BIOPOTENTIAL AMPLIFIERS

EE 471 – F2016

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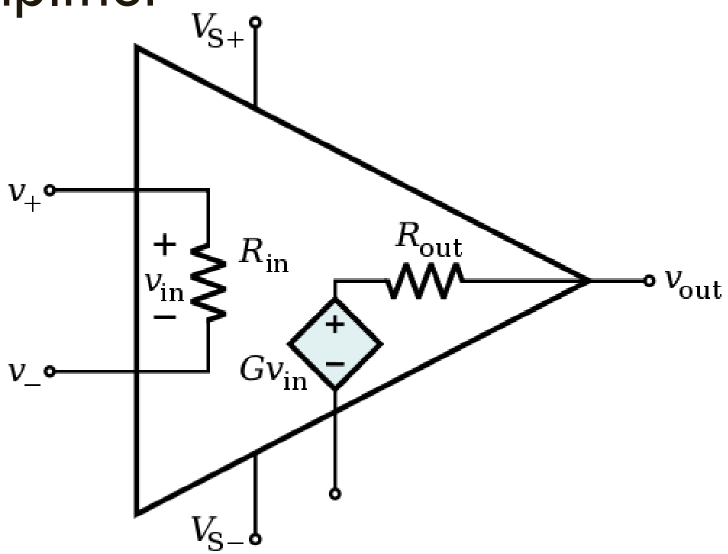
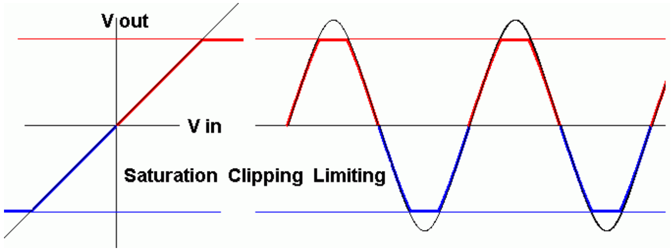
Op Amp Basics

- Op Amp is a high-gain differential amplifier
- Ideal Op Amp characteristics:
  - Gain is infinite
  - Input impedance is infinite
  - Output impedance is infinite
  - Bandwidth is infinite
- Ideal Op Amp rules for circuit design:
  - $V^+ = V^-$ (input terminals have same voltage)
  - $i+ = i^-$ (no current through input terminals)
- Basic design approach: design Op Amp circuit using ideal rules then check practical issues

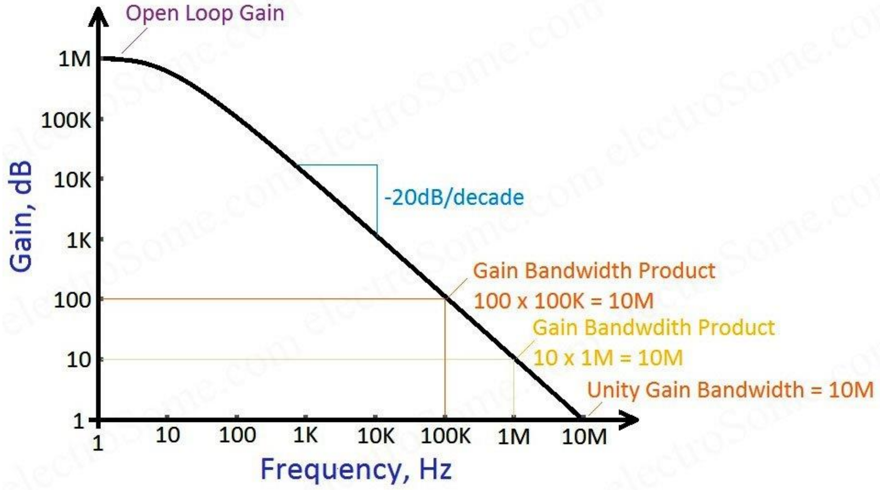


Practical Issues

- Linear range limitations (saturation)
  - Depends on power supply range (slightly less) and Op Amp type

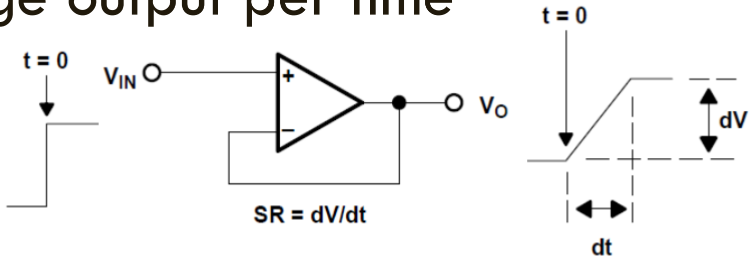


- Gain-Bandwidth Product = Constant for a given Op Amp
  - Maximum gain determined by bandwidth of signal for a given Op Amp

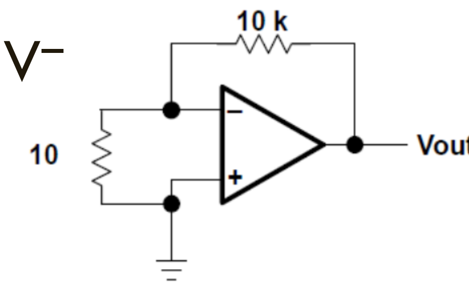


Practical Issues

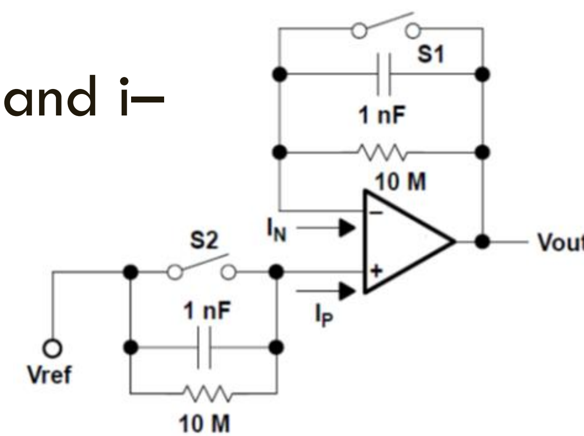
- Slew Rate: rate of change of voltage output per time
  - Identify maximum input frequency and amplitude applicable to amplifier such that output is not significantly distorted



- Offset voltage: small voltage between V^+ and V^-
  - Offset nulling available in some Op Amps
  - May also drift with time



- Bias Current: small currents flowing into i+ and i–
  - Always use DC coupling for input terminals

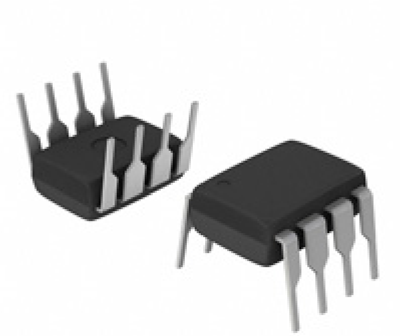


Practical Example: 741 Op Amp

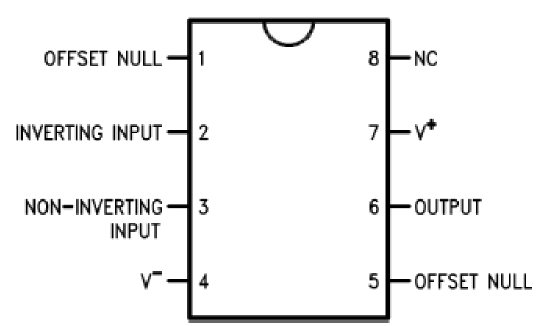
Bandwidth (Note 6)	1.5	MHz
Slew Rate	0.7	V/µs

Output Voltage Swing	$V_S = \pm 20V$

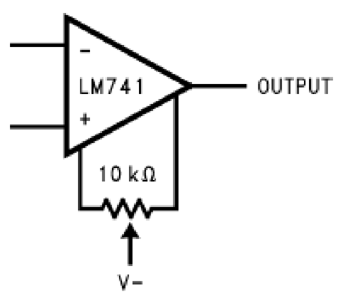
Parameter	Test Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	$T_A = 25°C$										
	$R_S \leq 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$R_S \leq 50\Omega$		0.8	3.0							
	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 50\Omega$			4.0							mV
	$R_S \leq 10\ k\Omega$						6.0			7.5	
Input Offset Current	$T_A = 25°C$		3.0	30		20	200		20	200	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			70		85	500			300	



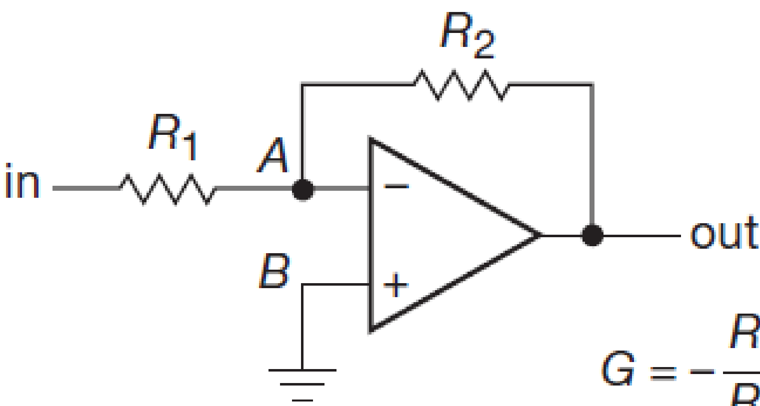
Dual-In-Line or S.O. Package



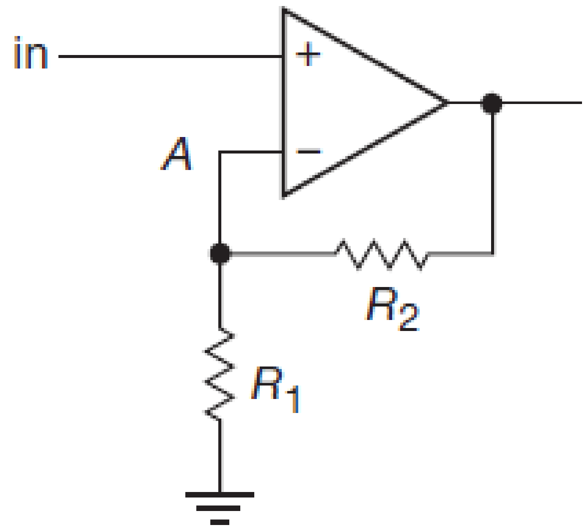
Offset Nulling Circuit



Example Basic Op Amp Circuits

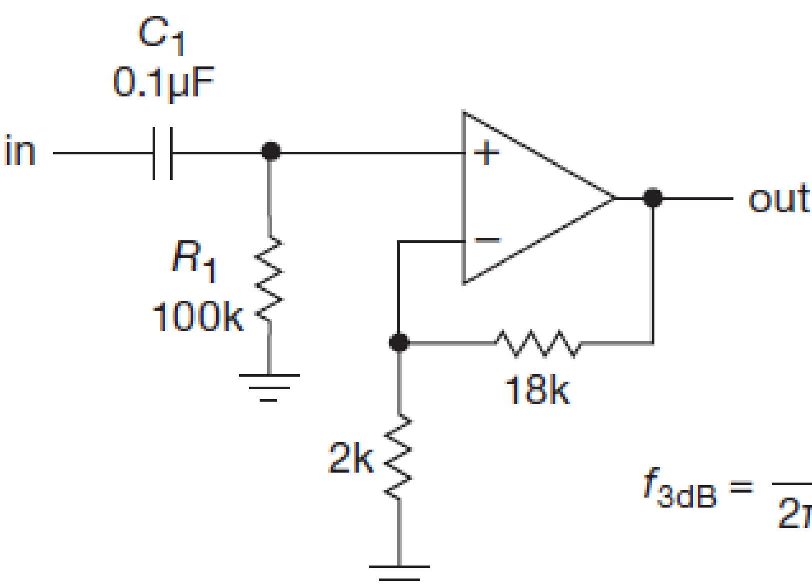


$$G = -\frac{R_2}{R_1}$$

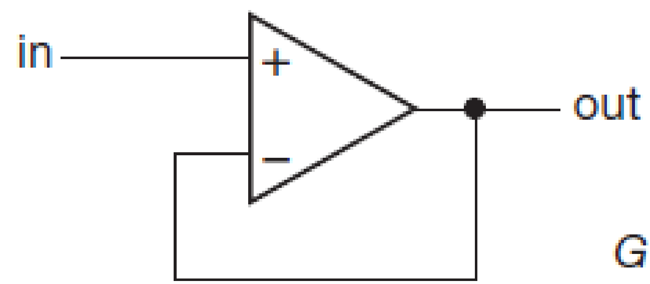


$$G = 1 + \frac{R_2}{R_1}$$

$$Z_{in} = \infty$$



$$f_{3dB} = \frac{1}{2\pi R_1 C_1}$$

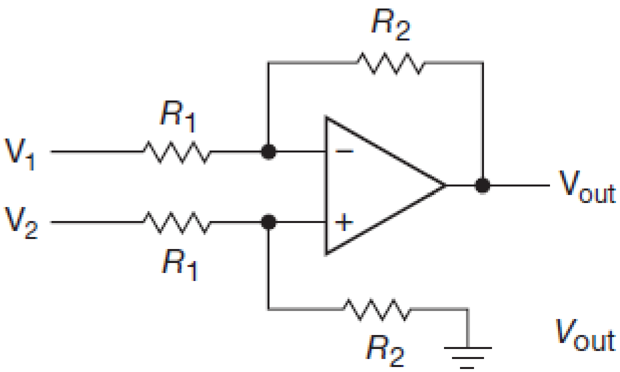


$$G = 1.0$$

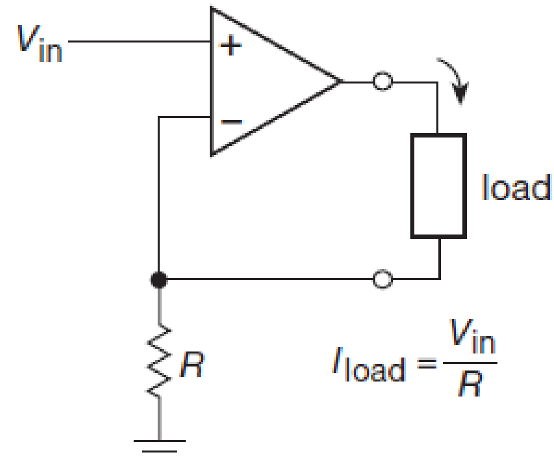
$$Z_{in} \approx \infty$$

$$Z_{out} \approx 0$$

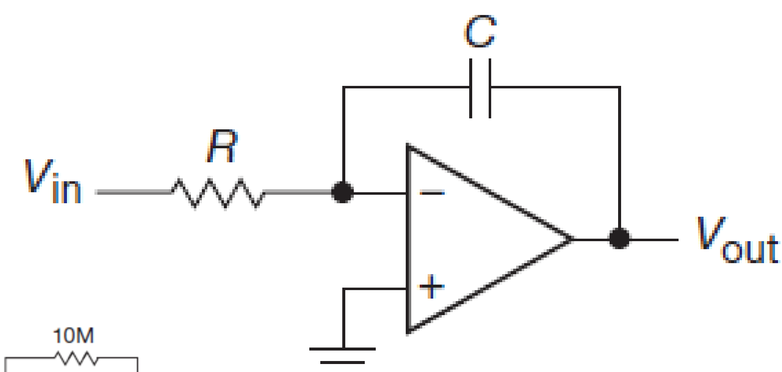
Example Basic Op Amp Circuits

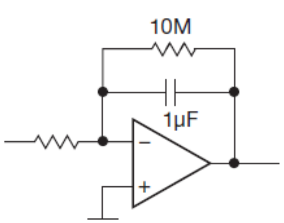


$$V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$$

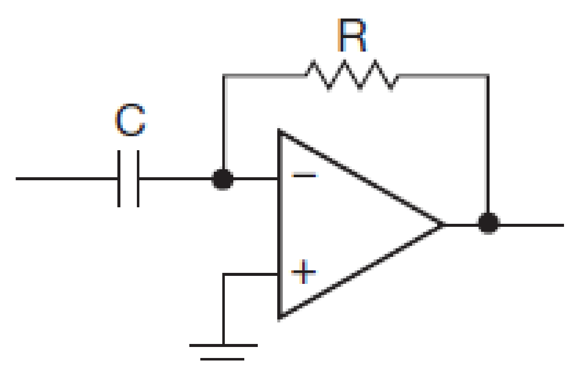


$$I_{load} = \frac{V_{in}}{R}$$

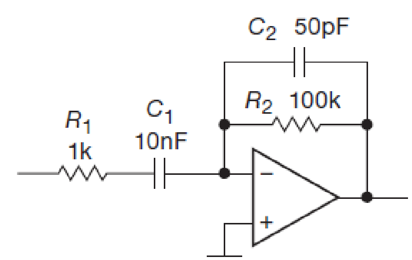




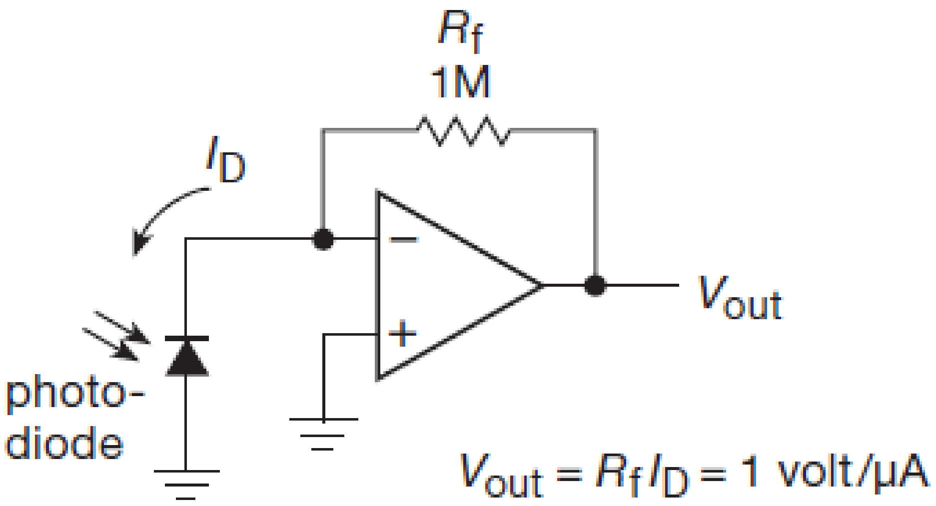
$$V_{out}(t) = -\frac{1}{RC}\int V_{in}(t)\,dt + \text{const.}$$

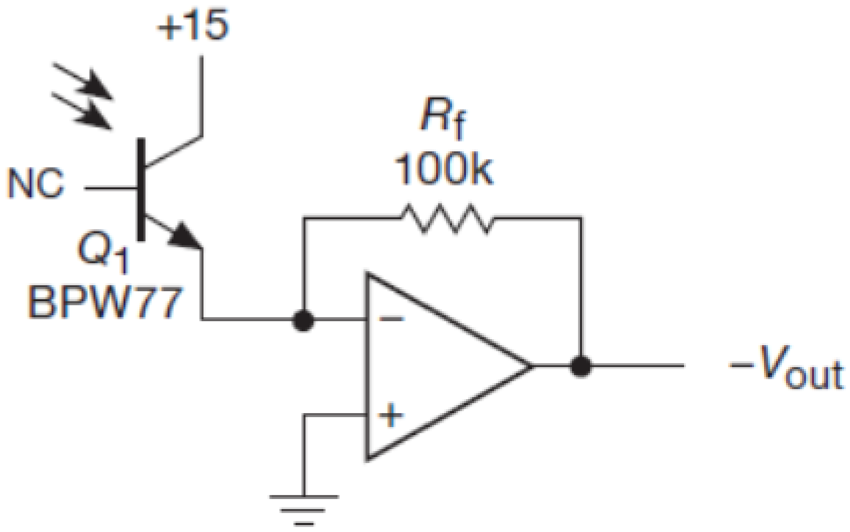


$$V_{out} = -RC\frac{dV_{in}}{dt}$$



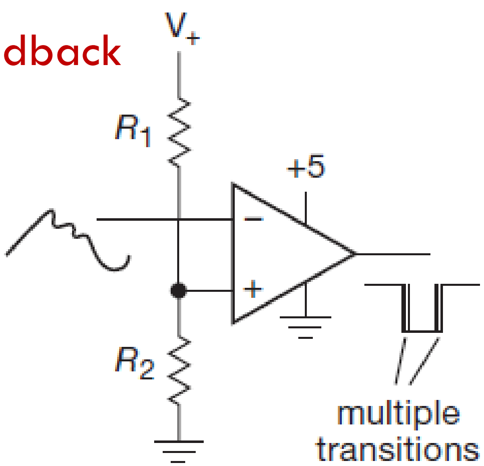
Photodiode/Transistor Amplifier

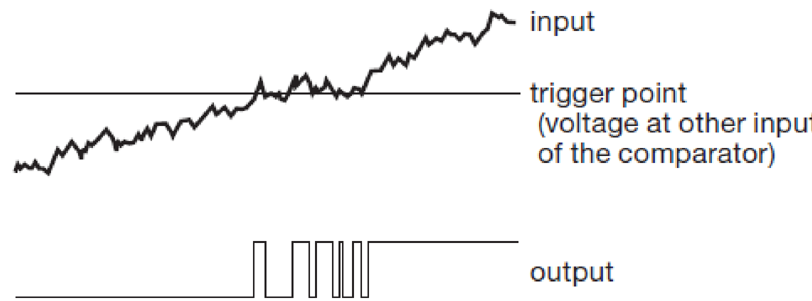




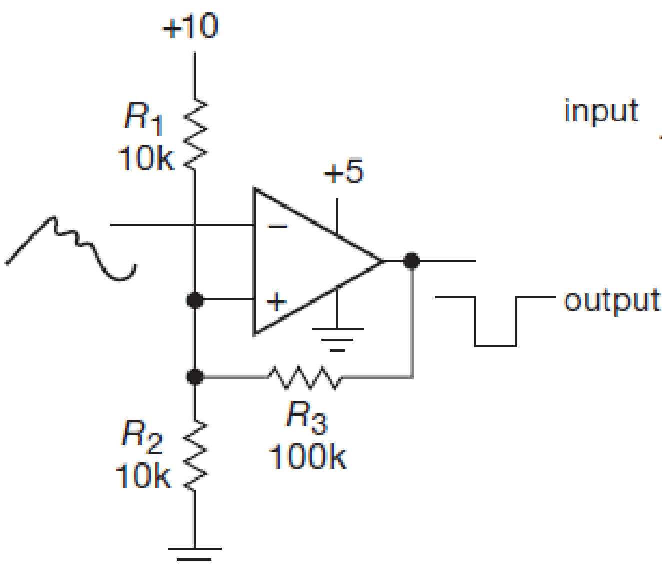
Comparator

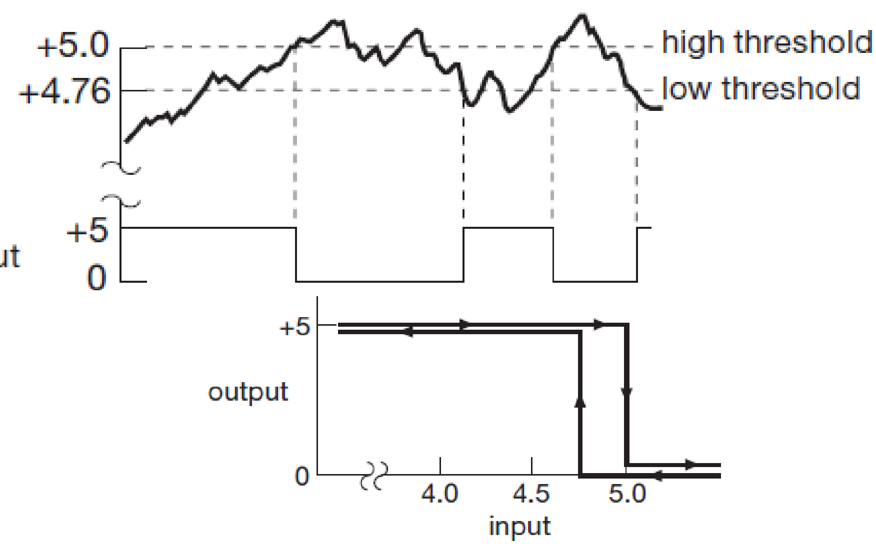
Op Amp without Feedback



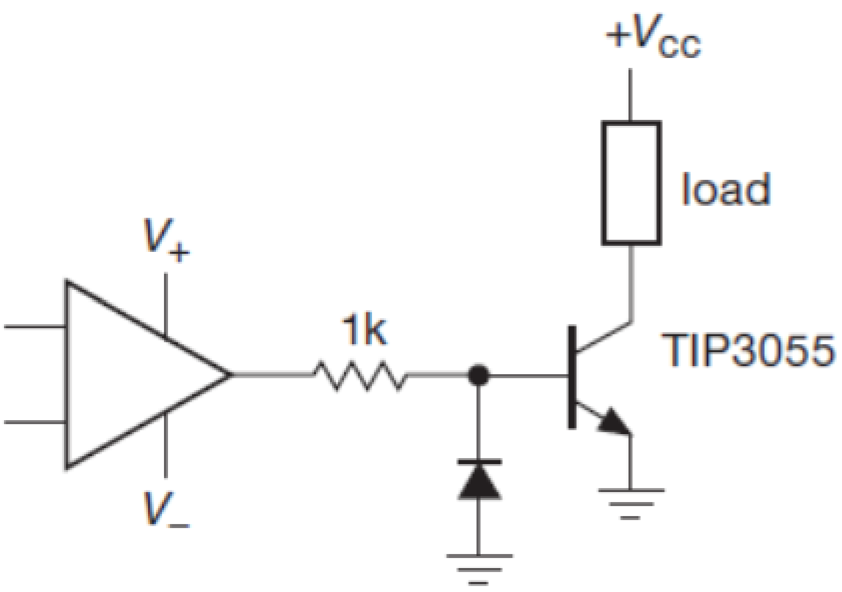


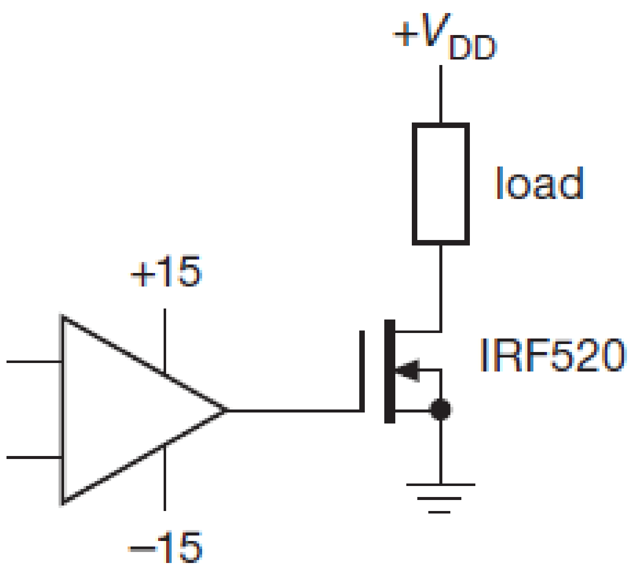
Schmitt Trigger





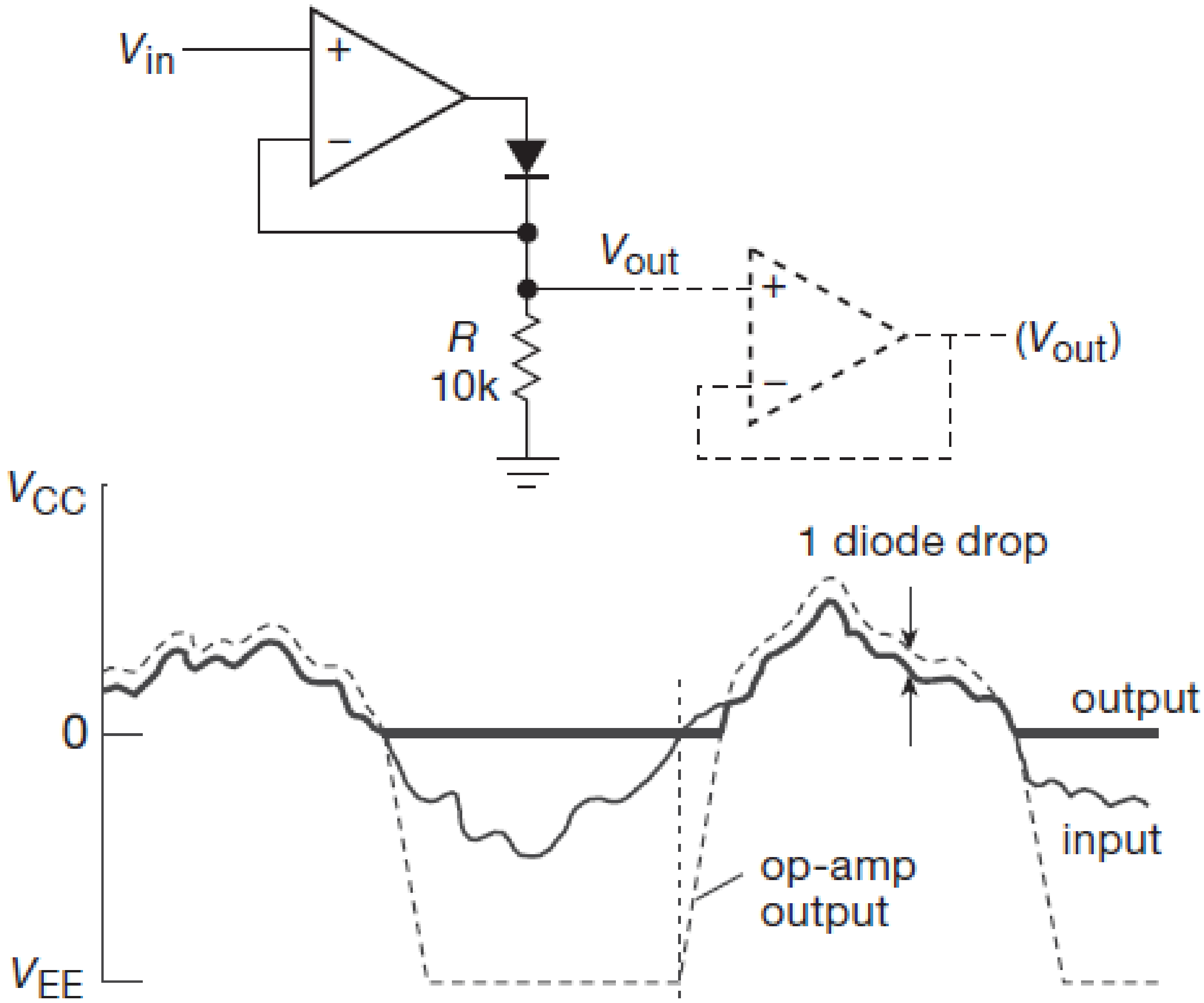
Power Switching





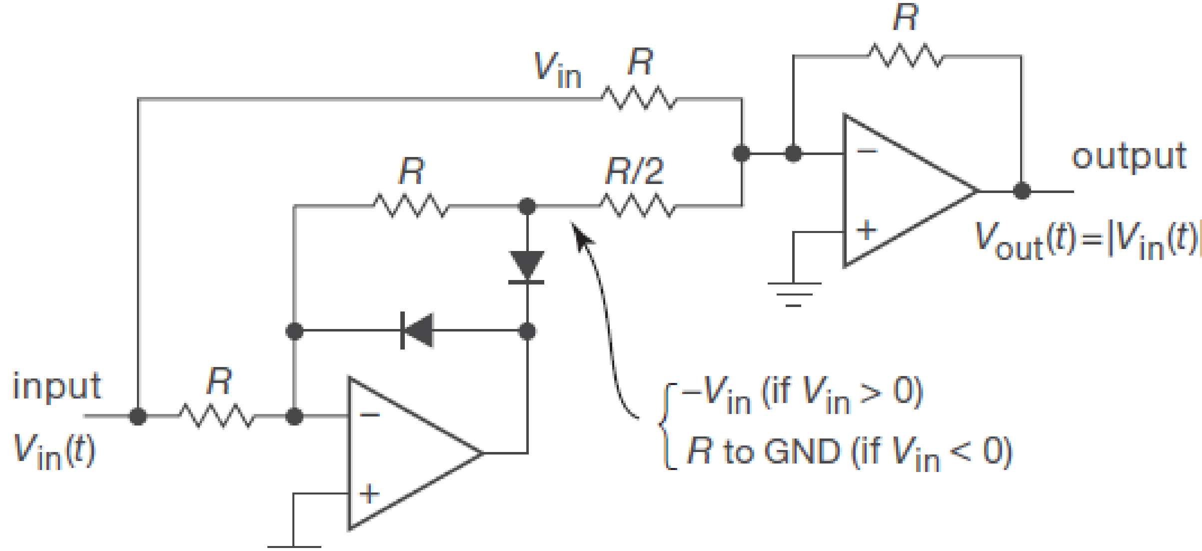
Note: Diode snupper is needed if load is inductive

Active Half-Wave Rectifier

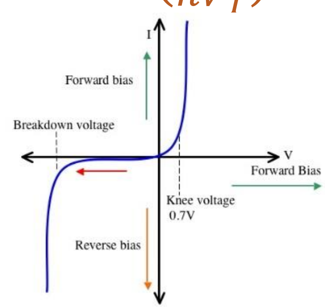


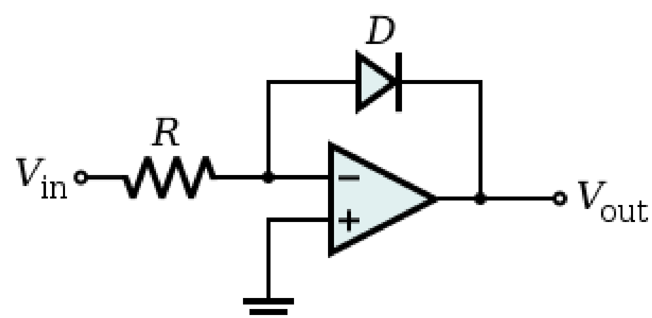
Absolute-Value and Log Amplifiers

- Active full-wave rectifier

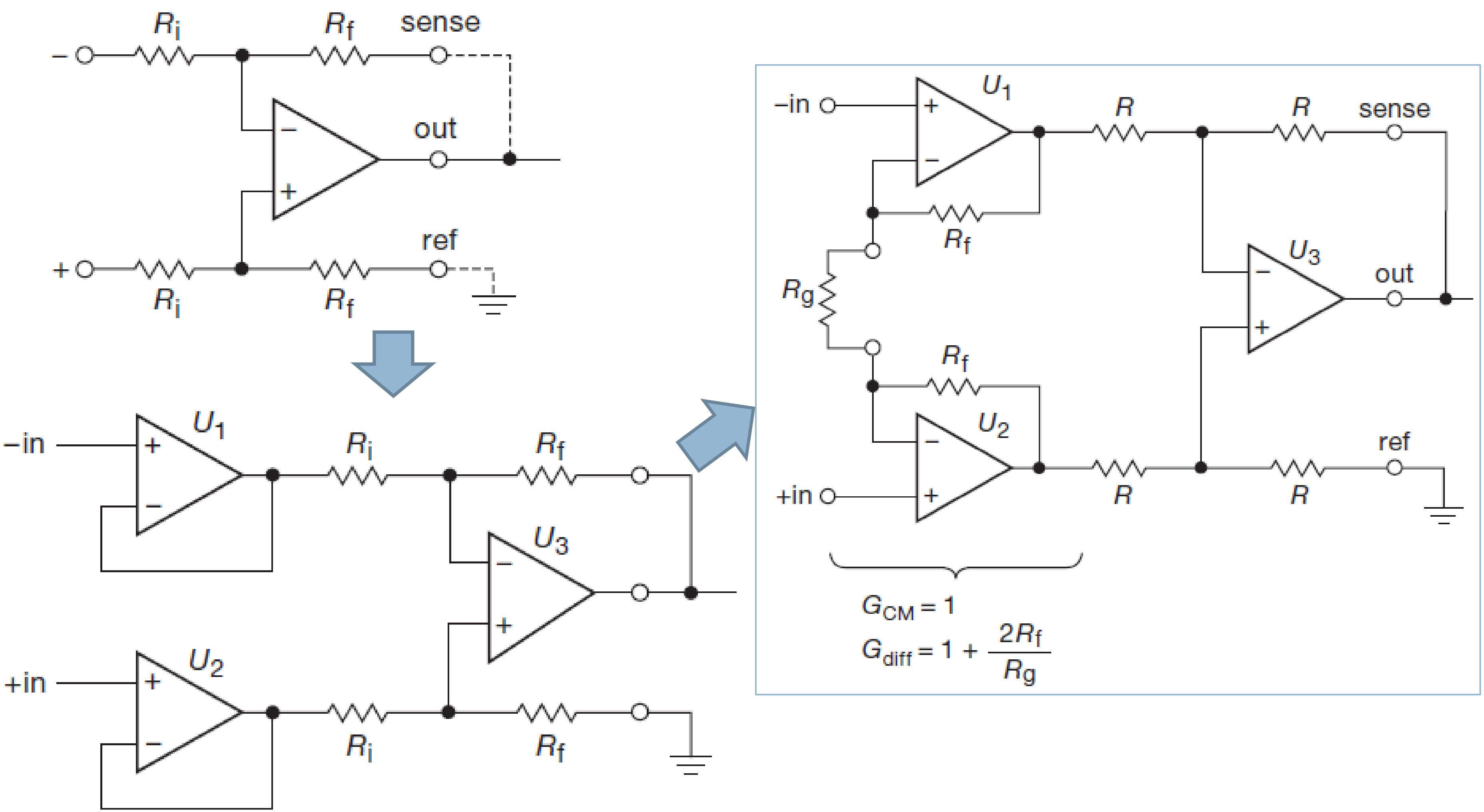


- Logarithmic Amplifier: add output stage with diode feedback
  - Ebers-Moll relation: $I_D = I_o \exp\left(\frac{V_D}{nV_T}\right) - I_o$
  - Valid for V_D>0

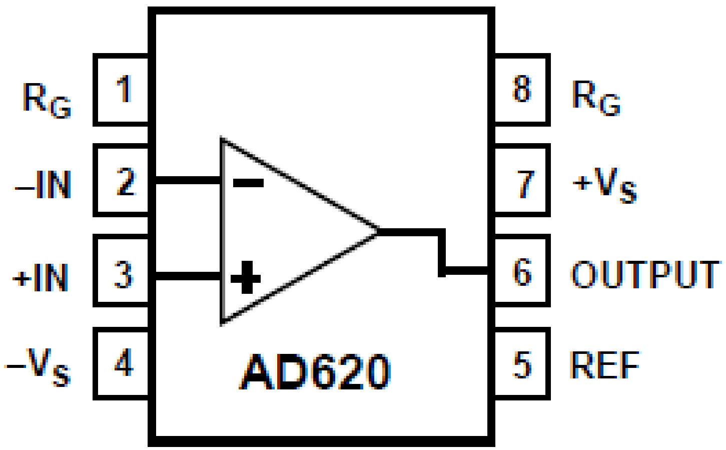


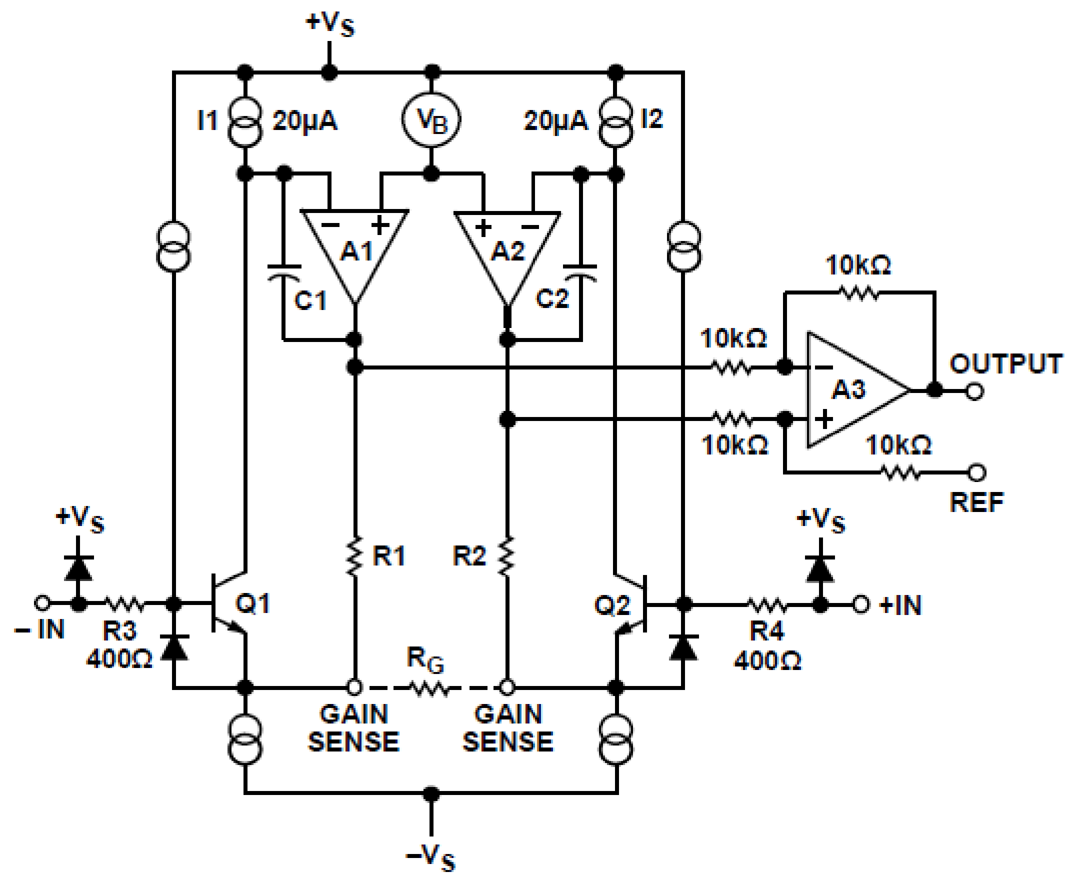


Instrumentation Amplifier



Practical Example: AD620





$$G = \frac{49.4k\Omega}{R_G} + 1$$

Final Notes for Op Amp Circuits

- Check practical limitations to ensure validity of Op Amp rules
- Feedback must be arranged so that it is negative
  - Must not mix up inverting and noninverting inputs
- There must always be feedback at dc in op-amp circuit
  - Otherwise op-amp is guaranteed to go into saturation

Reading Assignment

- Read Chapters 4, 5.15 of *Art of Electronics*