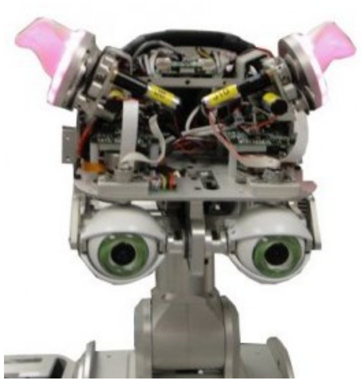
Sensors, and A/Ds

The good, the bad and the non-linear

What is a sensor?



The “eyes” and “ears” of your robot

Any transducer that converts something in the real world into some electronic signal
the ‘something’ could be:
temperature, air pressure, relative humidity, light level,
weight of your apples at Market Basket checkout

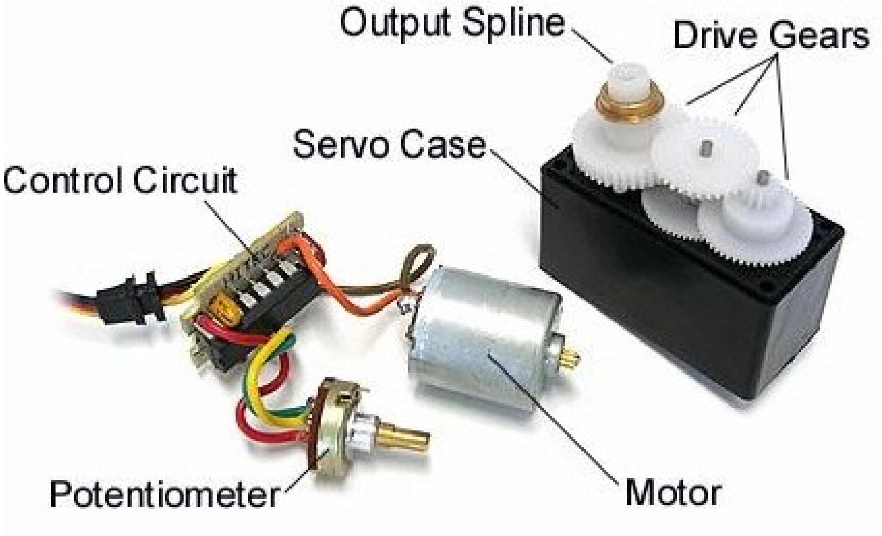
Usually a transducer provides a voltage output (but sometimes it provides a current)

This voltage provides an ‘analogous value’ proportional to the parameter you’re measuring

Actuator, R/C servo

This is the output ‘muscle’ of your robot
in our case we’re using a simple radio-control model airplane type servo,
It’s called an R/C servo from the history of radio-control airplanes and stuff

This will allow your program to “turn it’s head” and look around to see what’s left, right, etc



- Small motors run fast and happy
- Gear-train lets motor be fast, output be slow
- Potentiometer is angle feedback
- A “PWM” signal tells R/C servo the angle
- This is not the same as PWM for an h-bridge …

Microphone, speaker, motor, generator …

Ideal A/D converter

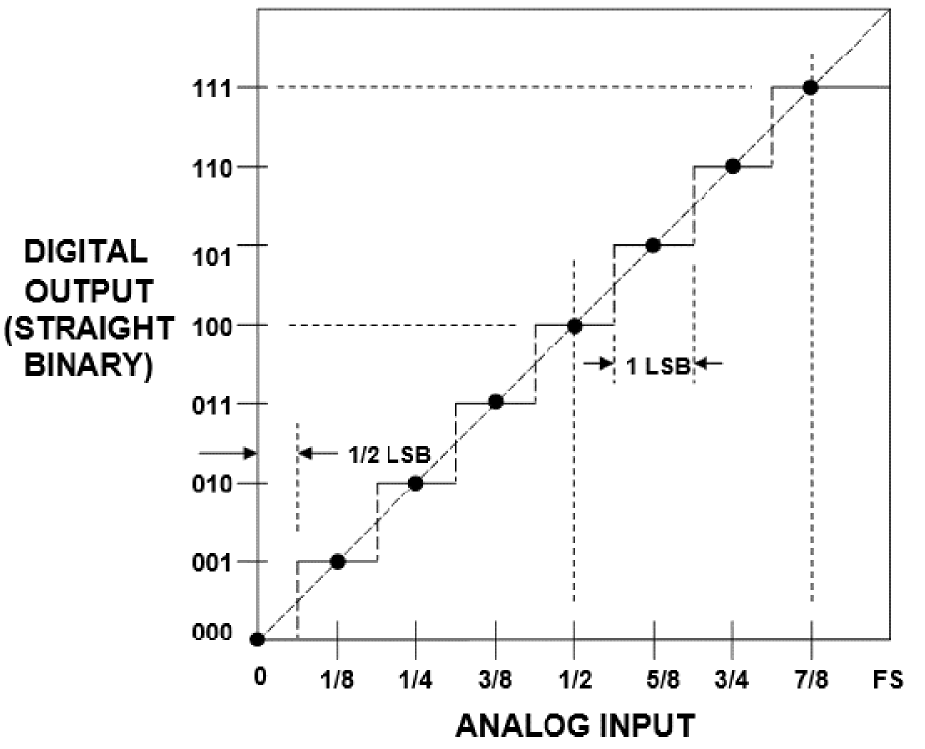


Figure 2.5: *Transfer Function for Ideal Unipolar 3-bit ADC*

Typical Arduino,
With 10 bit A/D,
2^10 = 1024,
So 3.3V/1024 = 3.22mV/LSB
Or 3.22mV per count, ideally

Teensy 3.1 has A/D with 16 bits,
13 bits are 'useable';
2^13 =8192;
3.3V/8192
= 0.402mV resolution, ideally

Note 3.3V/2^16 =
0.0503mV per count

Voltage input here, relative to
The max input voltage

Various non-ideal A/D conversions

▶ ANALOG-DIGITAL CONVERSION

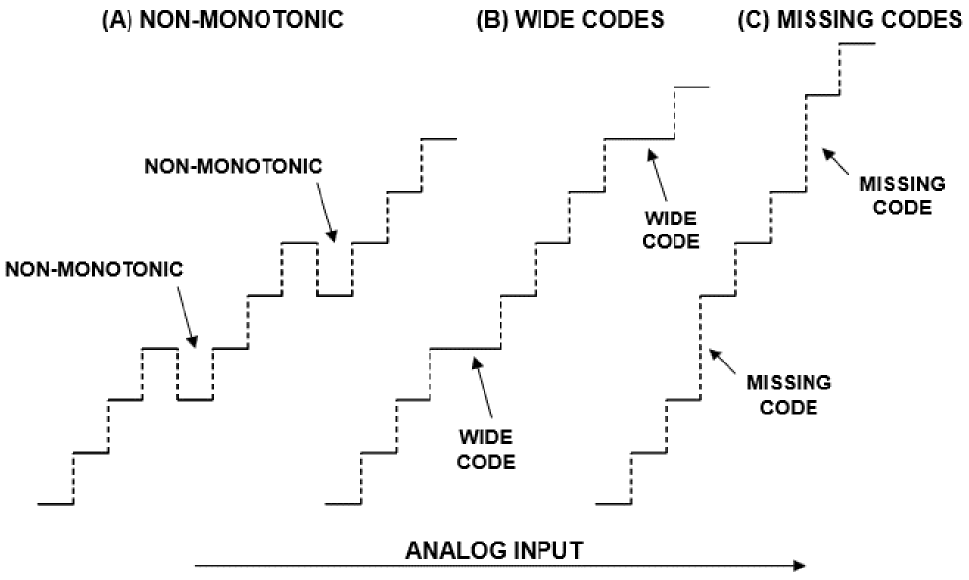
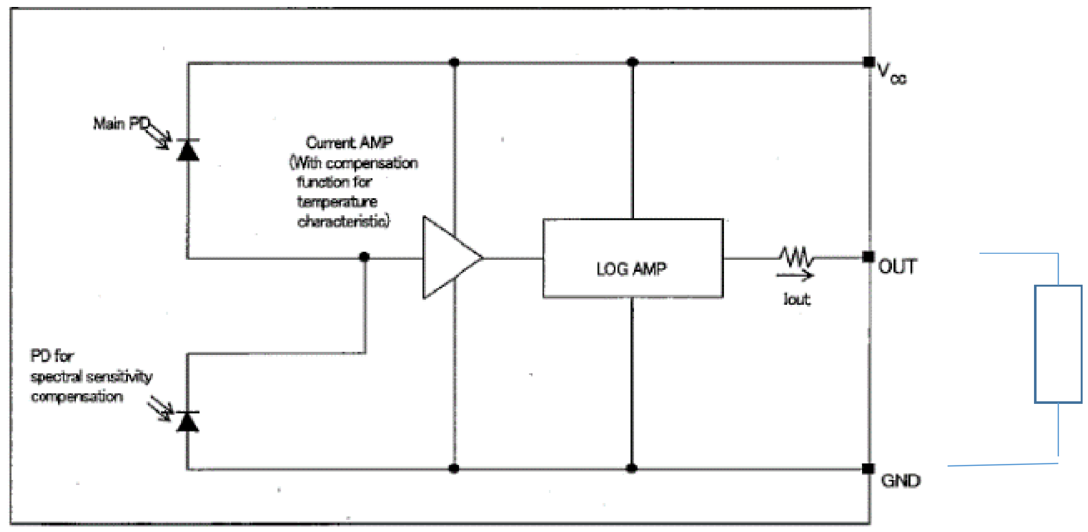


Figure 2.23: *Errors Associated with Improperly Trimmed Subranging ADC*

Lots more detail here: http://www.analog.com/media/en/training-seminars/tutorials/MT-003.pdf

Light sensor, wide range, analog output

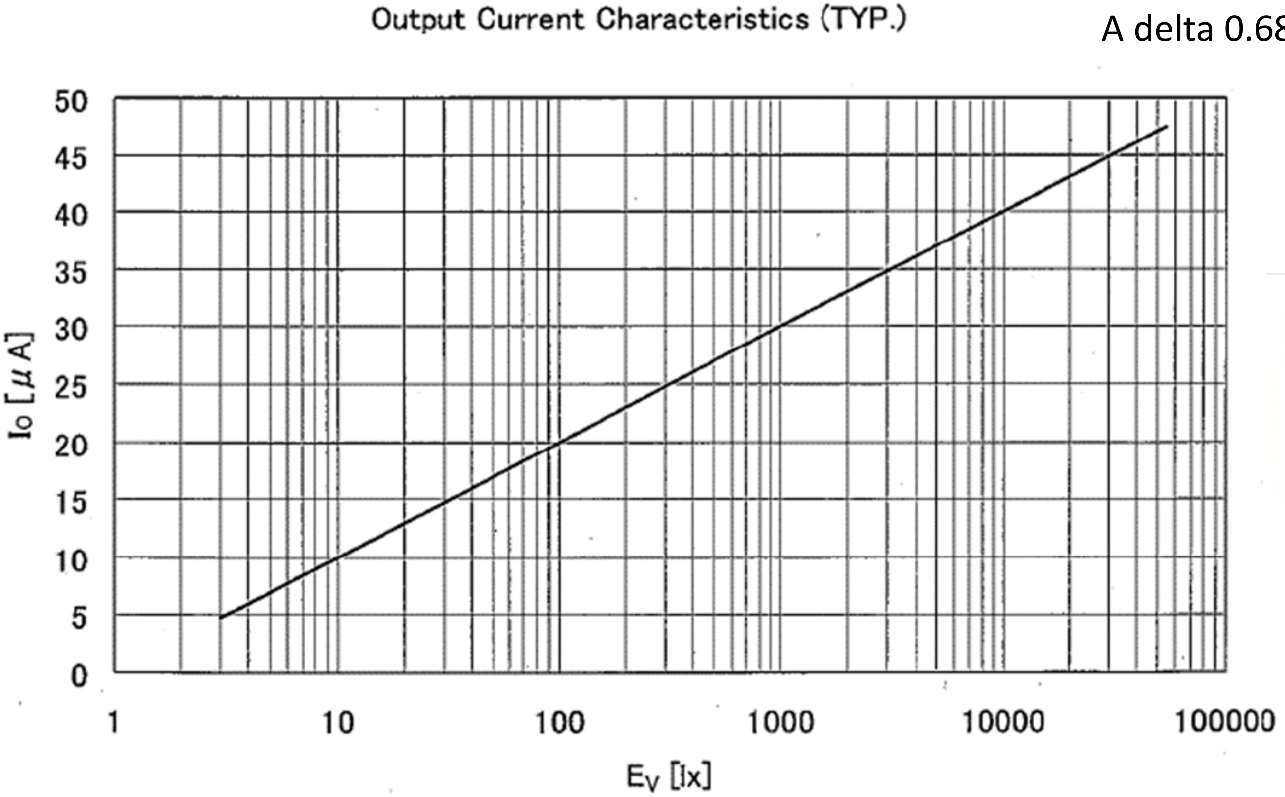
(6-1) Circuit block diagram



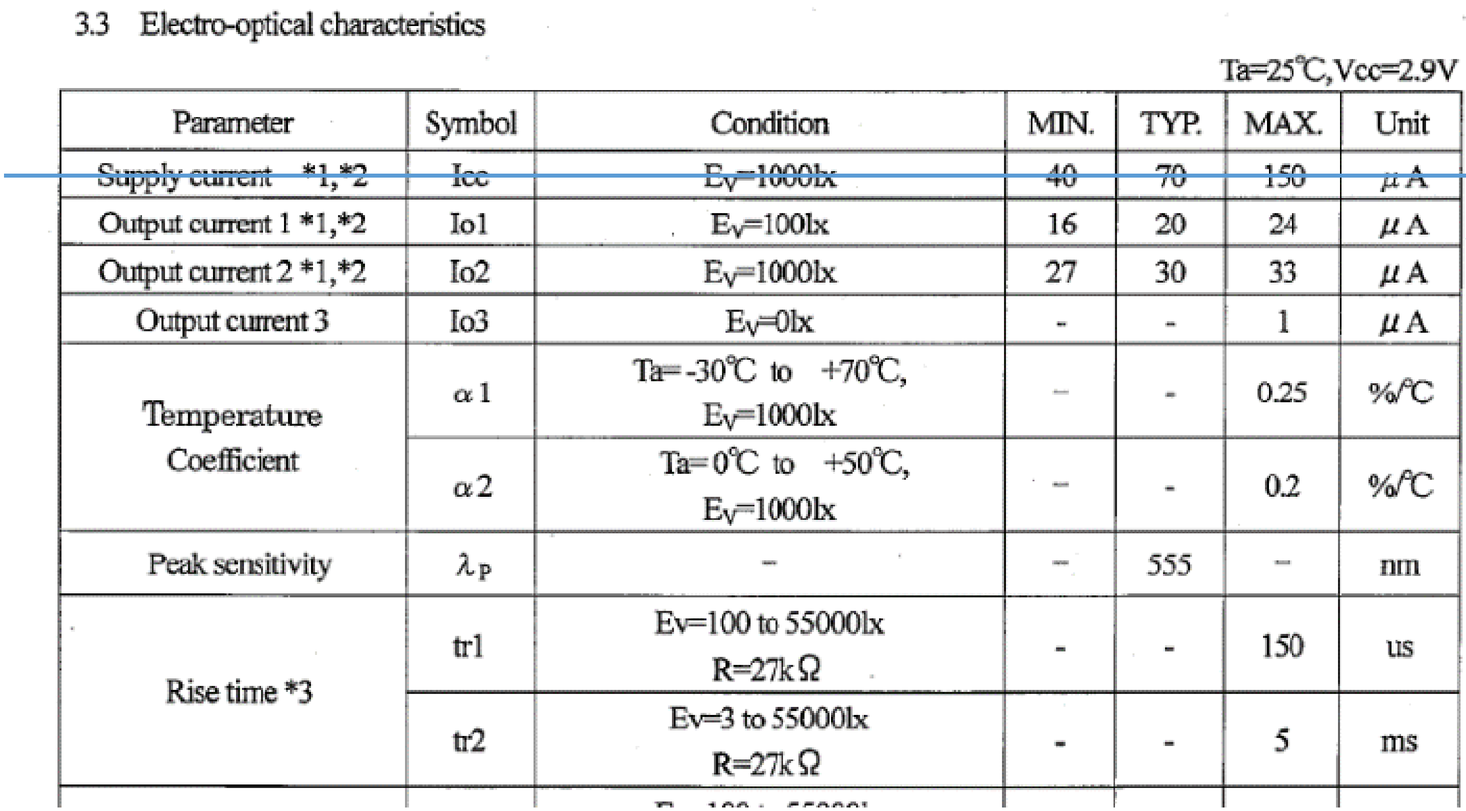
68K resistor converts
Current output to voltage;
3.3V/68K = 48.5uA max signal =
Approx. 55,000 lx light level

Light sensor light to current graph

A 10x change in light brightness
Results in a 10uA change;
With 68K resistor that's
A delta 0.68V for a 10X change



Some non ideal characteristics, for the light sensor (but relative meas. are OK)



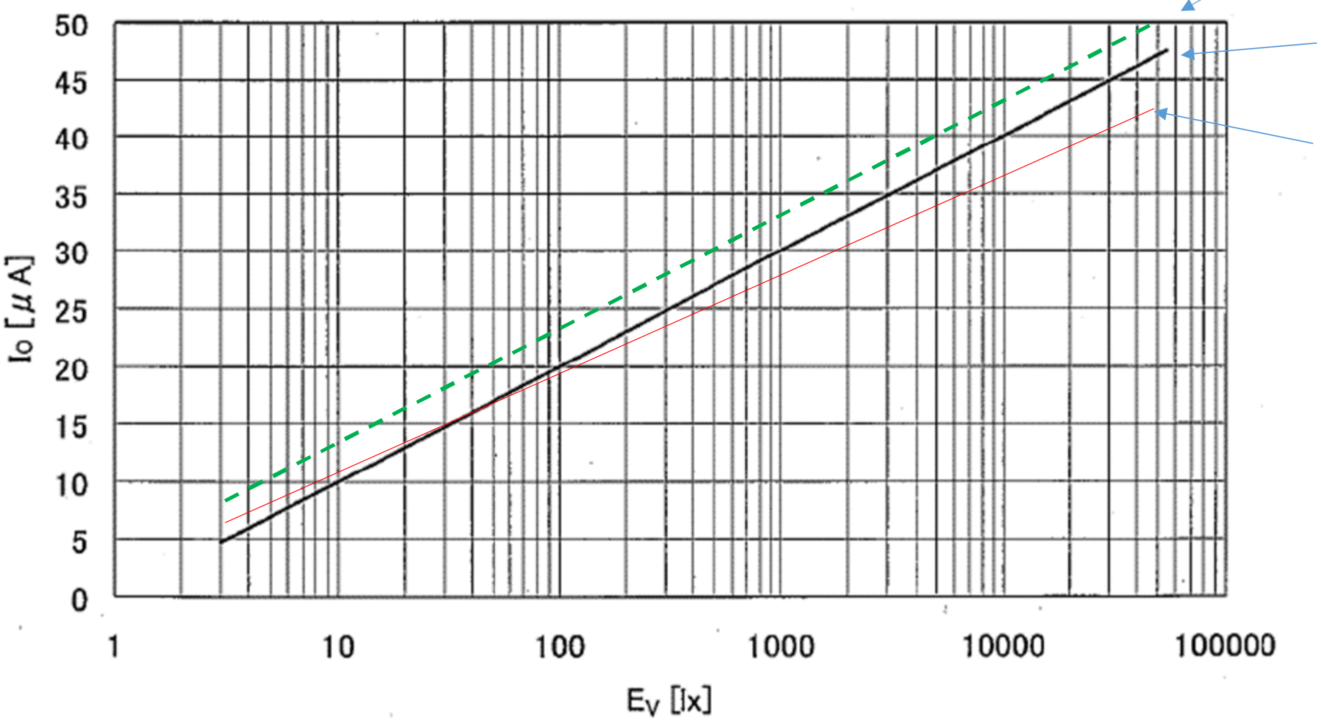
3.3 Electro-optical characteristics

Ta=25℃,Vcc=2.9V

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
~~Supply current *1,*2~~	~~Icc~~	~~E_V=1000lx~~	~~40~~	~~70~~	~~150~~	~~μA~~
Output current 1 *1,*2	Io1	E_V=100lx	16	20	24	μA
Output current 2 *1,*2	Io2	E_V=1000lx	27	30	33	μA
Output current 3	Io3	E_V=0lx	-	-	1	μA
Temperature Coefficient	α1	Ta=-30℃ to +70℃, E_V=1000lx	–	-	0.25	%/℃
	α2	Ta=0℃ to +50℃, E_V=1000lx	–	-	0.2	%/℃
Peak sensitivity	λ_P	–	–	555	–	nm
Rise time *3	tr1	Ev=100 to 55000lx R=27kΩ	-	-	150	us
	tr2	Ev=3 to 55000lx R=27kΩ	-	-	5	ms

Note the range
Of expected output,
FOR the SAME LIGHT
About 20 +/- 20%, 100 lx
And 30 +/- 10%, 1000 lx

Some variations, sensor to sensor



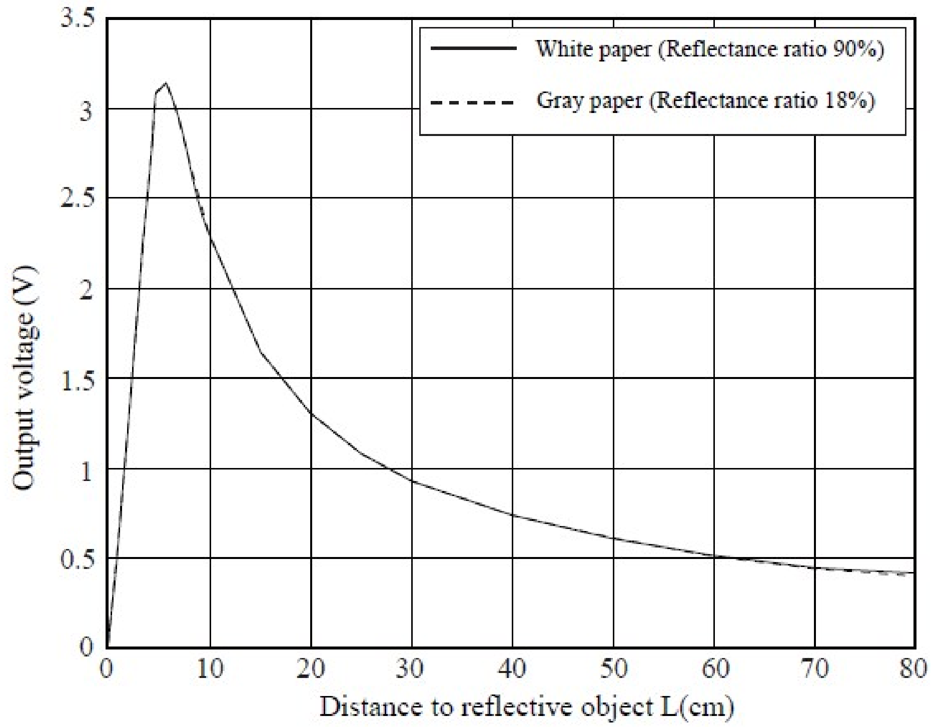
Sensor with offset

Typical sensor curve

Sensor with different gain

Distance sensor response graph

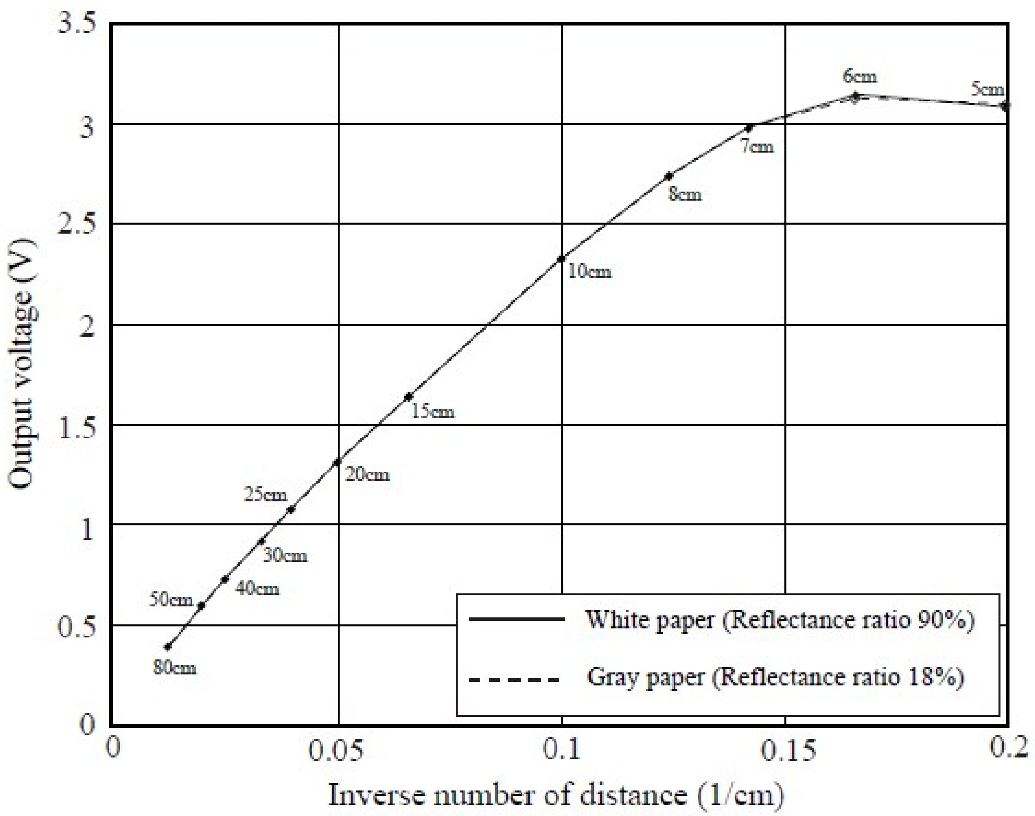
Fig. 2 Example of distance measuring characteristics(output)



Not really linear … but useful.
But watch out – closer than 5cm, and the signal slope reverses (closer is LOWER value!!)

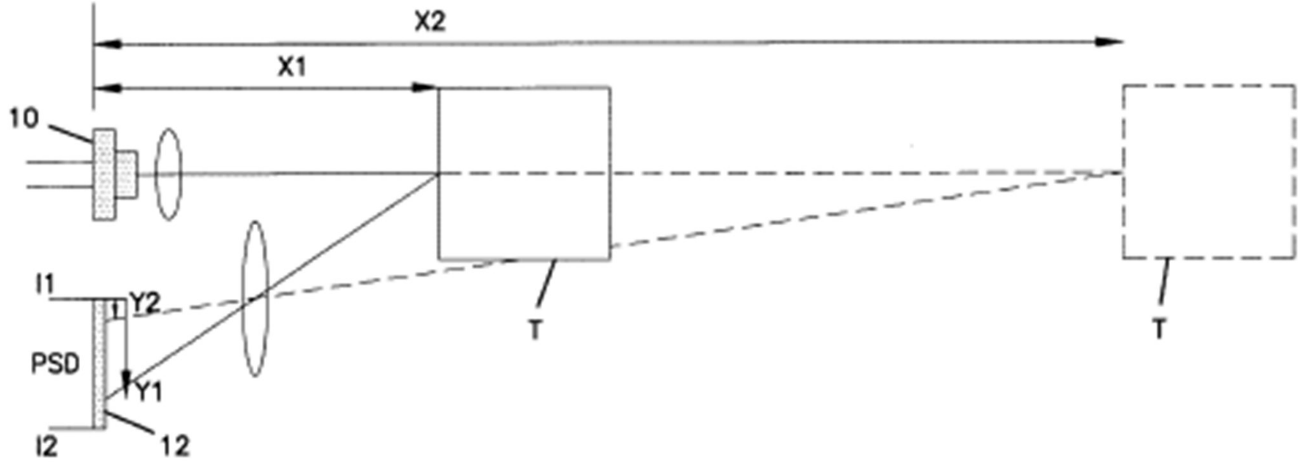
And a single voltage … could be one of two distances (yuck)

Distance sensor response graph, as “inverse distance” looks linear-ish



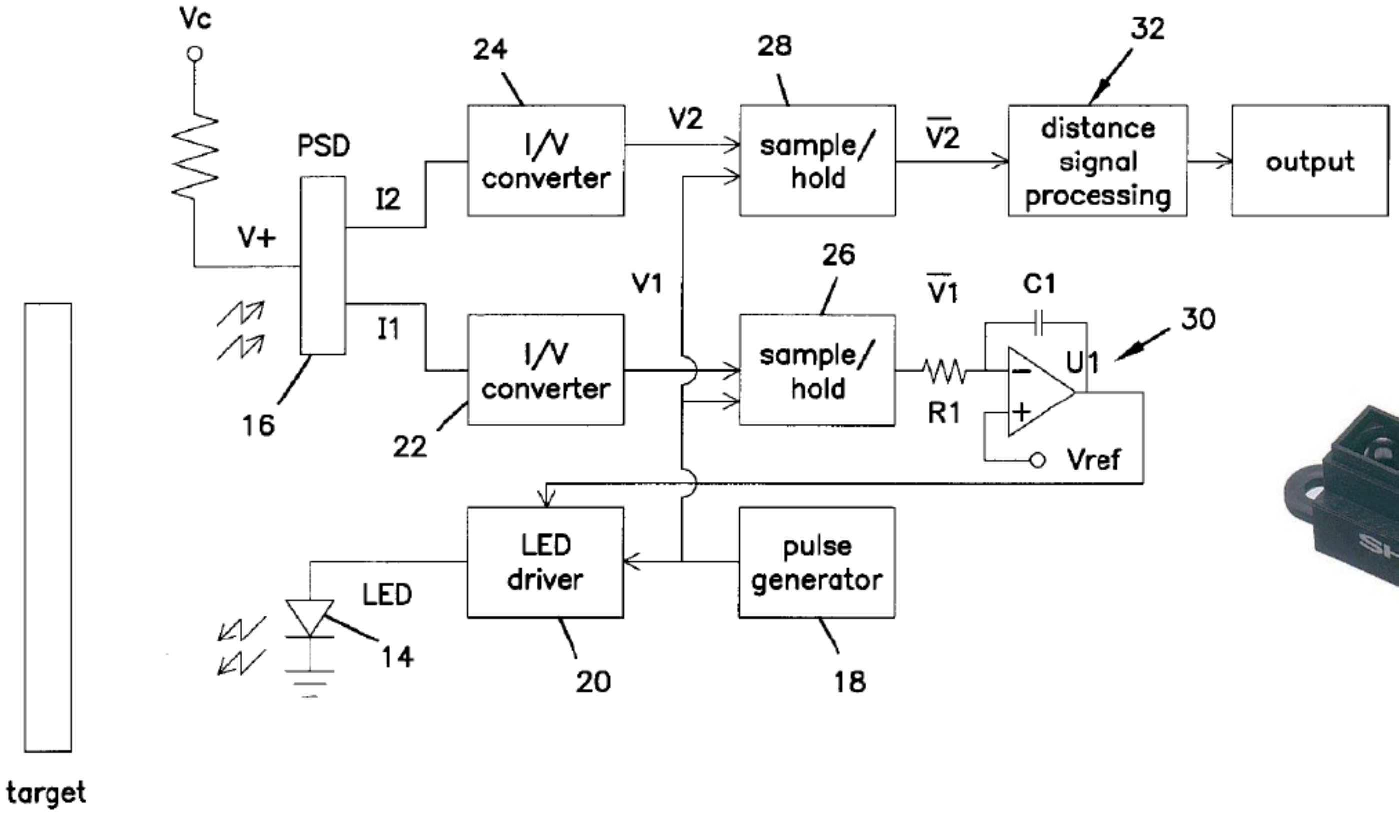
Reading data points from this graph can help make a function or look-up table to convert Voltage to distance

Inside the IR distance sensor, US patent 5,923,427

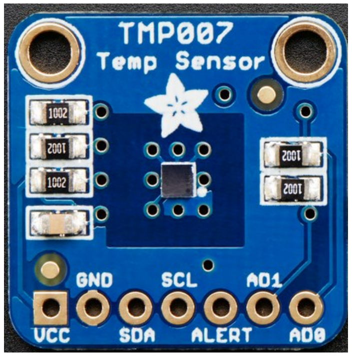


- Infra-red LED (10) lights up the target T
- A lens provides focus for LED source and the detector
- A slab of light sensitive silicon (PSD) can sense where the spot is along the slab
- Some extra electronics help is used to get a useful answer (next slide)

More stuff inside the IR Distance sensor



Infra-red non-contact thermometer sensor



This sensor can measure temperature without touching the object it is ‘looking at’

It is tuned to ‘see’ how hot the average area within its field of view

NOTE – the wide view angle could cause errors if a hot object is small
with a pinhole to limit the field of view, more focused measurements can be made

This sensor has its own A/D, and can only provide data through the digital I2C bus

Infra-red non-contact thermometer sensor

Field of view – without a pinhole

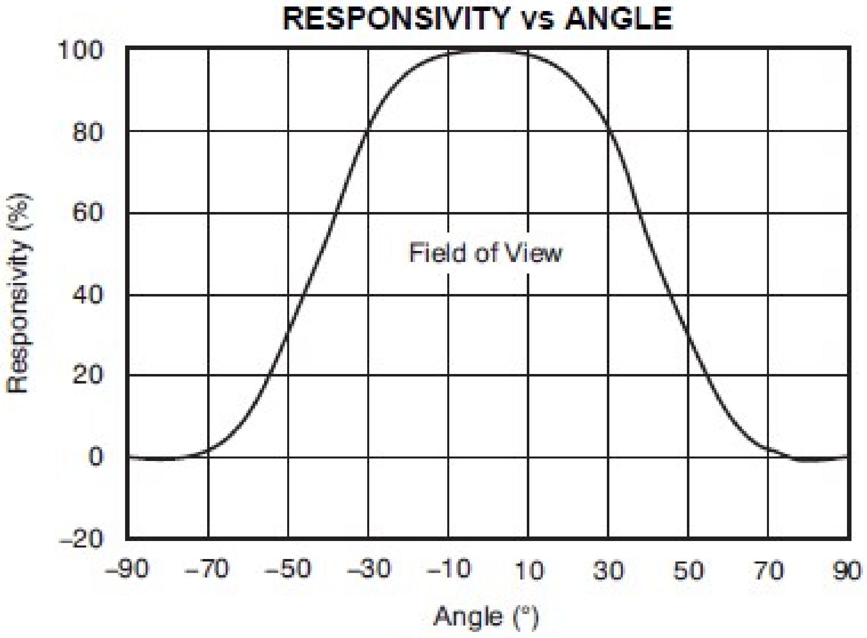
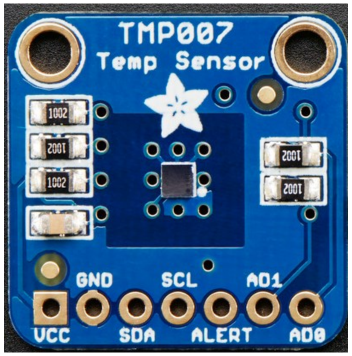
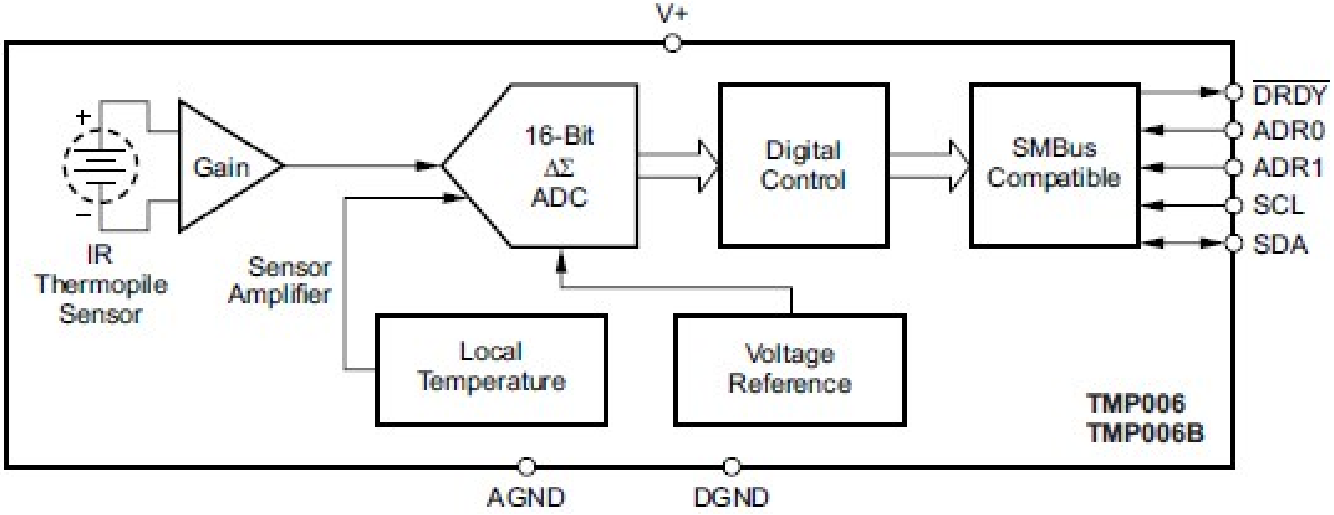
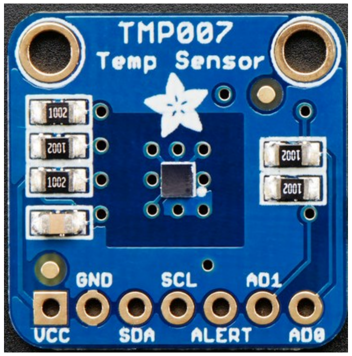


Figure 3.



Infra-red non-contact thermometer sensor





- A thermopile turns heat energy into a voltage
- The on chip A/D generates a number
- There’s a small dedicated micro that allows communication via the I2C bus

I2C data bus

Uses two signal lines

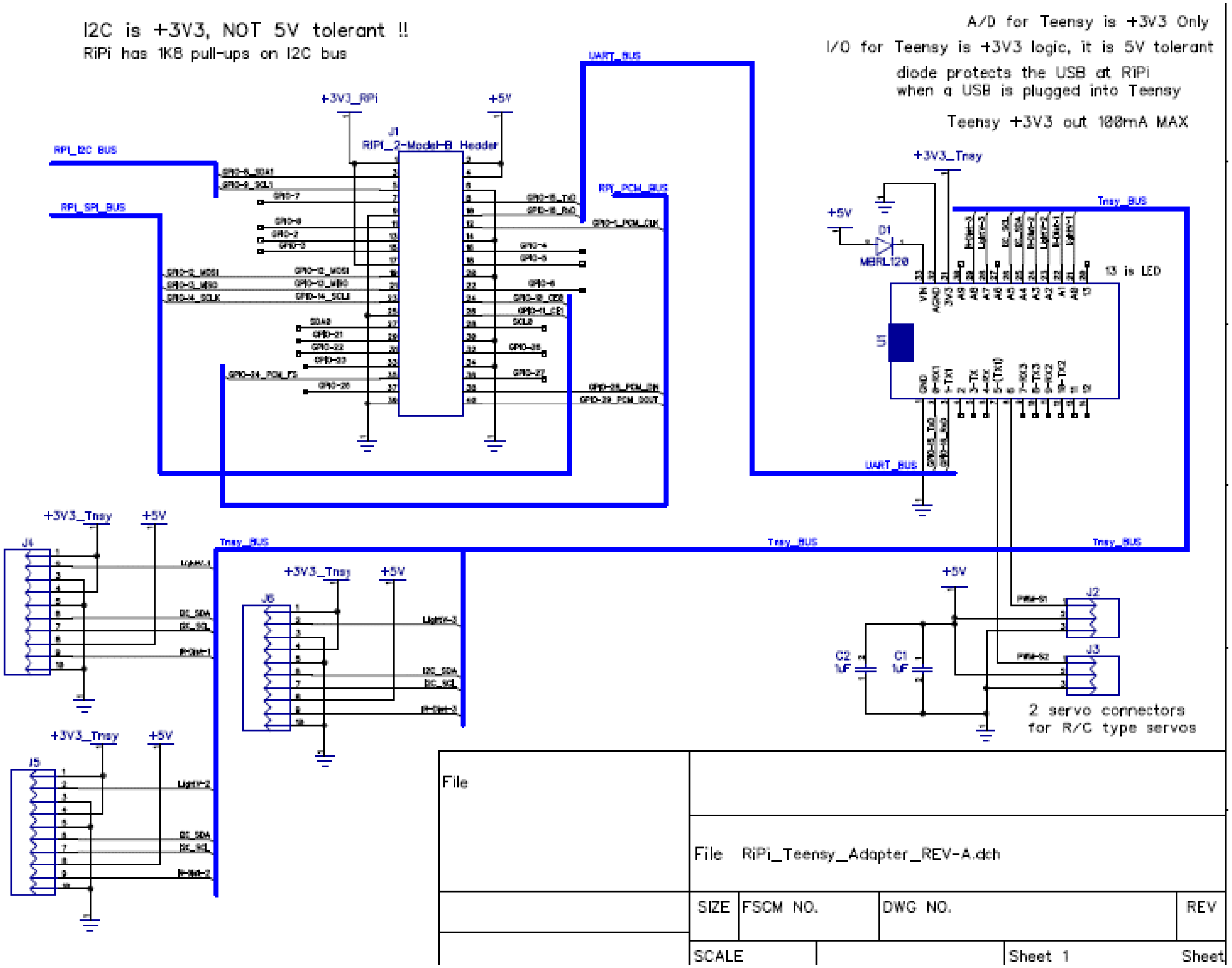
- serial clock, SCL
- serial data, bidirectional, SDA

Can put multiple devices on the same two wires (well, really 3 wires, you need a common ground reference)
Much less wiring than using a separate analog signal pin for every sensor!

Each device needs some software driver; multiple devices on the same bus need unique address

Can be annoying to debug – watch out for too much capacitance on the signal lines !!

Some ‘speed up’ chips are available to run I2C further and faster:
LTC4303 by Linear Technology, for example


I2C is +3V3, NOT 5V tolerant !!

RiPi has 1K8 pull-ups on I2C bus

A/D for Teensy is +3V3 Only

I/O for Teensy is +3V3 logic, it is 5V tolerant

diode protects the USB at RiPi
when q USB is plugged into Teensy

Teensy +3V3 out 100mA MAX

13 is LED

2 servo connectors
for R/C type servos

File

File RiPi_Teensy_Adapter_REV-A.dch

SIZE FSCM NO. DWG NO. REV

SCALE Sheet 1 Sheet

Serial data link, Rpi to Teensy

serial data at logic levels is different from the old RS232 serial data link

Don’t plug any RX, TX from a Rpi to Teensy directly into RS232 ports!!

the old RS232 uses a +/-12V signal level to provide long range data transmission

The Rpi and Teensy like 3.3V signal levels!

Baud rates have to be matched from Rpi to Teensy, or you’ll have no pudding:(

We will be using “software flow control” – so that the two systems can keep the data from getting lost

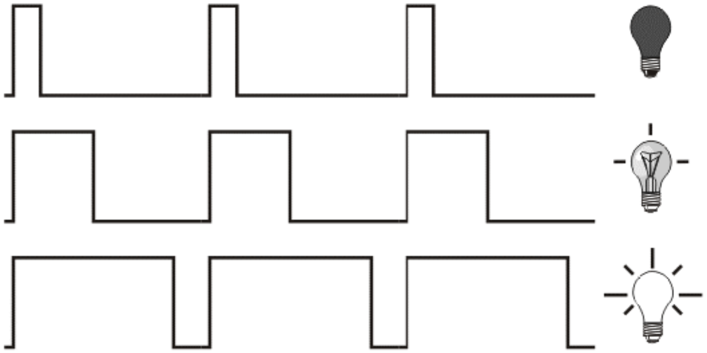
Our serial data link is only between two devices –

it’s not like I2C which can have multiple devices on the same 2 signal wires

Definitions of schematic labels

GPIO – general purpose input output pin; this certainly means a digital logic pin, sometimes can also be configured as an analog voltage input

PWM – pulse width modulation – looks like this:



Digital data – could be any of these:

- a single bit value at a single I/O pin (a H or L),
- a stream of digital data on the serial line,
- the data value at the output of an A/D converter
- a number in the look-up table to correct nasty curve of the distance sensor