Today's plan:

- Announcements: checks, progress report
- Using many ADC inputs
- Current regulators
- Measuring capacitance
- Noise suppression

Announcements:

Materials return:

You will need to return all the materials borrowed from the lab: (breadboard, launchpad, motors, cars, etc).

The sets should be returned to Sing, the project parts directly to me.

This can be done after the presentations and not later than April 15th. You need your deposits back!

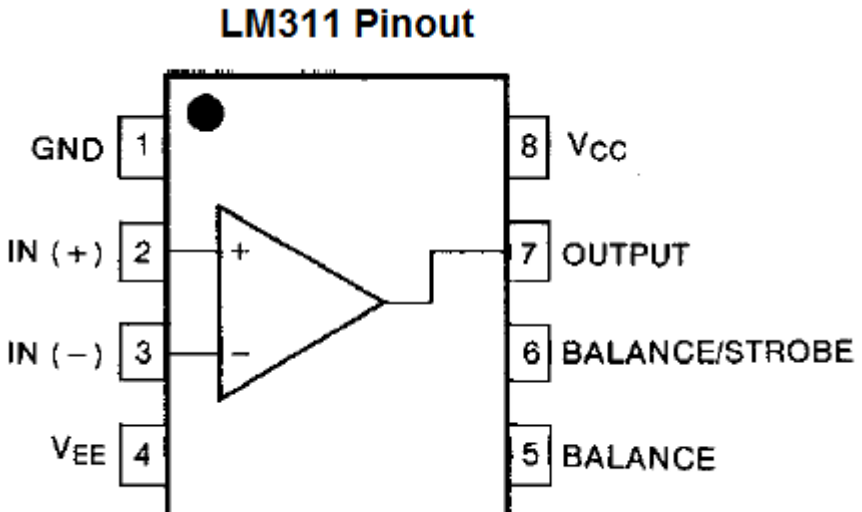
Announcements:

Time is going by quickly. You have only 2 weeks of labs before presentation!

Comparators

Basic device function: compare two voltages, indicate which is greater by a state of a digital output.

But also useful for:
- logic level shifting,
- threshold detection/ generating square waves
- driving the P-channel mosfet or pnp transistor on H-bridges



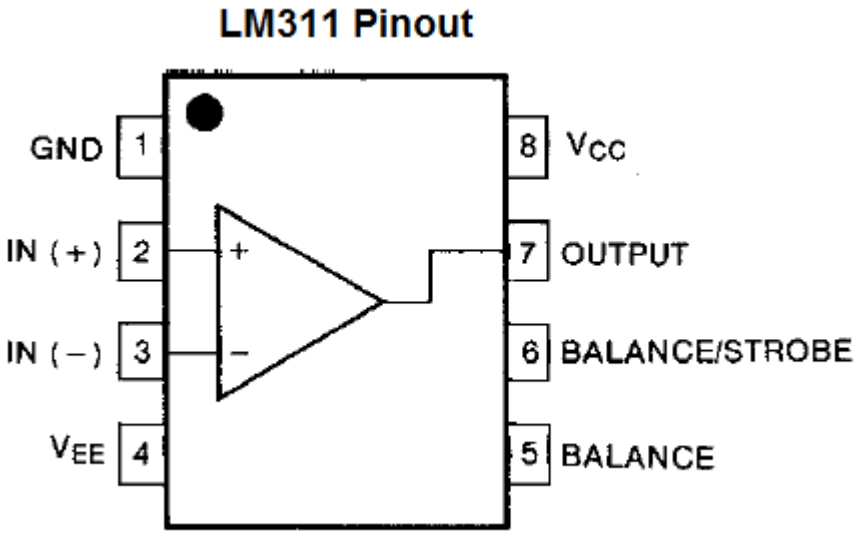
Notice: The output is an open collector – it needs a pull up resistor, which, if needed, can be connected to a different voltage. They need +-15V power supply

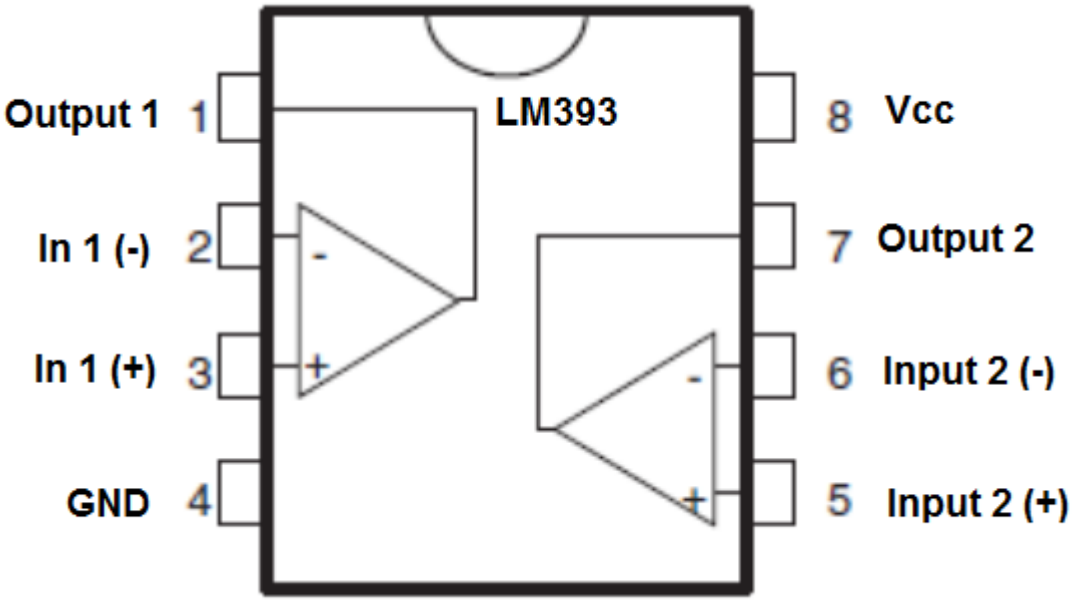
Comparators

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

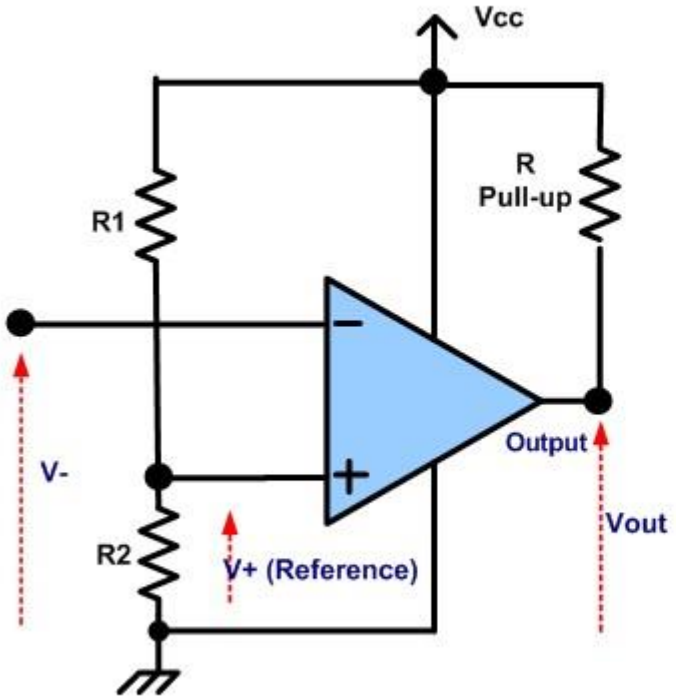
When V- > V+, then the output is connected to GND. When V+ > V-, the output floats.

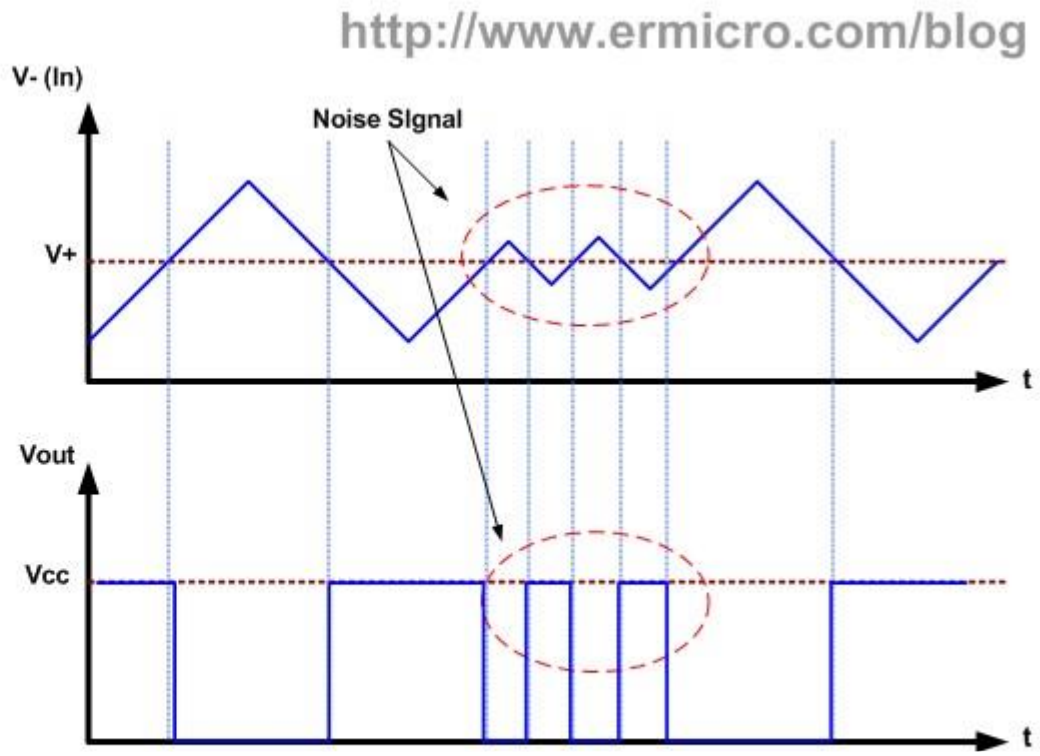
Balance: used to trim internal V+ vs V- offsets. Not usually needed.
Strobe: pull to ground to disable comparator.





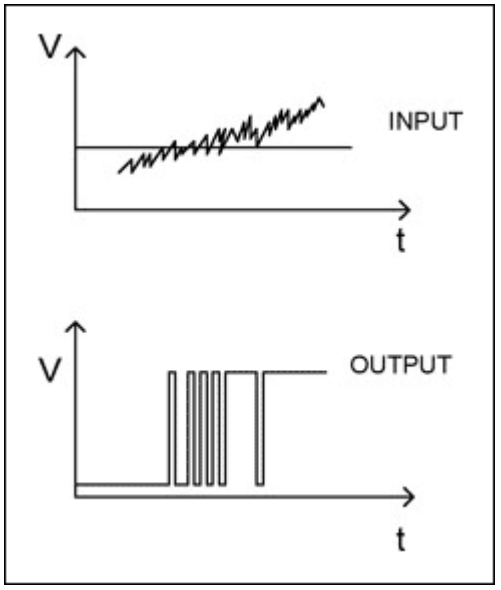
Comparators





Comparators

Noisy signals:



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

Comparators

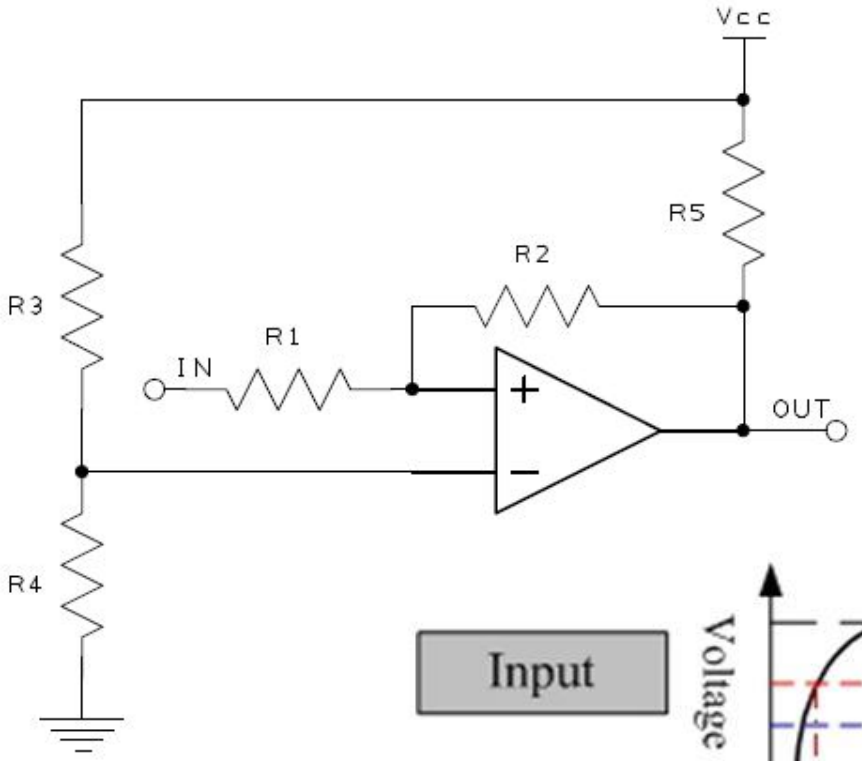
Hysteresis for noise immunity: add positive feedback.

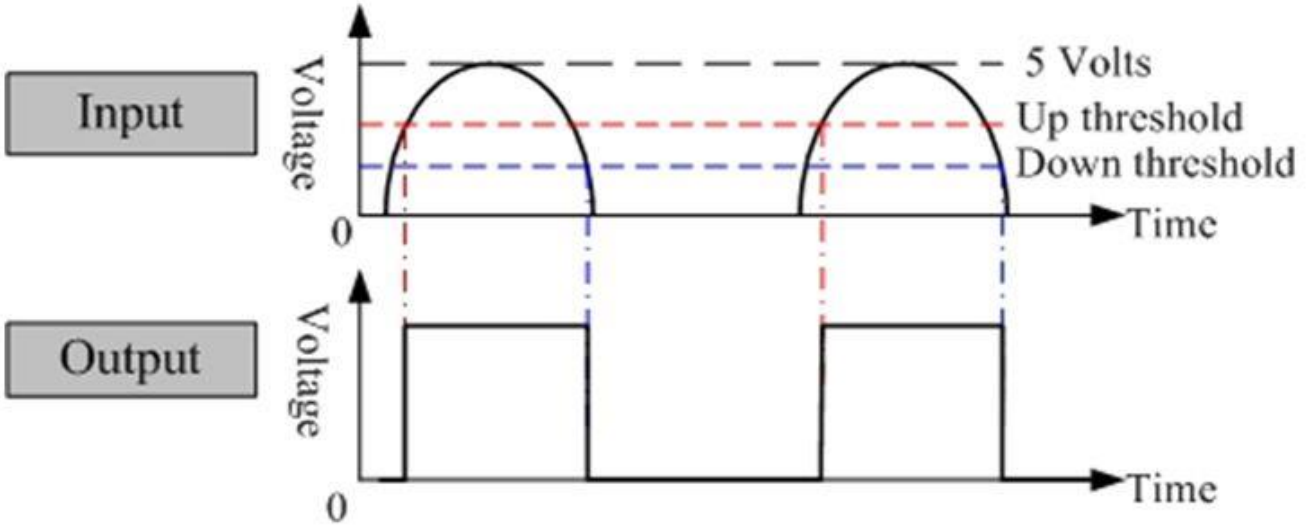
$$V_{ref} = V_{cc}\left(\frac{R4}{R4+R3}\right)$$

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

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

(Assumes $R_5 << R_2$)





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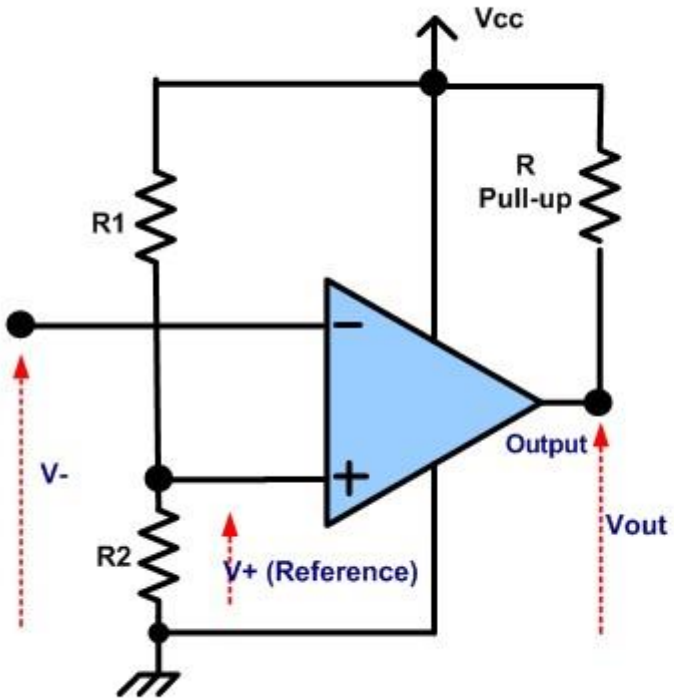
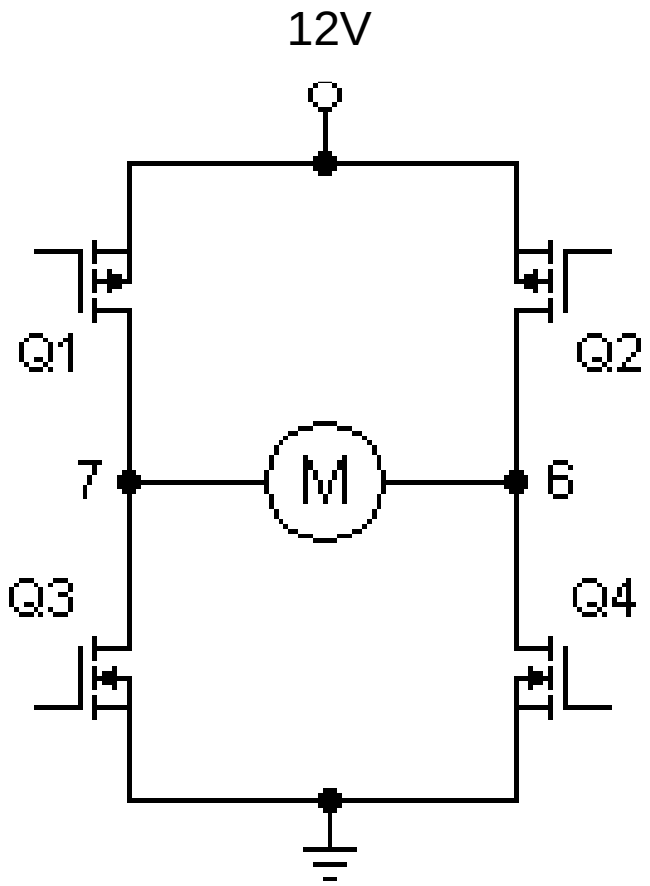
Comparators



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:

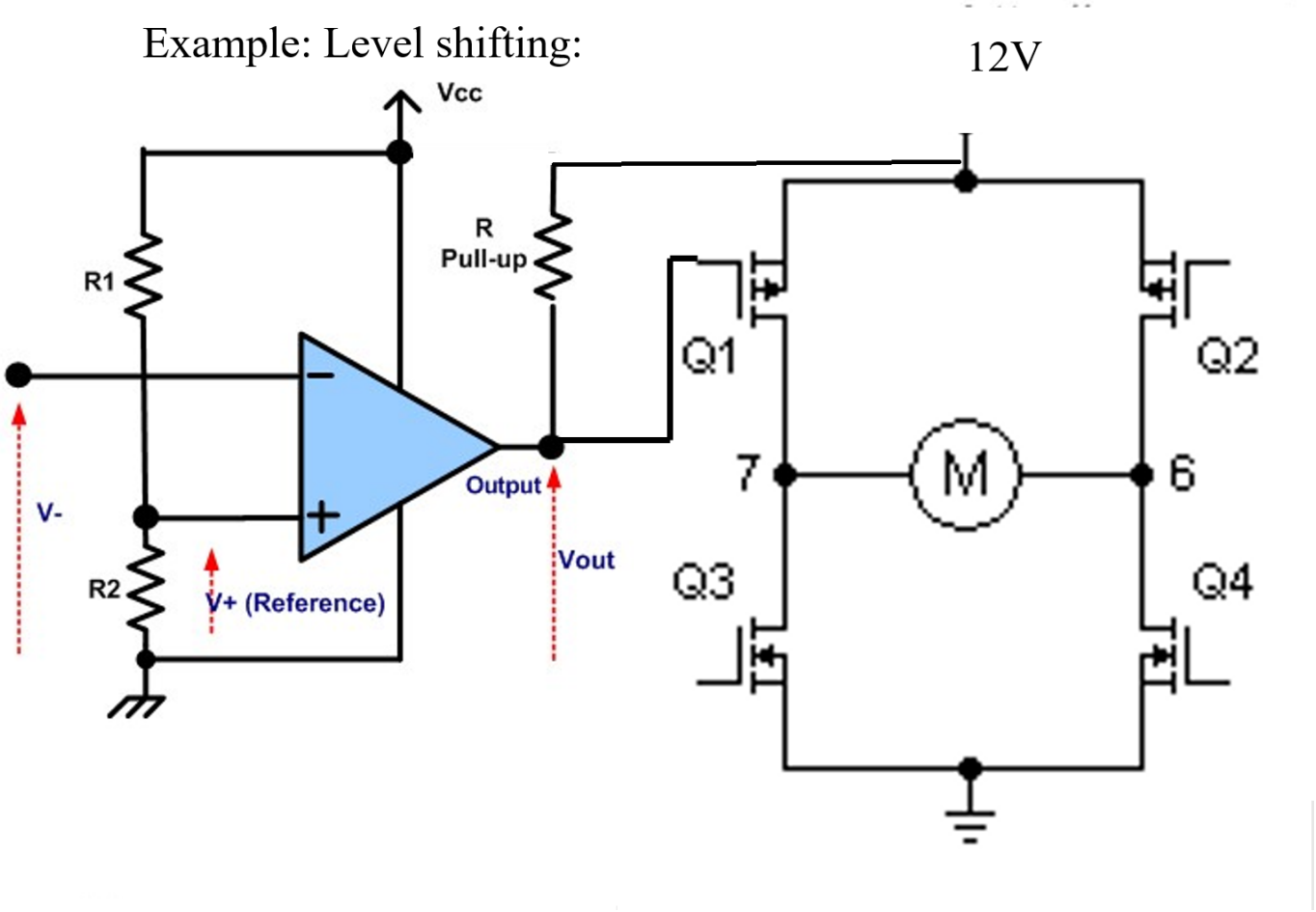


Q3 and Q4
can be turned on with a
5V logic device, off at 0.

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

Comparators

Example: Level shifting:



Q3 and Q4
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5V logic device, off at 0.
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Multiple ADCs

```
ADC12CTL0 = ADC12SHT02 + ADC12ON + ADC12MSC;
 // Sampling time, ADC12 on, automatic multiple conversions
  ADC12CTL1 = ADC12SHP | ADC12CONSEQ_1 |
ADC12CSTARTADD_0;        // sampling timer, multichannel,
starting memory address
  ADC12MCTL0 = ADC12INCH_0;
//selects A0 to be stored in memory ADC12MEM0
  ADC12MCTL1 = ADC12INCH_1+ADC12EOS;
//selects A1 to be stored in memory ADC12MEM1 and this memory
to be the last of sequence
  ADC12CTL0 |= ADC12ENC;                    // ADC enable
conversions
  P6SEL |= 0b00000011;                    // allow ADC on pin 6.0,6.1
```

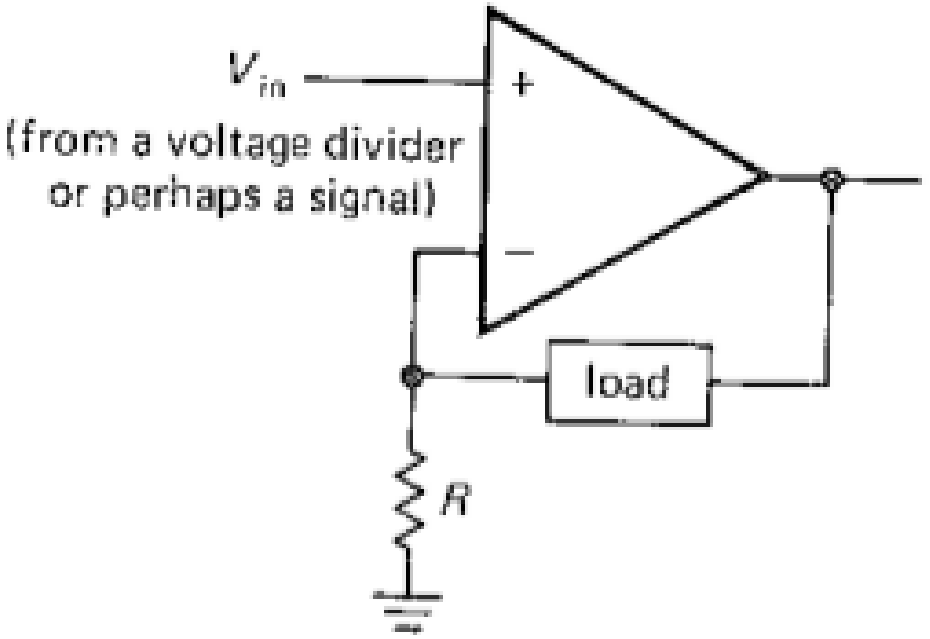
Family Manual ADC12

Page 740 program flow

Page 749 control registers

Page 754 memory control registers

Current Regulation



But load isn't grounded in this circuit.

Current Regulation

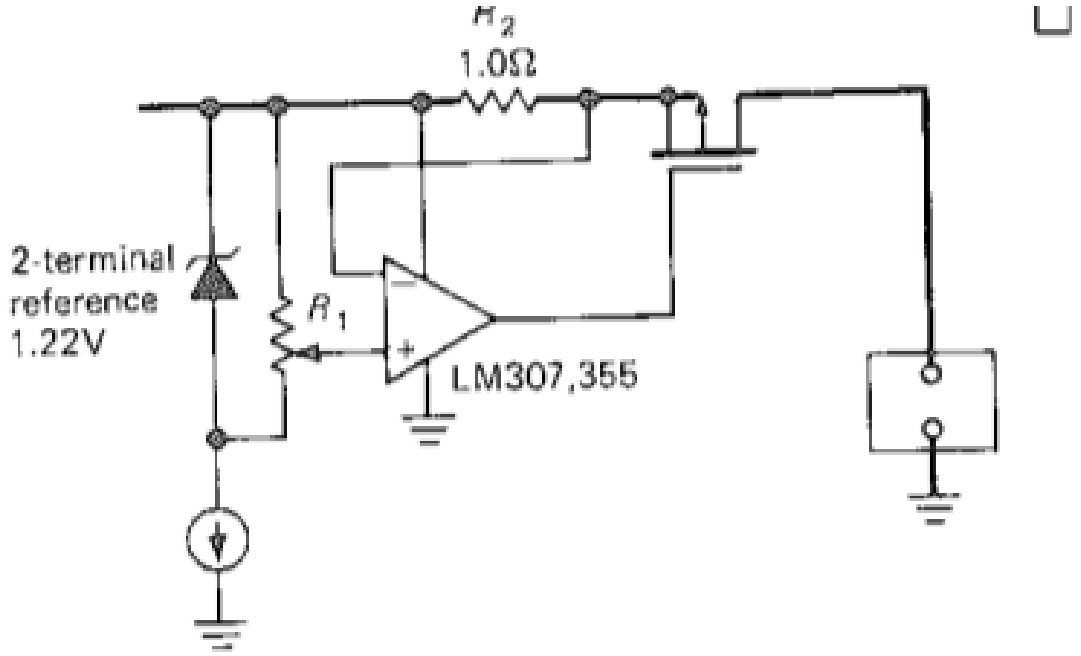
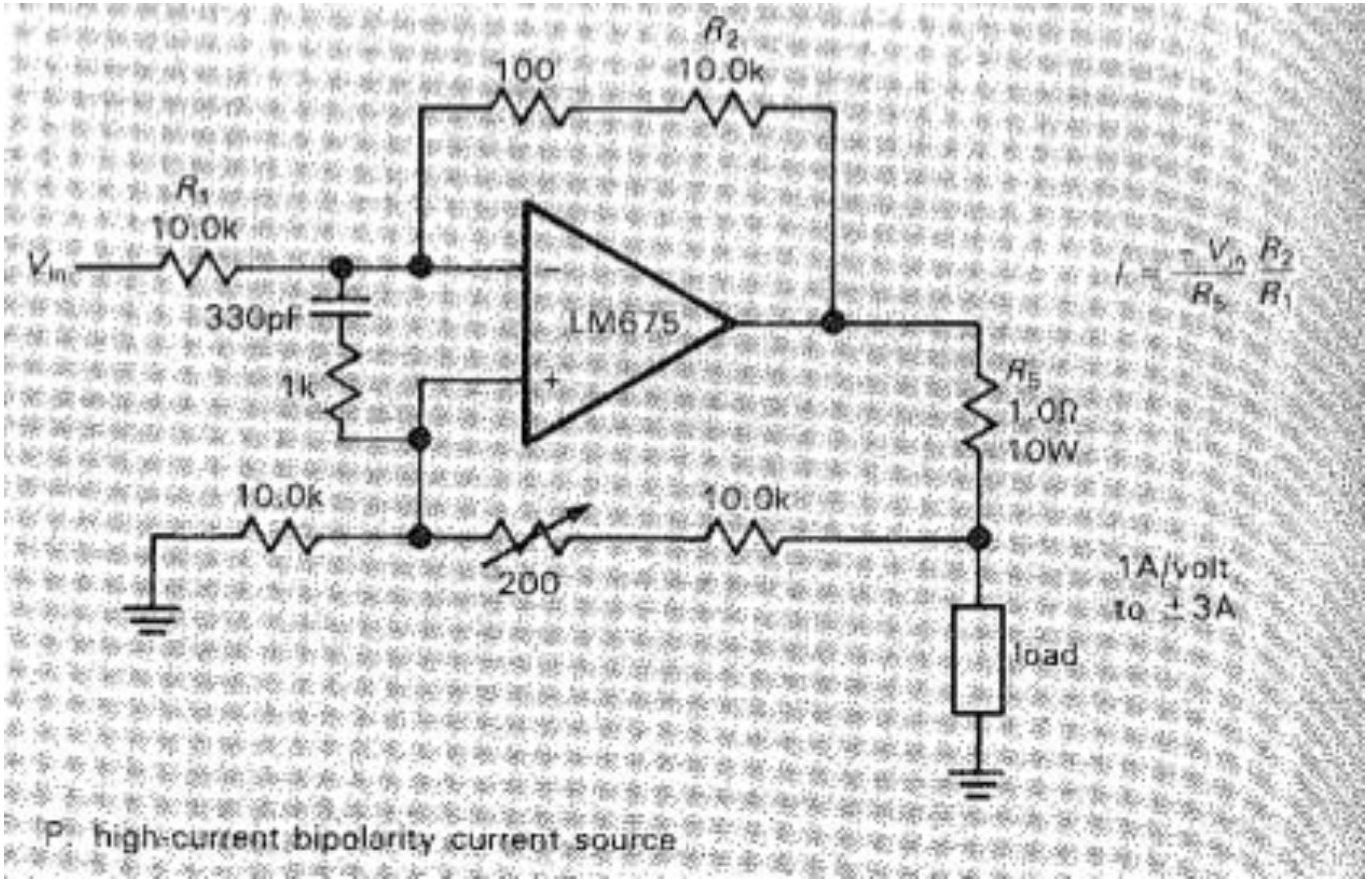


Figure 6.61. Input-rail current sensing.

Current Regulation



P. high-current bipolarity current source

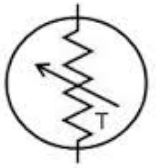
Overcurrent Protection

If one is using a DC power supply, generally it should be chosen so that it can supply the needed amount of current, and not too much more.

For battery powered projects though, it may make sense to include overcurrent protection to avoid: damaging the batteries or starting a fire.

Options include: fuses (kind of a pain as they need to be replaced), circuit breakers (expensive), thermal cut-outs (cheap, basically a fuse), PTC thermistors, or for a low power project, just a resistor in series with the supply may be ok (must be capable of dissipating the power developed in it when the load is short circuited).

The PTC thermistor is a semiconductor device where the resistance increases rapidly with temperature. If you try to draw “too much” current, the resistance rises and reduces the current.



DC-DC convertors

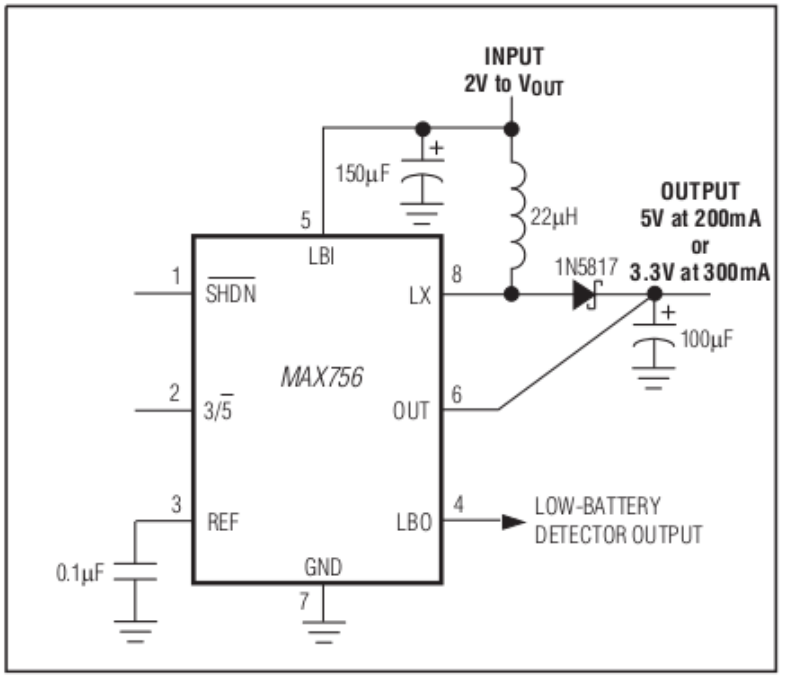
Step-up or step-down DC-DC converters are available.

Much more energy efficient than linear regulators

Noisier output

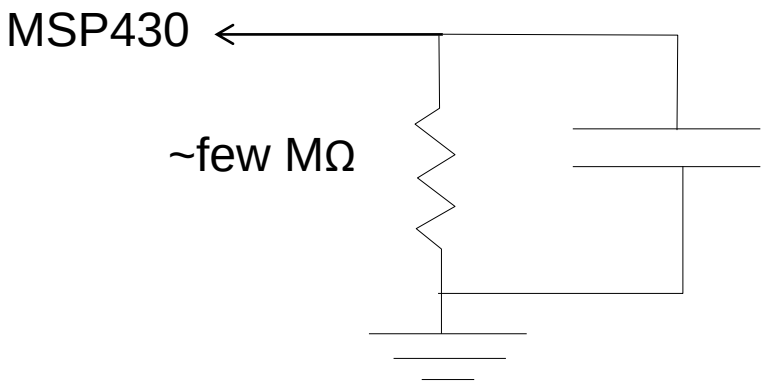
Allows, for example to generate

5V from 2 AA batteries.



Capacitance Measurements

Simplest:



- set the pin as an output, and set it to high
- then set as input, and time how long it takes to discharge to read as low.

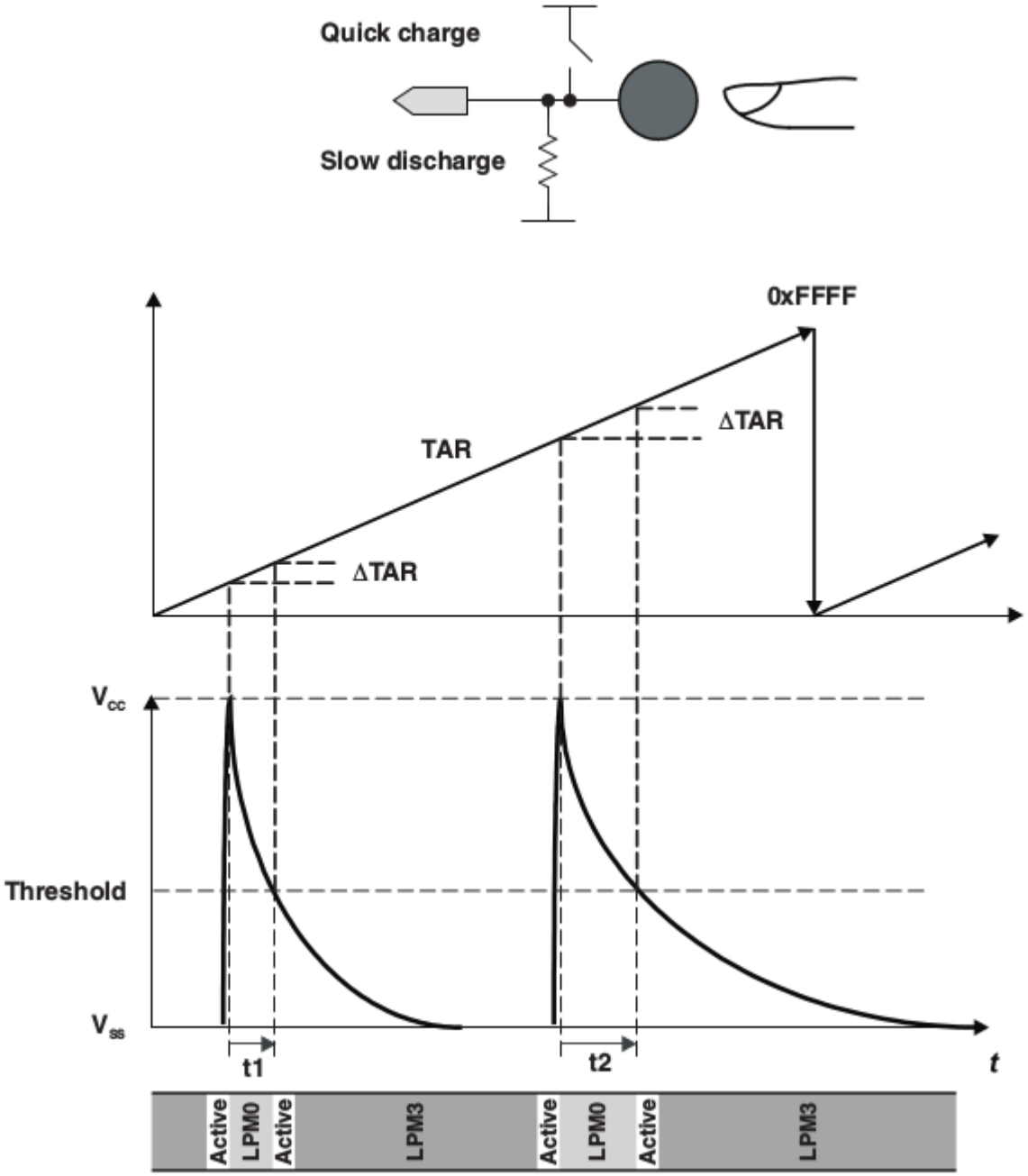
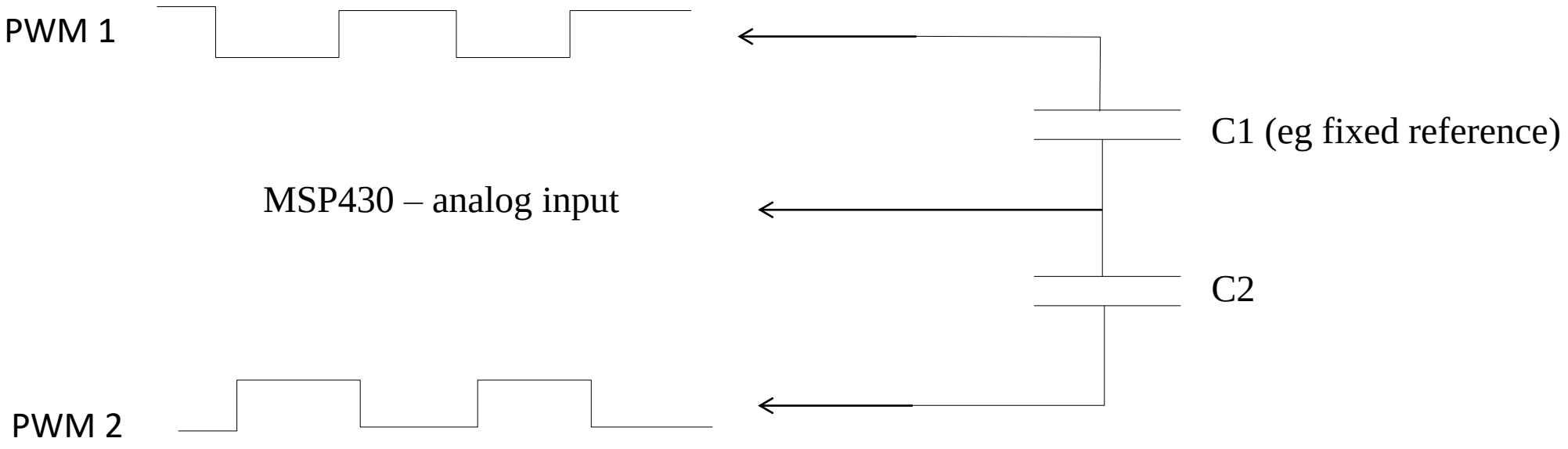


Figure 2. Charge-Discharge Sequence

Differential capacitance measurement:



Noise suppression

Software low-pass filter:

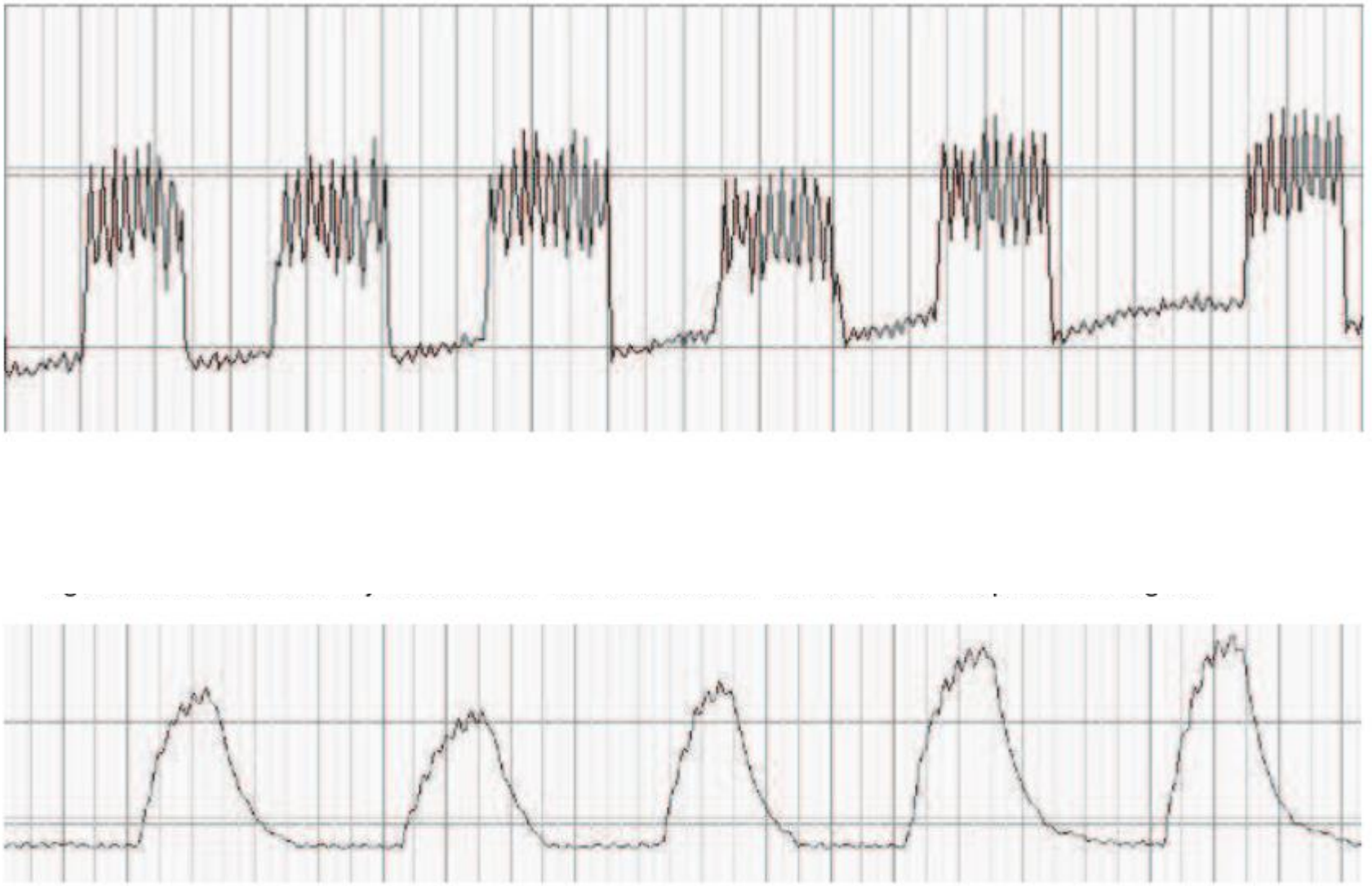


Figure 7. Oscilloscope With IIR Filter

Noise suppression

Software low-pass filter:

```
int current,filter;

// make measurement in here:

current = most recent measurement


filter = (1-K) * current + K*filter; // filter response same as simple RC low pass filter

// better implemented as, eg:
filter = (15*filter +current)/16;

// then output filter value.
```

This was our last Lecture!

I will be in the lab answering questions during the lecture hours during the last week of labs.