Today's plan:

Using data sheets

Using many ADC inputs – example program

Op-Amps continuation

Comparators

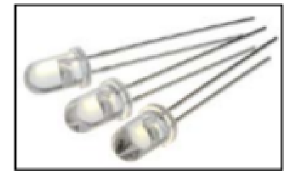
Powering your project

Measuring capacitance

A word about data sheets

- Beware of sections entitled “Absolute Maximum Ratings”
- These sections tell you about the most extreme conditions the component can be subjected to without being destroyed. These conditions are usually very far away from the optimal operating conditions! To find suitable operating conditions, there is often a table of Electrical Parameters – look for the conditions under which other parameters are measured.

LED1200-series



TECHNICAL DATA

Infrared LED InGaAsP

LED1200-series are InGaAsP LEDs mounted on a lead frame and encapsulated in various types of epoxy lens, which offers different design settings.
On forward bias, it emits a high power radiation of typical 5 mW at a peak wavelength at 1200 nm.

Specifications

- Structure: InGaAsP
- Peak Wavelength: typ. 1200 nm
- Optical Ouput Power: typ. 5 mW
- Resin Material: Epoxy resin
- Solder: Lead free

Absolute Maximum Ratings (T_a=25°C)

Type	Symbol	Value	Unit
Power Dissipation	P_D	140	mW
Forward Current	I_F	100	mA
Pulse Forward Current	I_{FP}	1000	mA
Reverse Voltage	V_R	5	V
Operating Temperature	T_{OP}	-40 … +85	°C
Storage Temperature	T_{STG}	-40 … +100	°C
Soldering Temperature (for 5 sec.)	T_{SOL}	265	°C

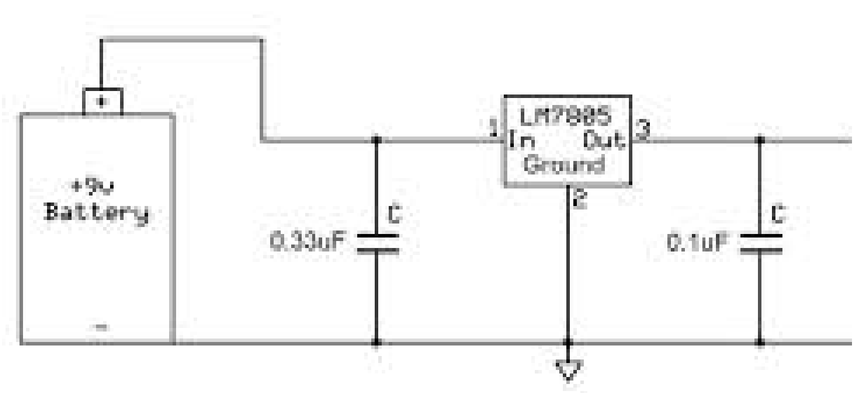
Electro-Optical Characteristics (T_a=25°C)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Forward Voltage	V_F	I_F = 50 mA	-	1.1	1.5	V
Reverse Current	I_R	V_R = 5 V	-	-	10	μA
Radiated Power	P_O	I_F = 50 mA	3	5	-	mW
Peak Wavelength	λ_P	I_F = 50 mA	1150	1200	1250	nm
Half Width	$\Delta\lambda$	I_F = 50 mA	-	80	-	nm
Rise Time	t_r	I_F = 50 mA	-	10	-	ns
Fall Time	t_f	I_F = 50 mA	-	10	-	ns

Voltage Regulation

- To power the Launchpad and most other circuitry, you'll want to use a regulated voltage. 3.3 V for the Launchpad, maybe 3.3V or 5V or 15V for other components. (one can run MSP430 off of 2 AA or AAA batteries directly).
- These voltages are most easily made with a 3 pin voltage regulator.
- eg LM7805, LM7815, UA78M33

- These can supply up to 1A, but may need a heatsink
- Notice that the values of the 2 capacitors are indicating just an order of magnitude! 1μF will work for both.

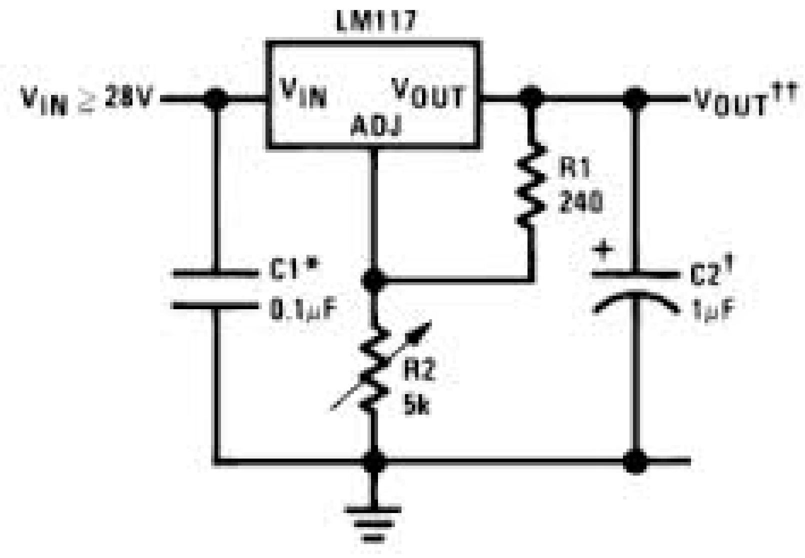


To 5V pin on Launchpad

To ground pin on Launchpad

Voltage Regulation

For 'non-standard' voltage, LM317 is a three-terminal, adjustable regulator



The regulator attempts to maintain:
$V_O - V_{ADJ}$ = 1.25 V (Vref)

So V_{out} is set by the ratio of R_1/R_2

$V_O = V_{REF} (1 + R_2/R_1) + I_{ADJ} R_2$
I_{ADJ} = ~50uA.

Choose R_1, R_2 so that $I_{ADJ} \times R_2$ is small, but also so $V_O \times (R_1+R_2)$ is not big.
$R_1 = 240\ \Omega$ is recommended.

Power dissipation

- Three pin regulators can get very hot, and may need a heatsink. They tend to draw exactly the same current from the supply as they output, and they dissipate the power difference.

For example, a 5V regulator operating from a 12V supply, supplying 1A has to dissipate (12V-5V)x1A = 7W. Without a heatsink, this would get very hot, very fast!

Dropout

- Many 3 pin regulators have a fairly high (1.5 – 2 V) “dropout” voltage. This means that for a 5V regulator, the input needs to stay above 6.5-7V. It will not work from 4 AA batteries!
- There exist “low-dropout” regulators, some of which are also low-power. LP2950 is a nice family.

Powering your project

Easiest, if it works:

- Launchpad from your computer
- the board/external circuitry with the wall wart we've provided.
- any higher current devices (eg big motors) from the batteries or a power supply available in the lab.

Powering your project

For mobile platforms or other devices:

- Launchpad and control electronics from 9 V battery and 5 V regulator.
- Higher current devices (motors, electromagnets) from the batteries.

DC power supplies

- DC supplies come in two general flavours:
- Switching and Linear

- The difference between these is in the internal structure of the supply. Switching supplies tend to be smaller/lighter/cheaper/more efficient than linear, but can introduce noise (10's to 100's of kHz).

Wall Warts or Bricks

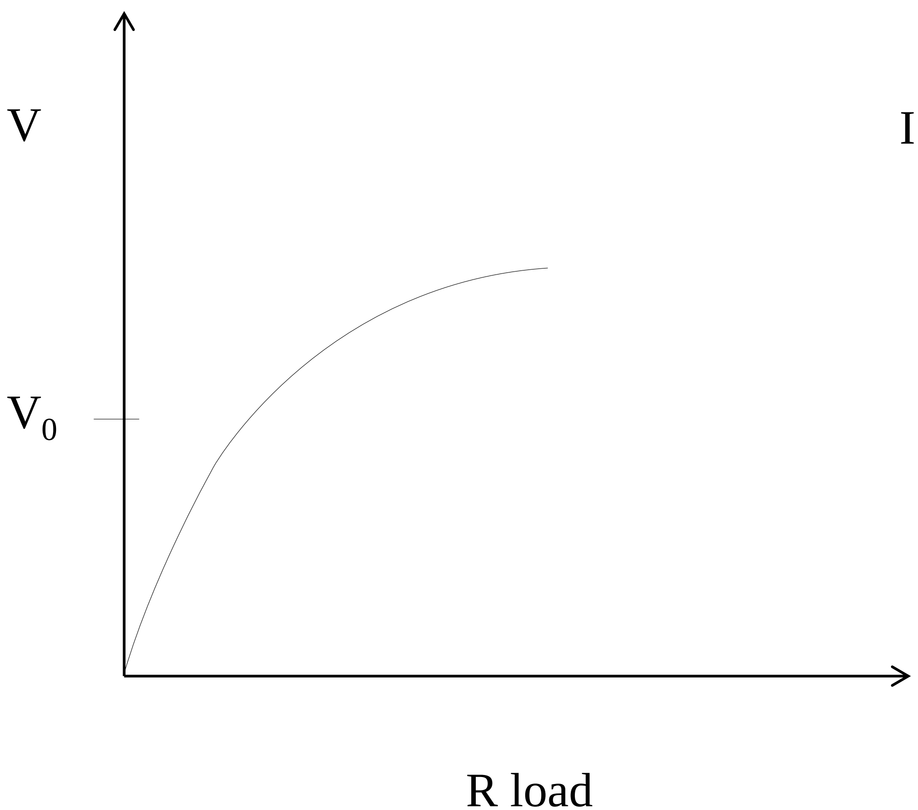
Most wall warts sold with consumer electronics are DC, switching, unregulated.

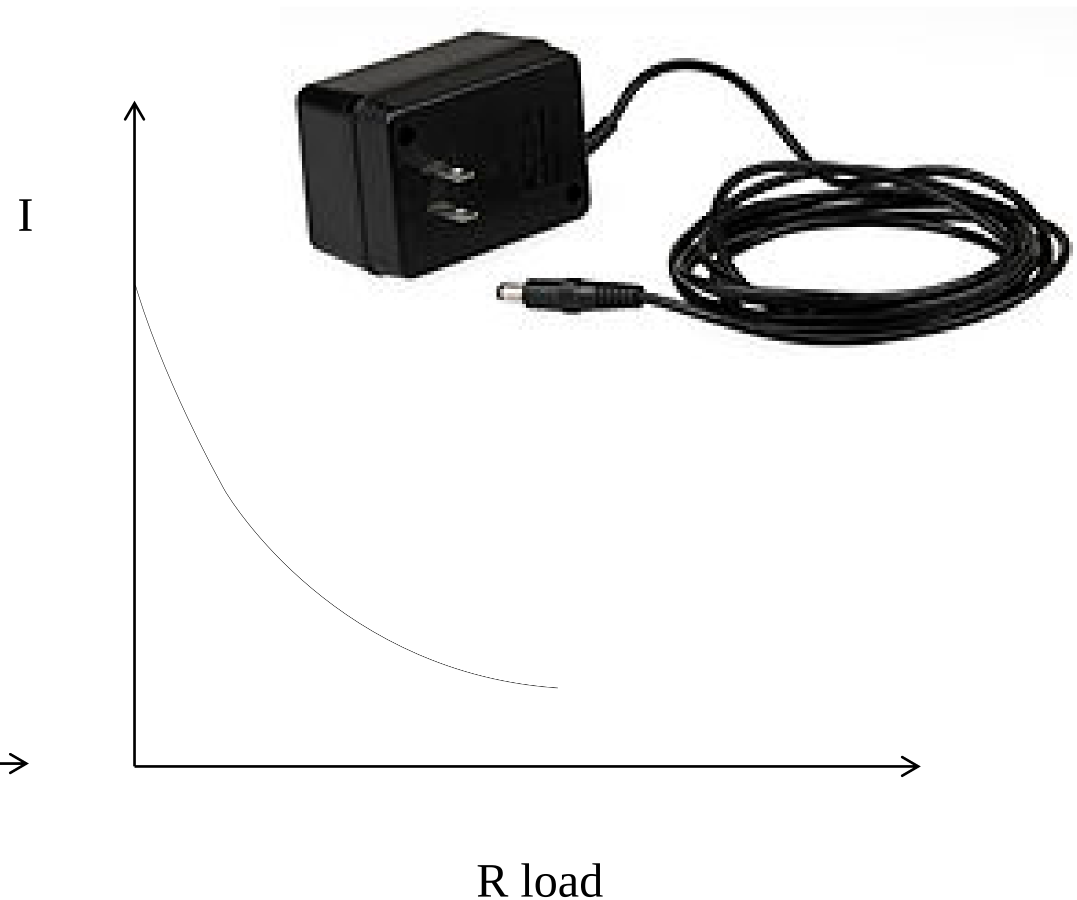
The voltage only matches the specified output voltage when the current draw is near to the specified current capability. Lower current draw yields higher voltage, may be as much as twice the specified voltage!

For driving motors, that may be ok, but for powering logic or amplifier circuits, you'll need to regulate wall wart outputs

Wall Warts

For most unregulated wall warts, voltage and current graphs look like these:





Wall Warts

Wall warts can be DC or AC, and regulated or not. Often we have to test them to find out.

Newer wall warts with USB connections are regulated at 5V

Batteries

Many sizes/shapes/chemistries:

Lead-acid - commonly available in 6V/12V. High power. Heavy, rechargeable.

Lithium. Rechargeable or not. Rechargeables are a little tricky to use – must not overcharge or undercharge. Light weight.

alkaline (AA and friends)

Ni-MH/NiCd – easiest rechargeables to use but rare now. Memory issue

coin cells/specialty (eg PX28L 6V camera battery)

Batteries

For most battery chemistries, the voltage changes as the battery is discharged. Eg alkalines start off ~ 1.5V, but discharge to ~ 1.0V.

Many batteries can supply very high peak current – A fresh D battery can supply ~ 10A for a short period! Lead acid batteries can supply 100's of A. Due respect is required. Short circuit protection and possibly reverse connection protection should be considered.

Like most other electronic components, batteries have data sheets with lots of useful information on them!

Single supply amplifier

- When working with microcontrollers it is often convenient to have an amplifier that can be powered from 0/5V or 0/3.3V rather than +/-15V.
- Previous circuits need some modifications: (a) need to reference inputs from the supply midpoint. (b) often want to AC couple the input.
- TI has some nice documents:

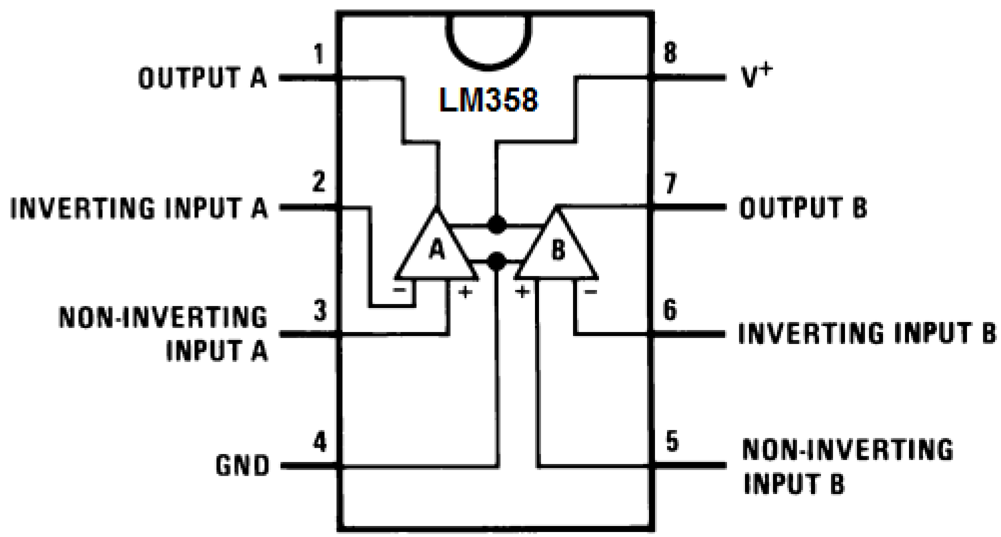
https://courses.cit.cornell.edu/bionb440/datasheets/SingleSupply.pdf

www.ti.com/lit/ml/sloa091/sloa091.pdf

www.ti.com/lit/an/sloa030a/sloa030a.pdf

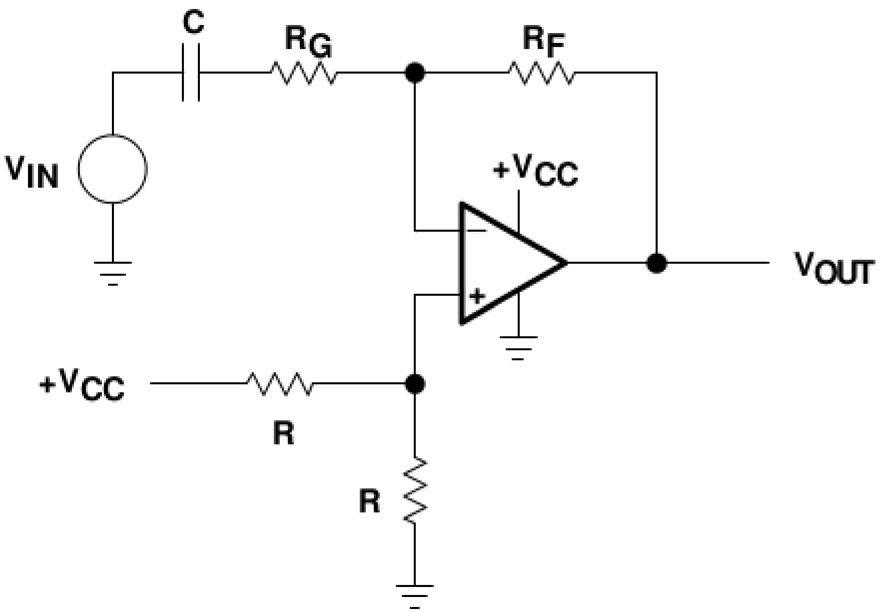
Single supply amplifier

- LM358. Dual, single supply.
- V+ = 5V (pin 8), V- = 0V (pin 4).
- Outputs can swing from ~0 V to ~ 3.5 V.



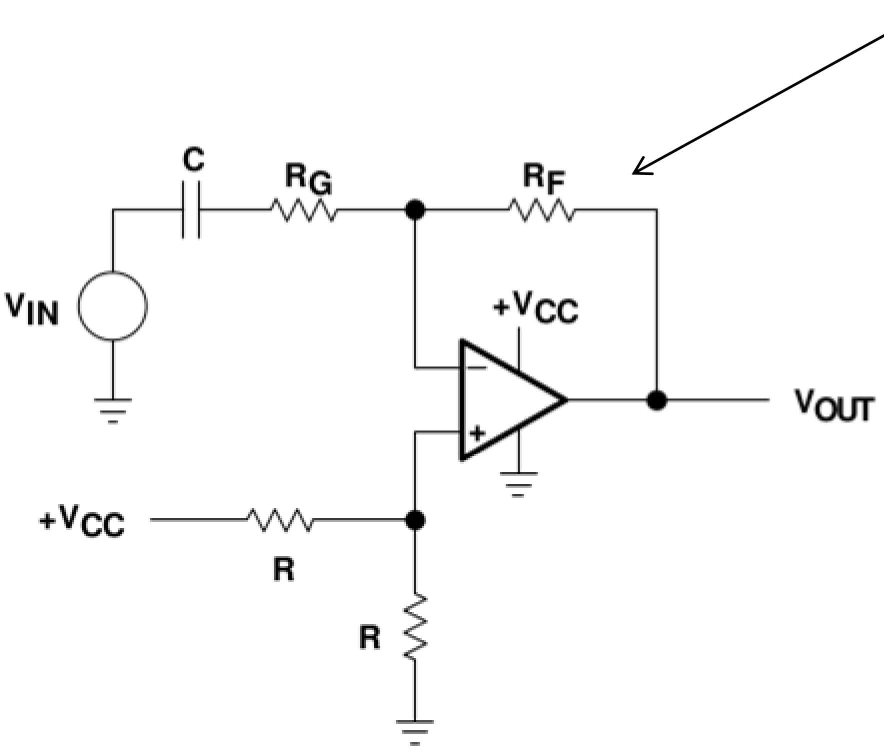
Inverting AC amplifier:

Gain = R_F/R_G



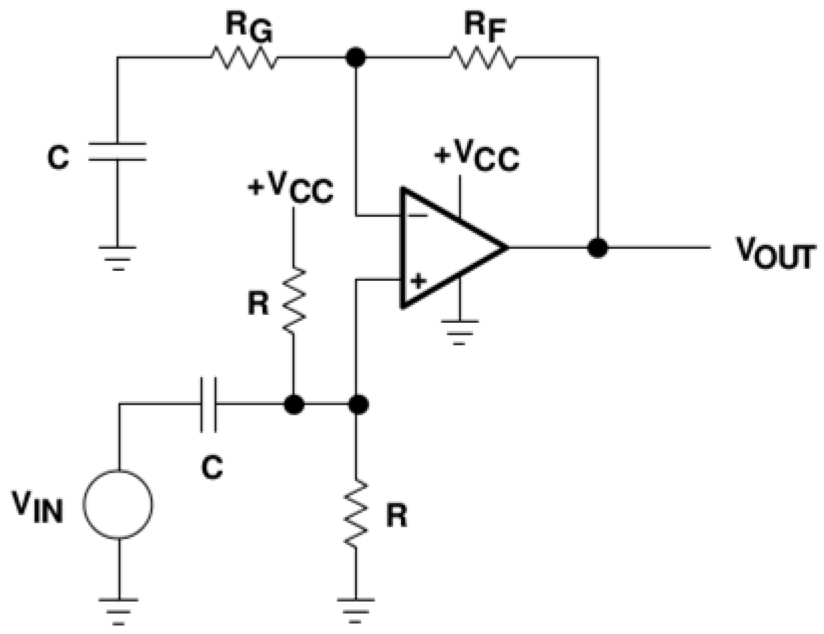
Inverting AC amplifier:

add a capacitor
in parallel with R_F
to get a low-pass filter



A non-inverting amplifier:

Gain = $1+R_F/R_G$



A non-inverting amplifier:

add a capacitor
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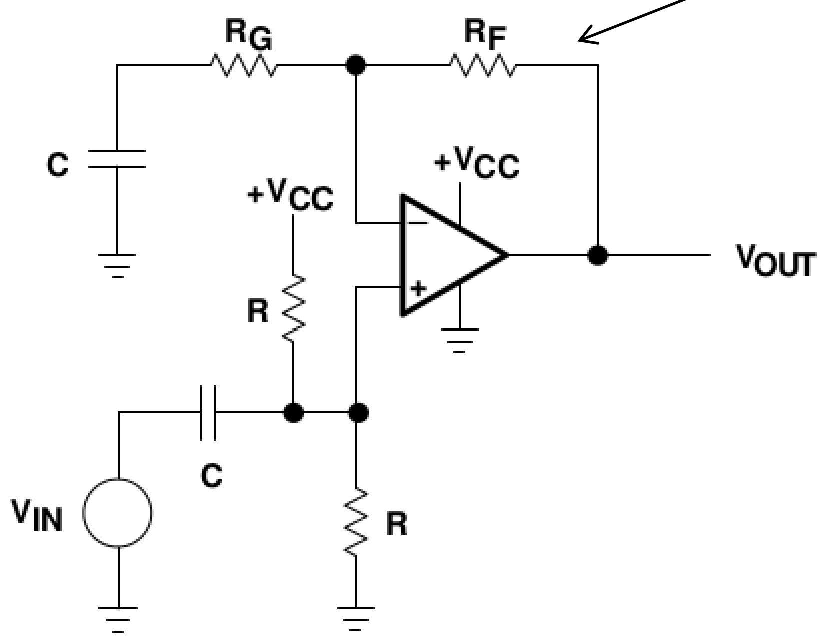


2^{nd} order filters:

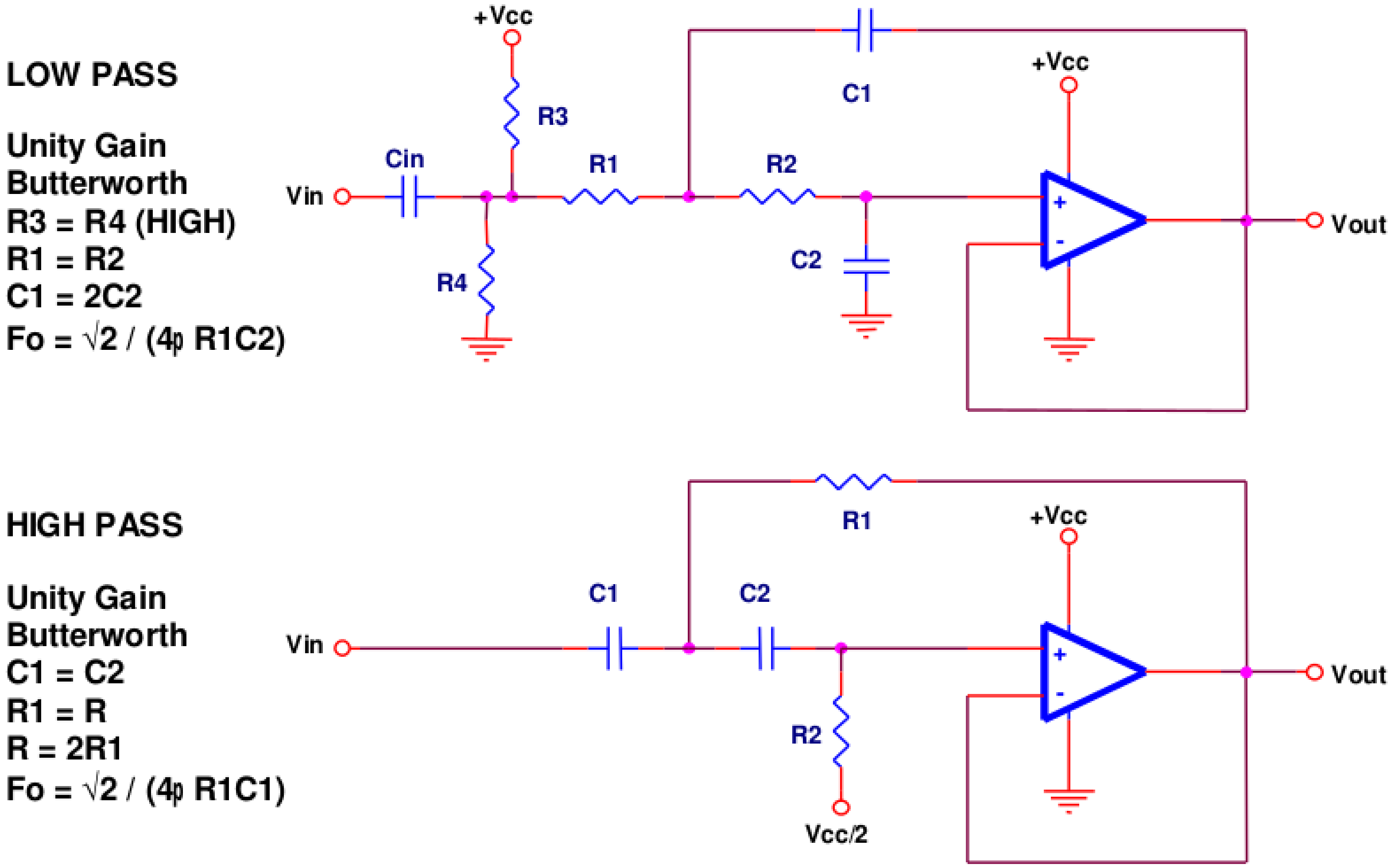
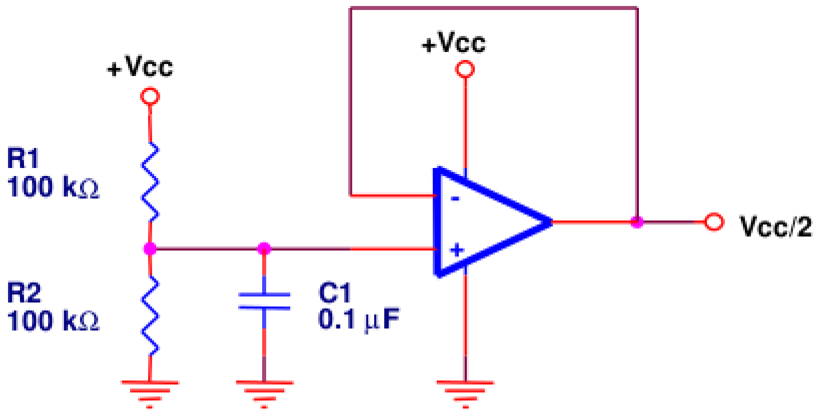


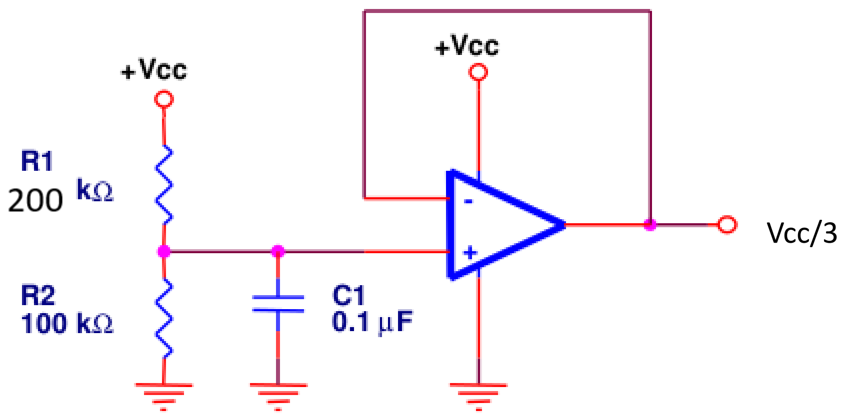
Figure 16. Sallen-Key Low- and High-Pass Filter Topologies

If you need to generate stable Vcc/2 (which is the op-amp “ground”) use a second op-amp:



If you need to generate Vcc/3 use a second op-amp:

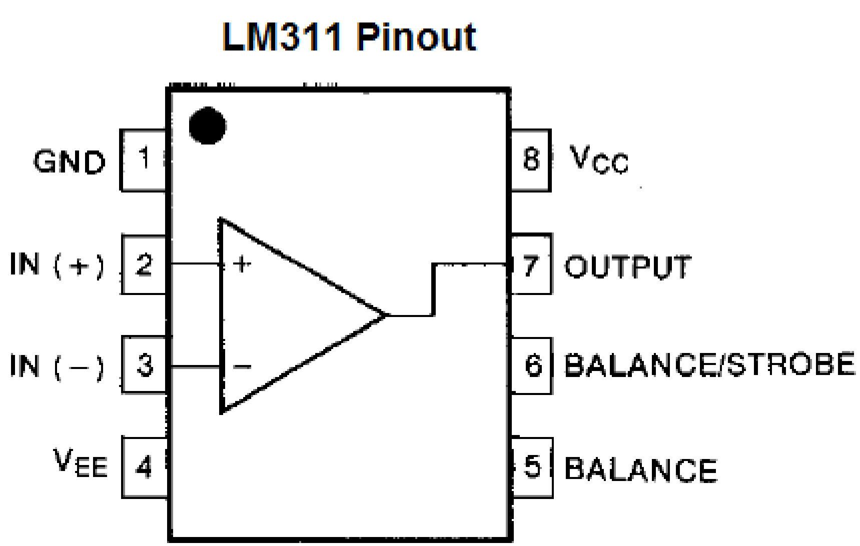
If Vcc = 5V,
make R_1=200k, R_2= 100k,
puts output at:
1.67 V.



Comparators

Basic device function: compare two voltages, indicate which is greater.

But also useful for:
- logic level shifting,
- threshold detection/ generating square waves
- driving the P-channel mosfet or pnp transistor on H-bridges
- turning a logic output into a 'tri-state' output.



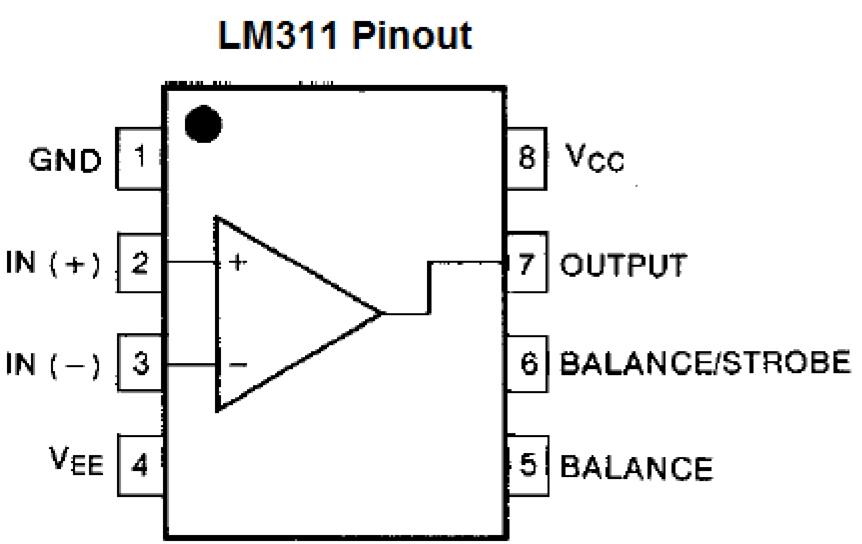
Notice: The output is an open collector – it needs a pull up resistor, which, if needed, can be connected to a different voltage.
They need +-15V power supply

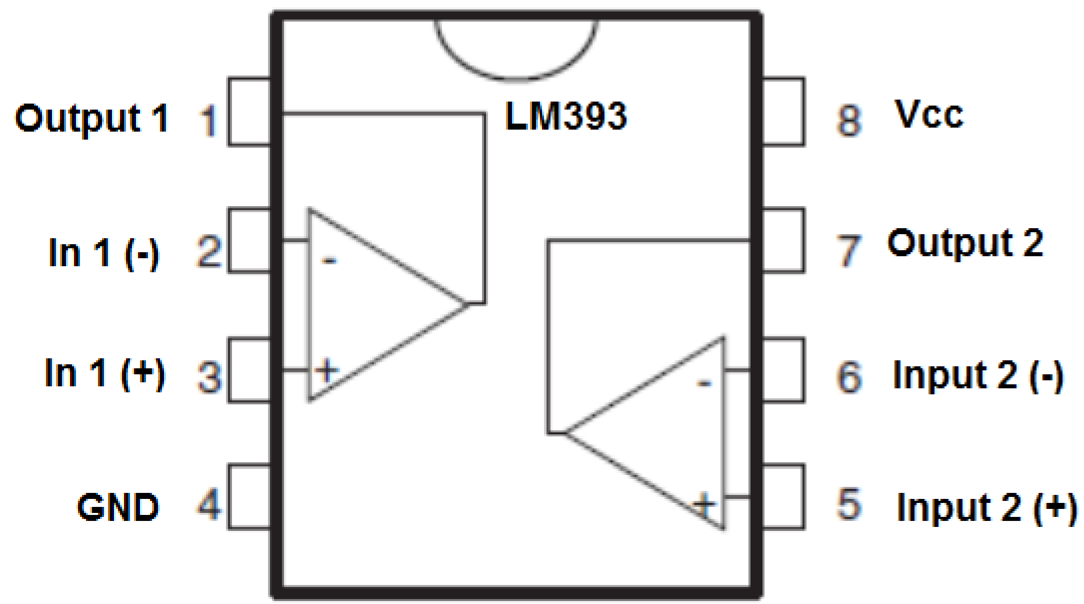
Comparators

V_{CC}, V_{EE} - +, - supplies. The inputs must stay between the supply voltages. Can be +/-15V or +5/0.

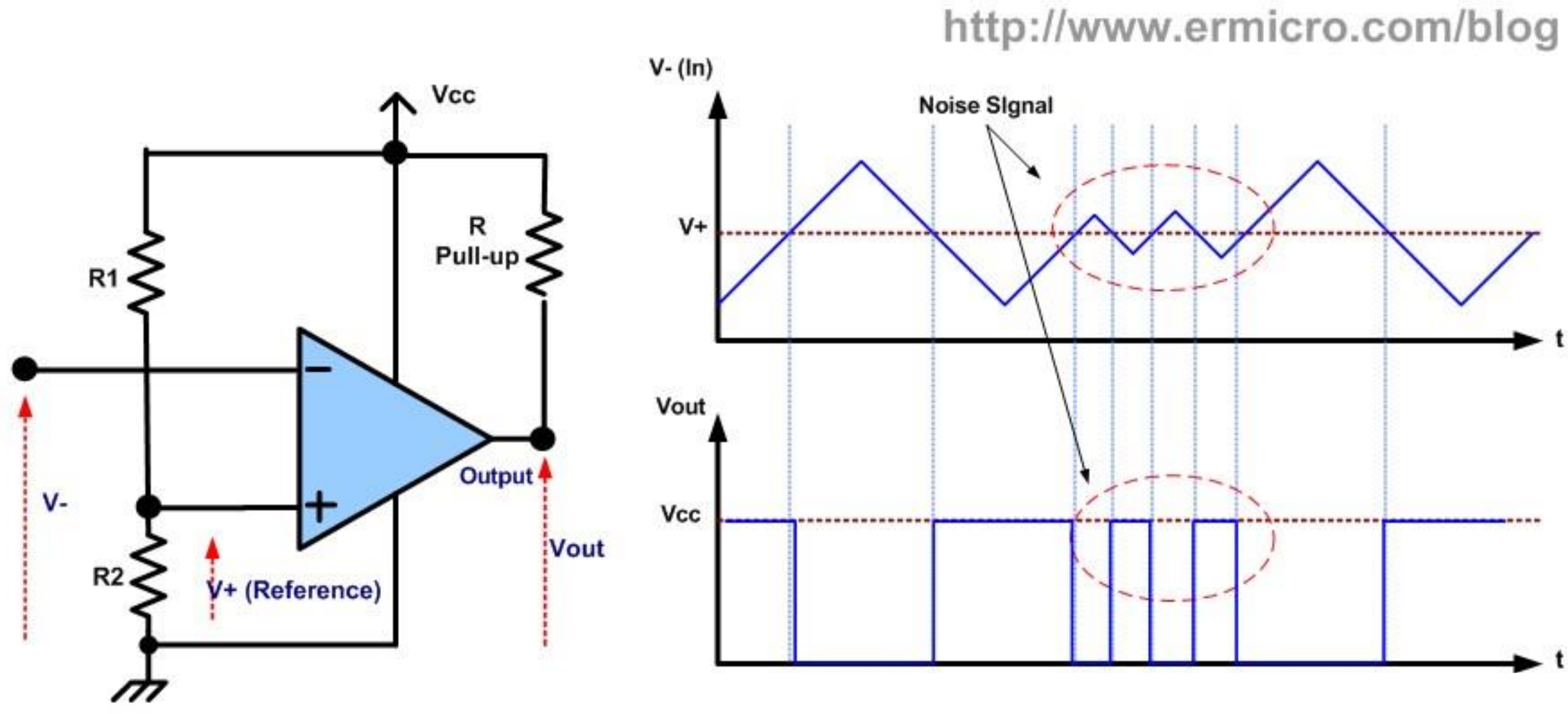
When V- > V+, then the output is connected to GND. When V+ > V-, the output floats.

Balance: used to trim internal V+ vs V- offsets. Not usually needed.
Strobe: pull to ground to disable comparator.



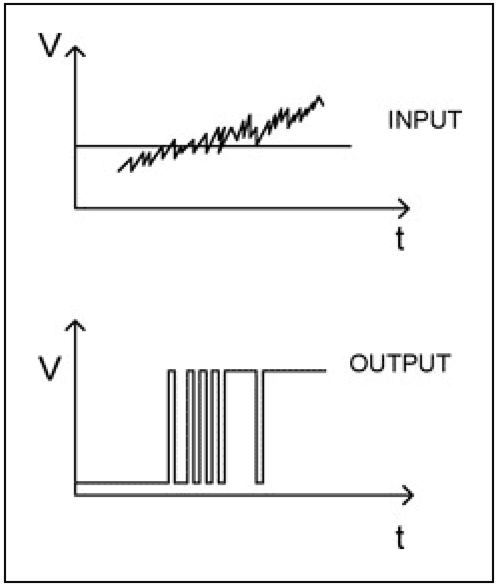


Comparators



Comparators

Noisy signals:



http://hades.mech.northwestern.edu/index.php/Comparators

Comparators

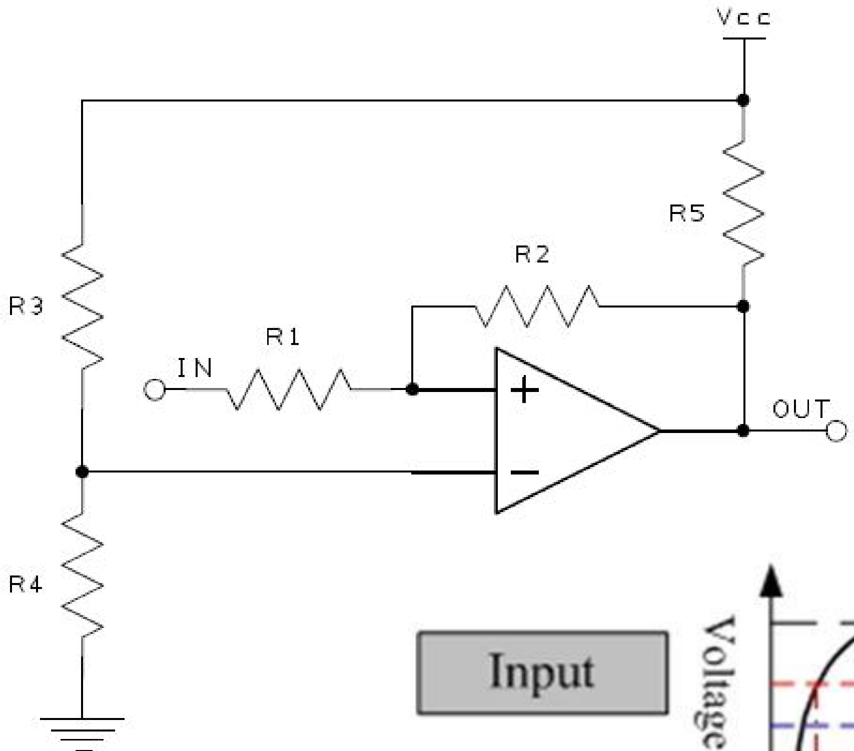
Hysteresis for noise immunity: add positive feedback.

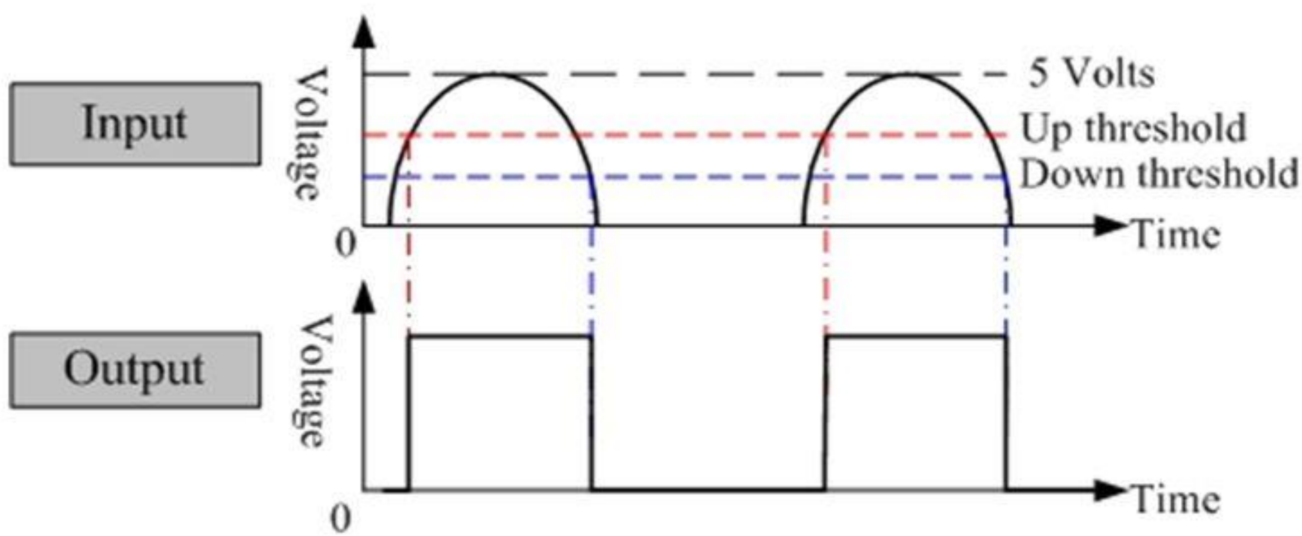
$$V_{ref} = V_{cc}\left(\frac{R4}{R4+R3}\right)$$

$$V_U = V_{ref}\left(\frac{R1+R2}{R2}\right)$$

$$V_L = \frac{V_{ref}\,(R1+R2) - V_{cc}\,(R1)}{R2}$$

(Assumes $R_5 << R_2$)





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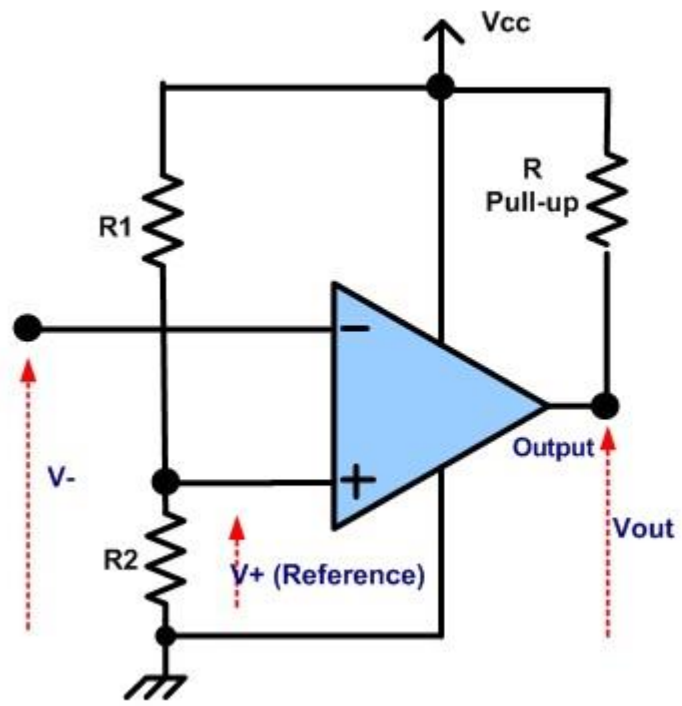
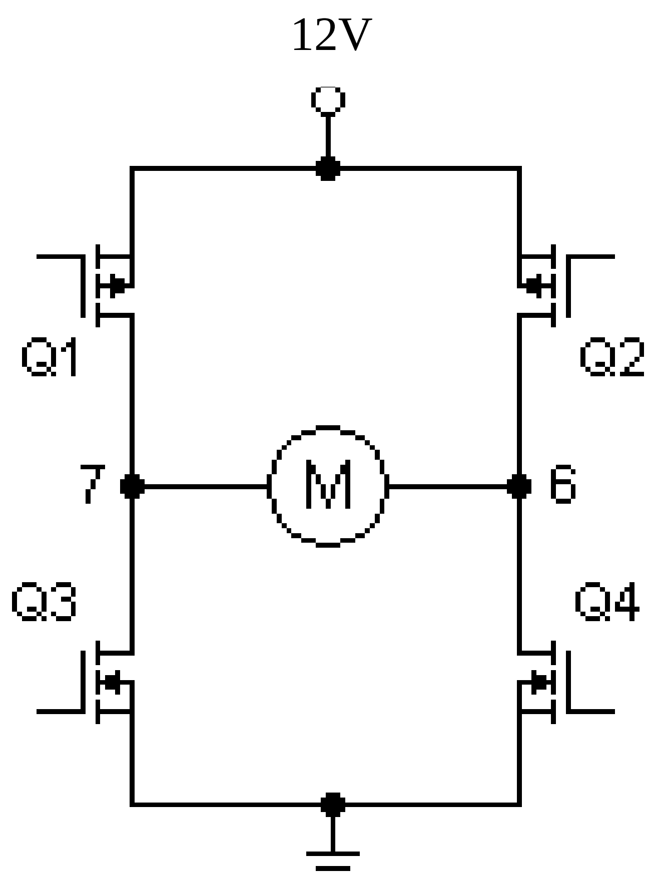
Comparators



The pull-up doesn't have to be connected to the same supply voltage as the comparator supply, it can be higher or lower. This makes the comparator output very flexible for level shifting!

Comparators

Example: Level shifting:

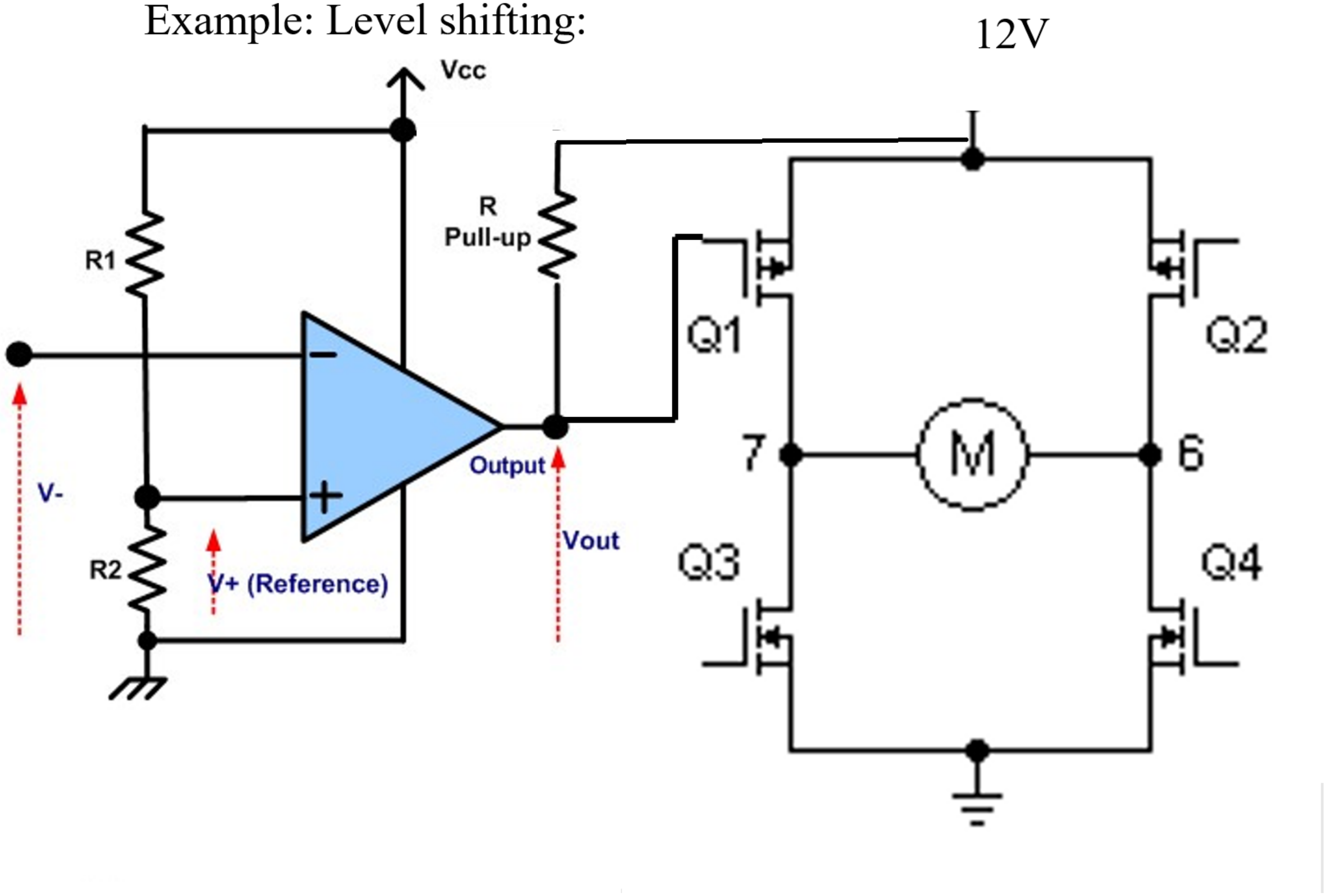


Q3 and Q4
can be turned on with a
5V logic device, off at 0.

But Q1 and Q2 need to be up at 12V to be turned off, then pulled down to turn on.

Comparators

Example: Level shifting:



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