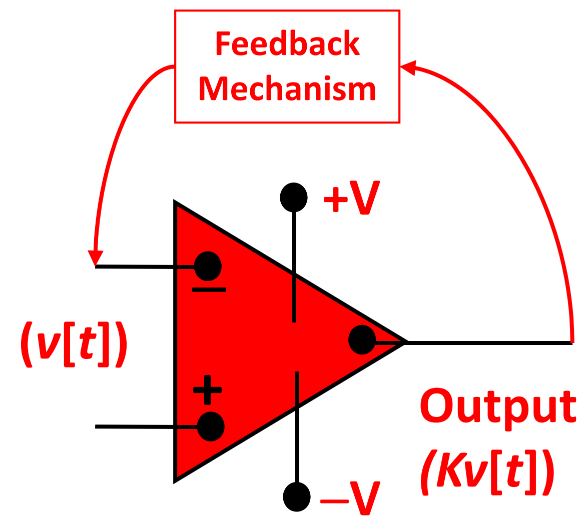


# Making a Useful Amplifier

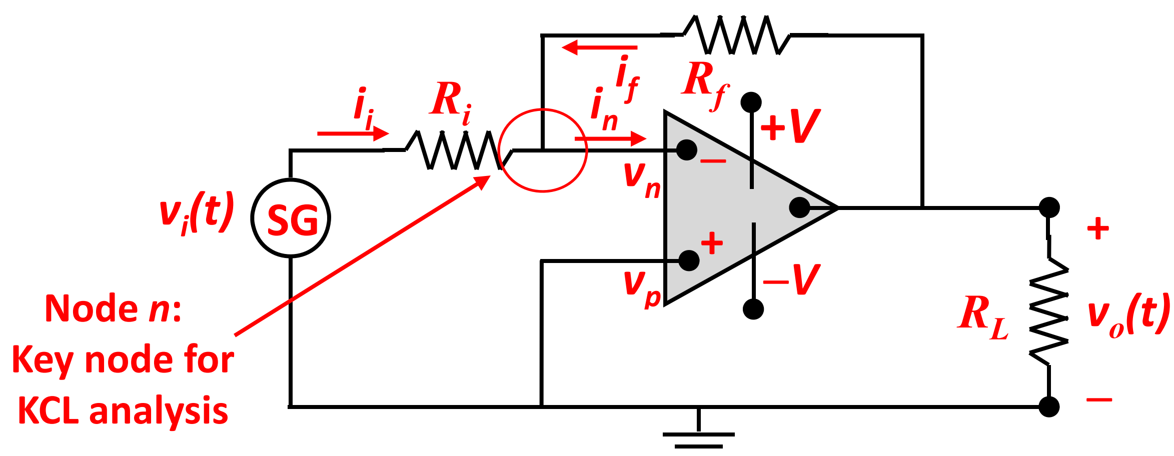
- **To design a useful amplifier circuit using the op amp, we make several assumptions (basically approximations) about op amp characteristics:**
  - **Since output impedance (resistance) is low, assume it is 0.**
  - **Since input impedance (also resistance) is high, assume it is ∞.**
  - **Since the "open loop" gain is high, assume it is also ∞.**
- **The open-loop gain (infinite or not) is far too large to be useful.**
- **We need to design a circuit that amplifies a useful amount, while still remaining linear.**
- **To design a useful amplifier, we make use of the technique of negative feedback.**

# Negative Feedback

- **A negative feedback circuit is a mechanism that feeds a portion of the output signal of an amplifier back to the negative amplifier input in order to control the gain.**
- **This feedback enables control of the amount of gain that the circuit provides. Given the very high *K* of most op amps (>100,000), they could be used only to amplify extremely small signals without the ability to regulate gain to a manageable amount.**
- **Our amplifiers in Experiment #7 will use negative feedback to control the gain.**

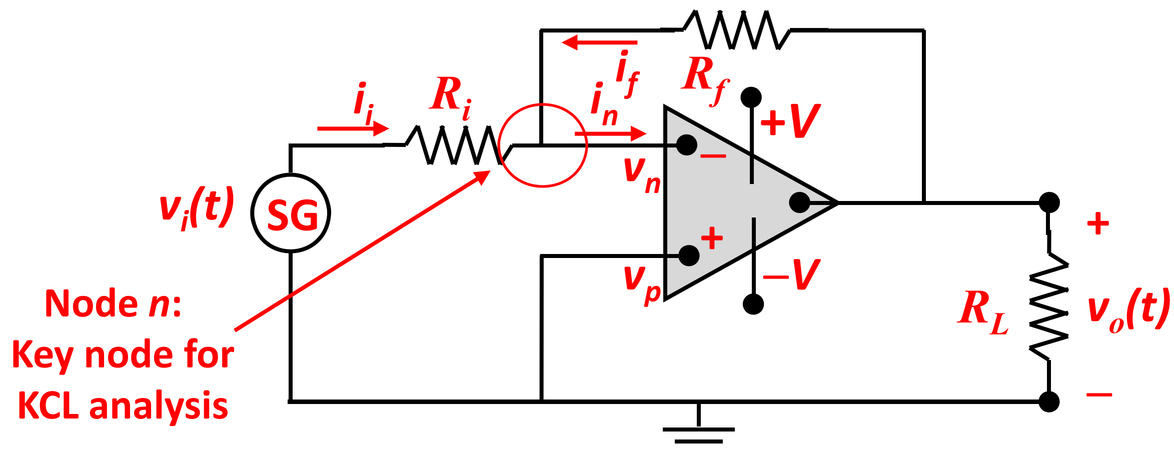


# Using KCL to Determine *K* for a Negative-Feedback Op Amp Circuit



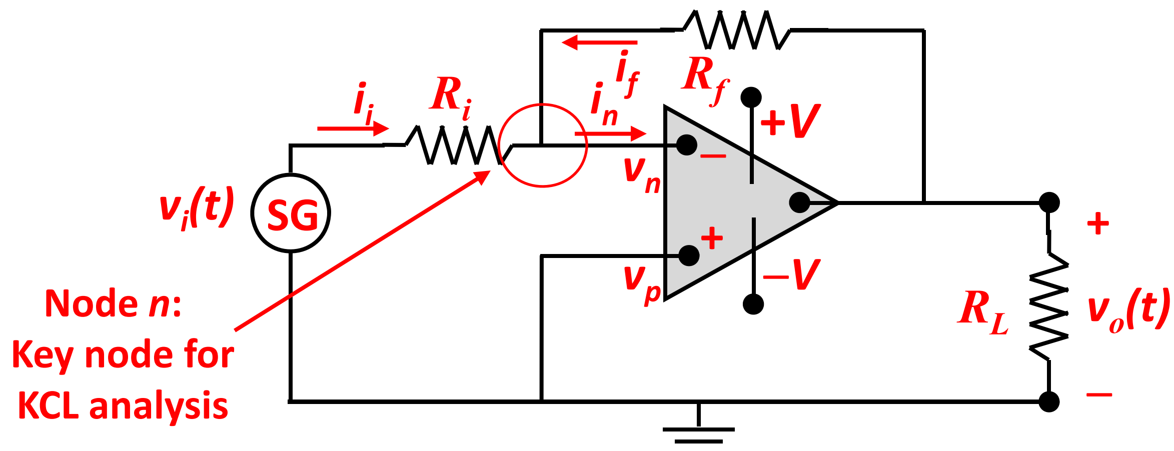

- Kirchoff's Current Law is very useful in analyzing an op amp negative feedback circuit to develop the equations for *K* in the circuit.
- Note that the signal to be amplified is input into the negative op amp input.
- The positive input is grounded (set to 0 V).
- A portion of the amplified output $v_o(t)$ is fed back into the negative input via the feedback resistor, $R_f$.

# Negative Feedback Analysis (2)




- Note that $R_L$ represents the amplifier load, but does not enter the analysis.
- The signal to be amplified, $v_i(t)$ (from the signal generator SG), enters the amplifier negative input via input resistor $R_i$.
- Remember the op amp approximations:
  - Input resistance (impedance) = ∞
  - Output resistance (impedance) = 0
  - *K* in "open loop" condition = ∞

# Negative Feedback Analysis (2)




- Since the input resistance = ∞, then $i_n = 0$. Also, since the positive input is grounded, then $v_p = 0$. But since $i_n = 0$, then $v_n = v_p = 0$ (and node n = 0V).
- By KCL at node n, $i_i + i_f + i_n = 0$. But $i_n = 0$. Then $i_i + i_f = 0$, or $i_i = -i_f$.
- But $v_n = 0$, so $i_i = v_i(t)/R_i$, and $i_f = v_o(t)/R_f$.
- We also note that by definition $K = v_o/v_i$. USE THESE RELATIONS TO SOLVE FOR *K* IN TERMS OF THE CIRCUIT COMPONENTS.

# Building the Negative Feedback Circuit

- **After solving for $K$ in terms of the circuit parameters, choose an $R_f$ and $R_i$ such that $K = 10$.**
- **Follow instructions in the manual to build the circuit using the calculated instructions. The circuit will look schematically exactly like the previous page, without the load resistor (in this case, we will not use the load resistor, simply making the oscilloscope the load).**
- **Make the measurements on the circuit per manual instructions.**

# Inversion of Signal

- You should note in the expression for *K* that you developed that it is a negative number.
- This means that your amplifier inverts the signal while amplifying it.
- Thus if the input signal is some small DC voltage *V*, then the output is –*KV*, *K* times larger than *V*, but of the opposite sign.
- If the input is a sinusoidal AC signal *v(t)*, then the output will be –*Kv(t)*; it will be 180° out of phase with the input signal. When the AC signal is rising above 0, the output will be falling below 0.
- In a single-stage (one amplifier only) negative feedback amplifier, <u>the output is always inverted compared to the input signal</u>.

# Non-Inverting Amplification

- Sometimes we need non-inverting amplification of a signal.
- Other types of amplifiers can be designed that are non-inverting.
- For the negative-feedback amplifier circuit, a single amplifier will always invert the sense of the output (with relation to input).
- However, op amp circuits are easy and convenient to cascade, that is, to connect in series to increase amplification while keeping *K* manageable.
- Regardless of connecting amplifiers in series, each one still inverts the signal between input and output.
- Use this information for the last part of your experimental exercises.

# 741 Op Amp Input/Output

- The diagram at right shows pin-outs for the 741 op amp.
- Pins 2 and 3 are inputs, with polarity shown.
- Pin 6 is amplified signal out.
- Pins 7 is +15 V, 4 is –15 V.
- Pins 1, 5, 8 are not connected.
- There is no ground or common input pin.
- The power supply ground or common can serve this purpose.