Introduction to Measurements Systems
Real Opamps
LA-CoNGA physics - 2024

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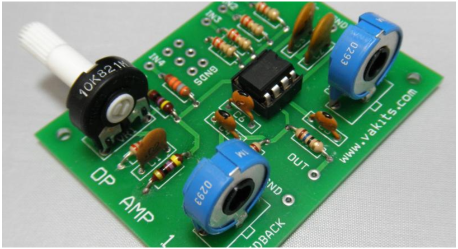
Contents



- How op-amps works?
- Open Loop Gain, Closed Loop Gain
- Noise Gain
- Gain Bandwidth
- Slew Rate

Introduction

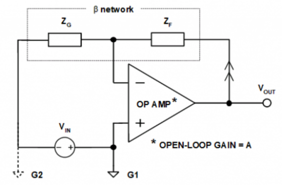
The following are some ways actual Op Amps differ from ideal performance:

- **Finite open loop gain**. It is impossible in an actual opamp for the open loop gain to be truly infinite.
- **Offset voltage**. The input stage of the op amp consists of a differential pair of transistors
- **Bias current**. The transistor inputs actually do draw some current.
- **Noise gain**. An opamp amplifies the signal and its noise.
- **Slew rate**. Capacitive effects in opamps set a finite speed of response

Operational Amplifiers

Noise Gain β

- One of the most distinguishing features of op amps is their staggering magnitude of DC voltage gain. 100000 (100dB) for $\mu A741$
- But in reality, op amps do have finite gain, and errors exist in practical circuits.



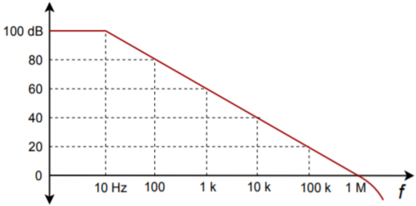
Feedback attenuation

$$\beta = \frac{Z_G}{Z_G + Z_F} = \frac{1}{G_{noise}}$$

- Noise gain can now be simply defined as: The inverse of the net feedback attenuation from the amplifier output to the feedback input.
- In other words, the inverse of the β network transfer function.
- This can ultimately be extended to include frequency dependence. item Noise gain can be abbreviated as NG.

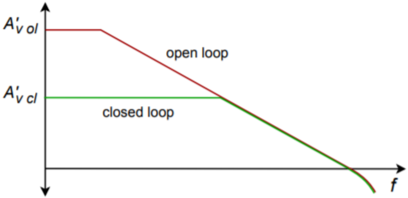
$$G_{CL} = \frac{1}{\beta}\left(\frac{1}{1+\frac{1}{A_{OL}\beta}}\right)$$

- The open loop frequency response of a general-purpose op amp is shown in Figure.
- all devices will exhibit this same general shape and 20 dB per decade rolloff slope.



- **Gain Bandwidth** (GBW): The product of any break frequency and its corresponding gain is a constant. In other words, the gain decreases at the same rate at which the frequency increases.

- As you already know, operating an op amp with negative feedback lowers the midband gain.



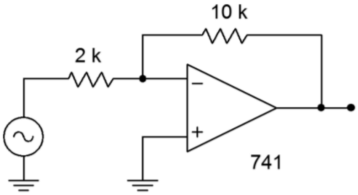
- By knowing GBW and the gain, the associated break frequency can be quickly determined. For the inverting and non-inverting voltage amplifiers:

$$f_2 = \frac{GBW}{Gain}$$

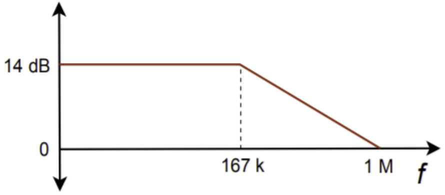
1. Using a $\mu A741$ op amp, what is the upper break frequency for a noninverting amplifier with a gain of 20 dB?
   - A $\mu A741$ data sheet shows a typical GBW of $1MHz$
   - Converting $20dB$ into ordinary form yields a gain of 10.

$$f_2 = \frac{GBW}{Gain} = \frac{1MHz}{10} = 10kHz$$

2. Sketch the frequency response of the circuit



- The resulting gain Bode plot



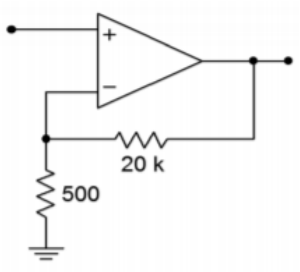
- where:

$$f_2 = 167kHz$$

- Let's simulate this circuit

GBW calculations
Example

- Determine the minimum acceptable f_{unity} for the circuit if response should extend to at least $50kHz$



- where:

$$f_{unity} = 2.05MHz$$

- Let's simulate this circuit

- General-purpose op amps contain a compensation capacitor that is used to control the open loop frequency response.
- Due to this, the compensation capacitor can be charged no faster than a rate determined by the standard capacitor charge equation:

$$i = C\frac{dv}{dt}$$

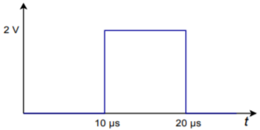
$$\frac{dv}{dt} = \frac{i}{C}$$

- This quantity is called **Slew rate**, for a $\mu A741$ op-amp $SR = 0.5V/\mu s$

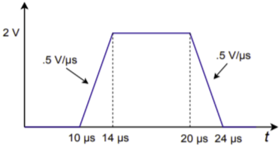
Practical Considerations

The Effect of Slew Rate on Pulse Signals

- An ideal pulse waveform will shift from one level to the other instantaneously



- In reality, the rising and falling edges are limited by the slew rate.



Exercises

- A $\mu A741$ is used as part of a motor control system. If the highest reproducible frequency is 3 kHz and the maximum output level is 12 V peak, does slewing ever occur?
- An audio pre-amplifier needs to reproduce signals as high as 20 kHz. The maximum output swing is 10 V peak. What is the minimum acceptable slew rate for the op amp used?