Workshop on building a

Near-Field Intra-Body Communication Personal Area Network (PAN) Device

Based on a paper by: Thomas Guthrie Zimmerman

(Massachusetts Institute of Technology February 1980)

(Ingo Randolf - e-textile springbreak – 2018)

http://etextilespringbreak.org

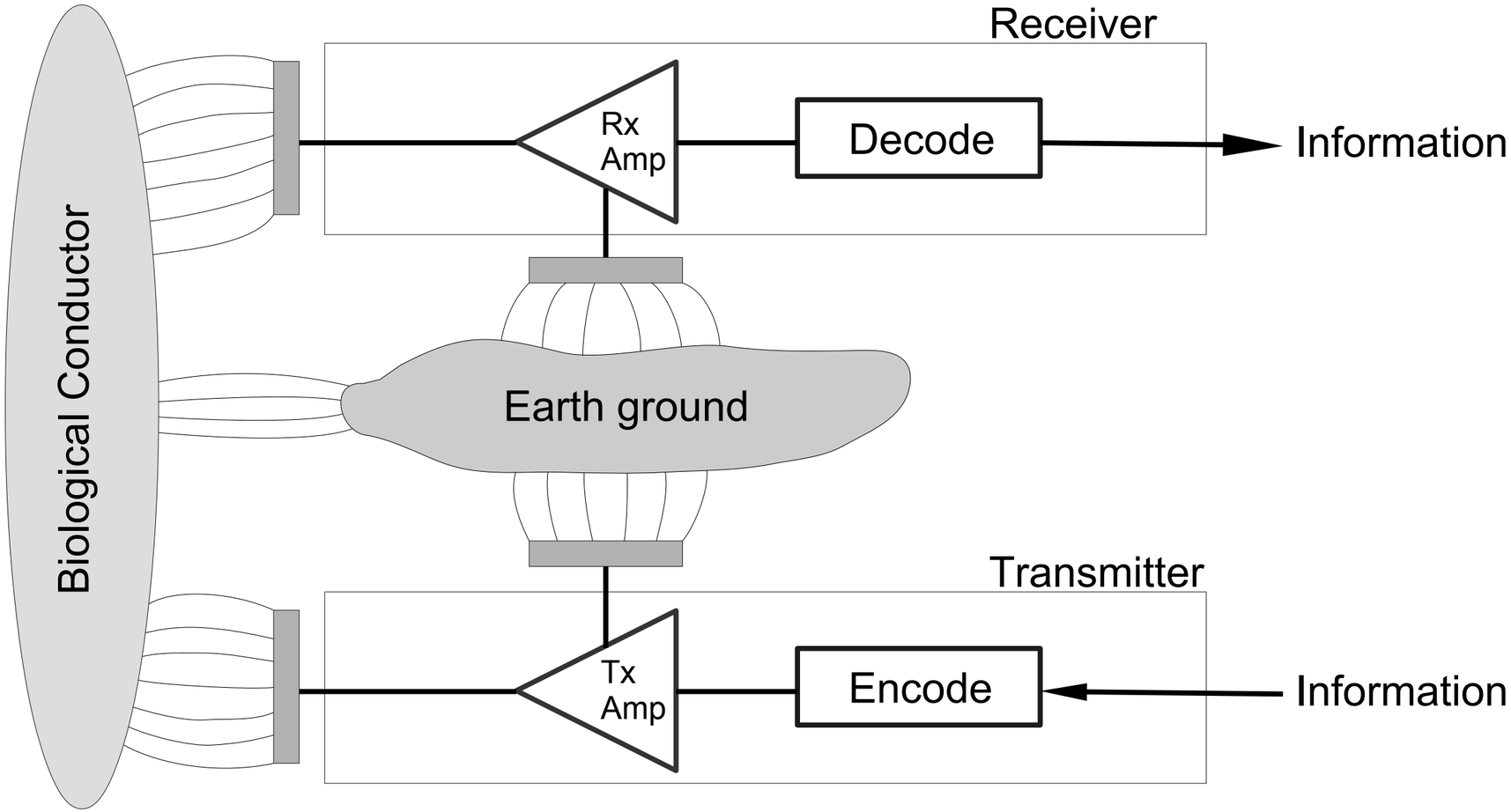
PAN – basic idea

- Use capacitive coupling to transmit data
- Use a body as communication channel
- Human body – a perfect conductor
  - internal resistance: ~250 Ohm / meter
  - Isolated with skin in order megaohms to gigaohms
  - Internal impedance can be considered negligible

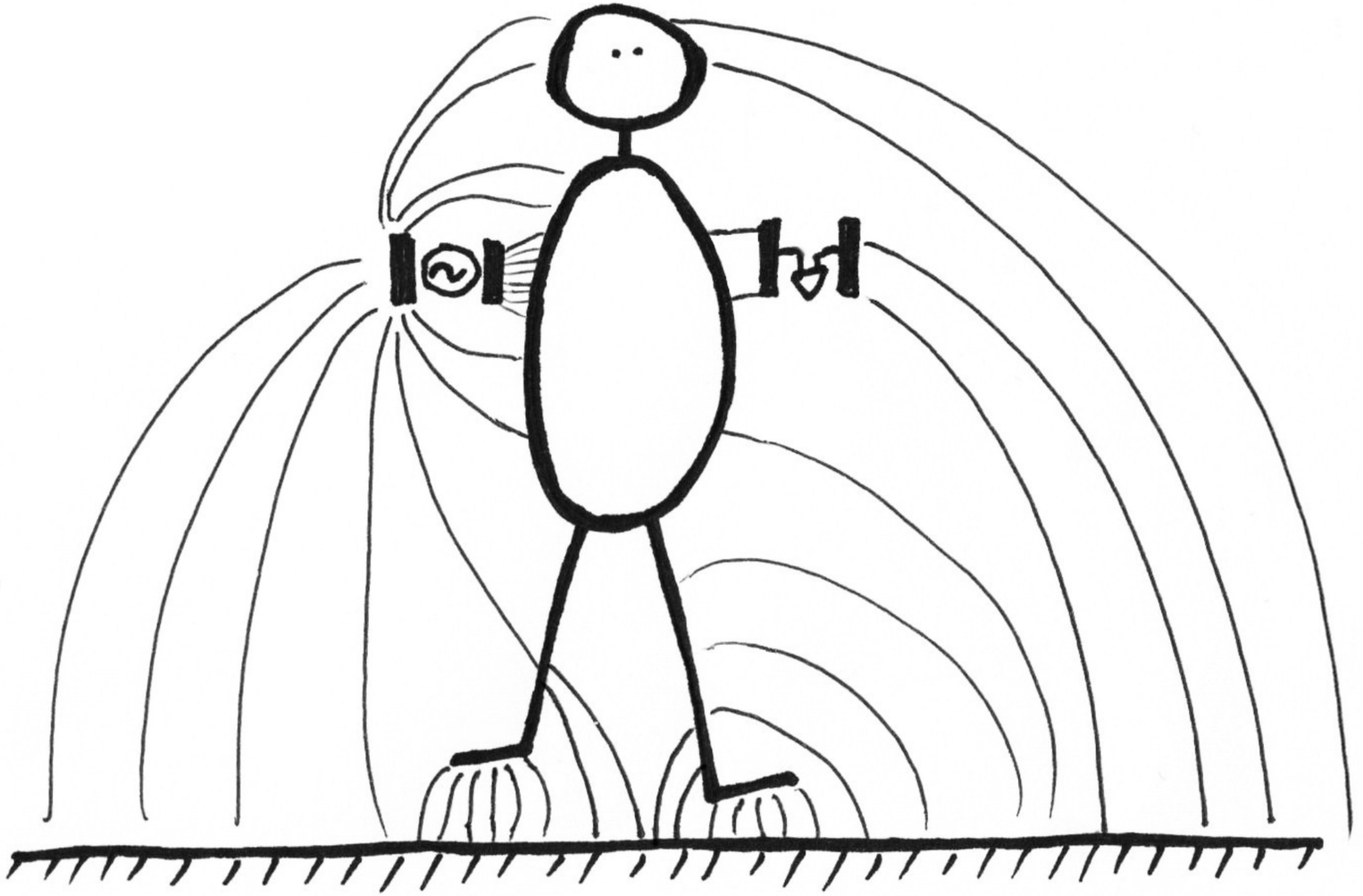
PAN – basic idea

- In general terms a PAN transmitter perturbs the electrical potential of the environment and the receiver detects these perturbations. Another way to state the communication mechanism is to say the transmitter is capacitively coupled to the receiver.
- The current return path is provided by the air (dielectric) and earth ground (dielectric and conductor)

PAN – basic idea

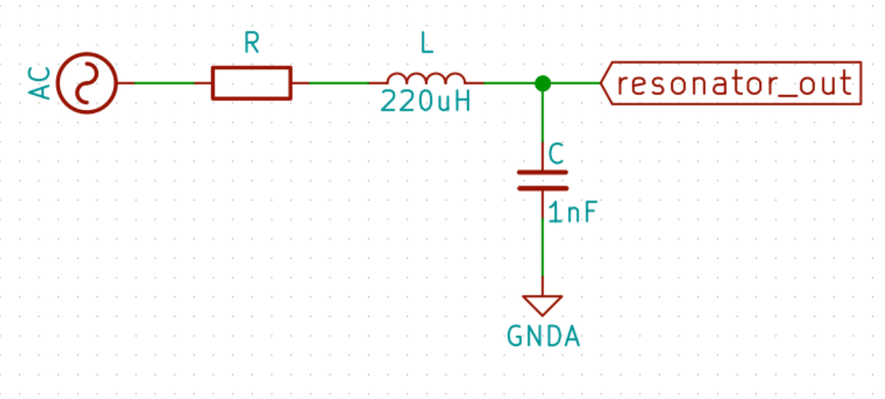


PAN Electric Field



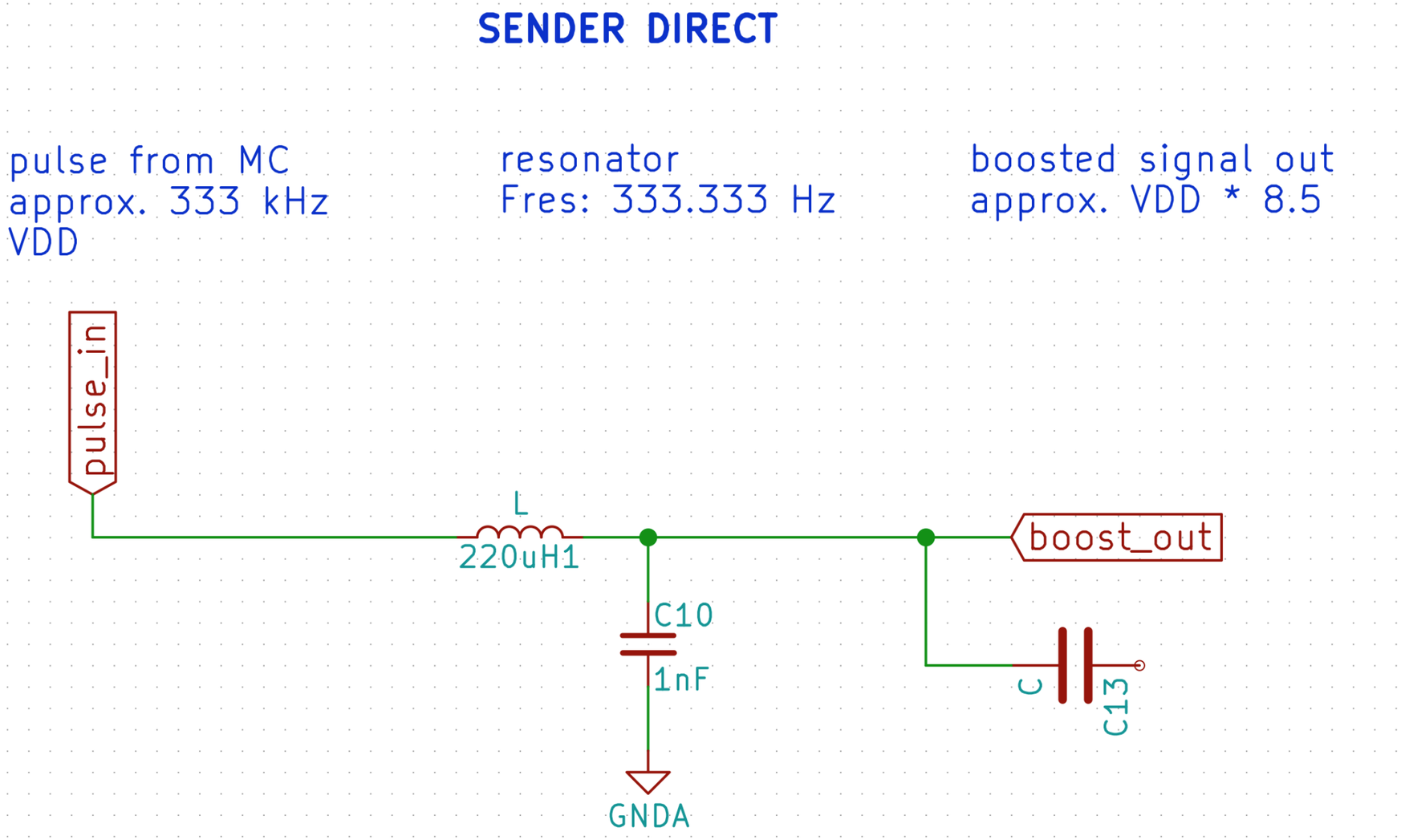
PAN Transmitter

- Electrode driven by oscillating voltage (e.g. Square wave)
- Resonant Transmitter
  - LC Tank (Coil + Capacitor) stores energy in electric and magnetic field oscillating
  - Resonance frequency: $$fr = \frac{1}{(2 * \pi * \sqrt{L * C})}$$
    - e.g.:
    - L: 220uH, C: 1nF → fr = 339,32 kHz



- Resonator Q
  - The "quality factor" Q, is a measure the selectivity of the r
  - $$Q = \frac{2 * \pi * F * L}{R}$$
  - For a given frequency Q depends on the inductor L
- Data-rate: ~5000 bit / sec

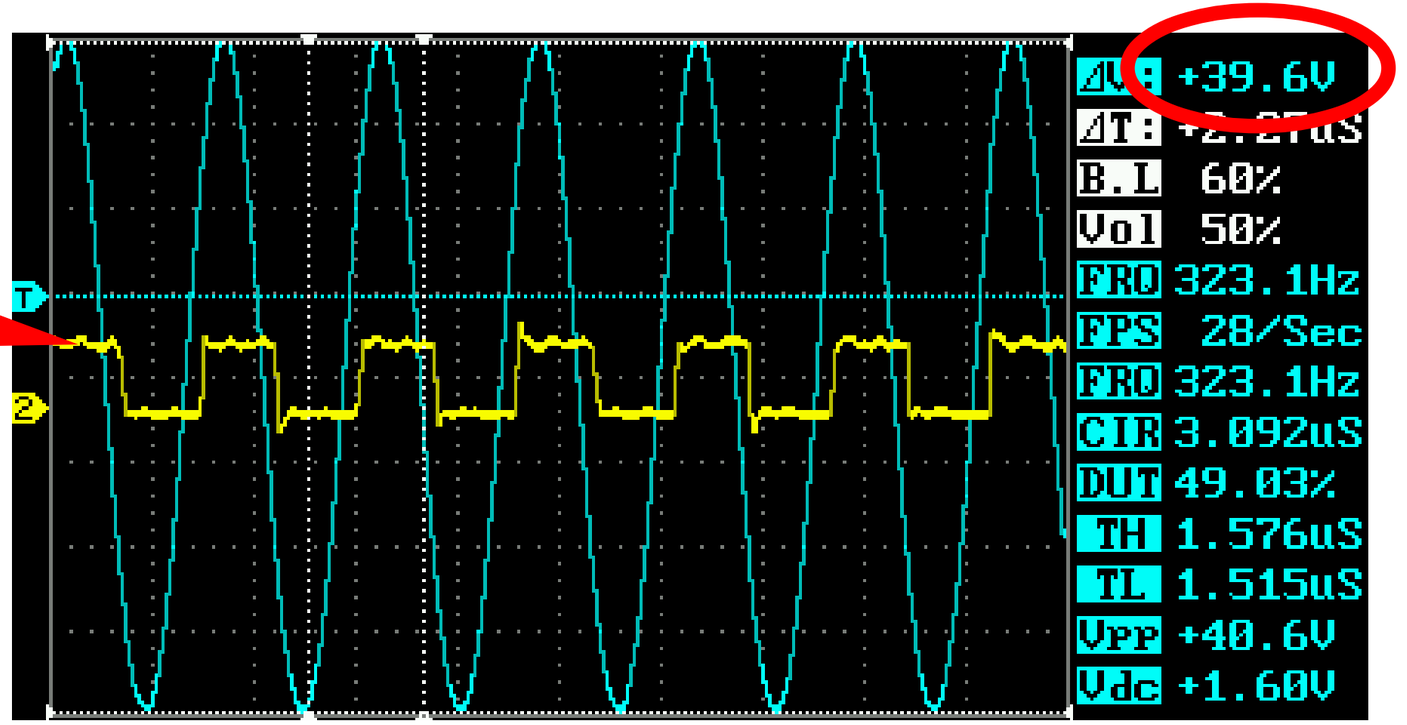
PAN Transmitter - Resonator



PAN Transmitter - Resonator

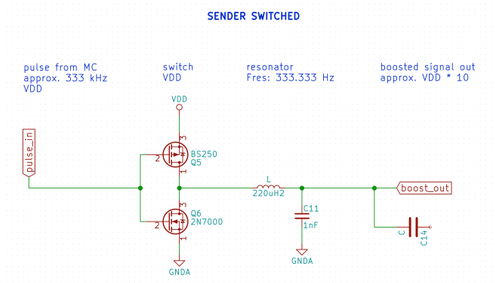
Drive oscillator circuit with a square-wave

Output: 39.6 V



Input: 3.7 V

(transistor switched for cleaner input waveform)

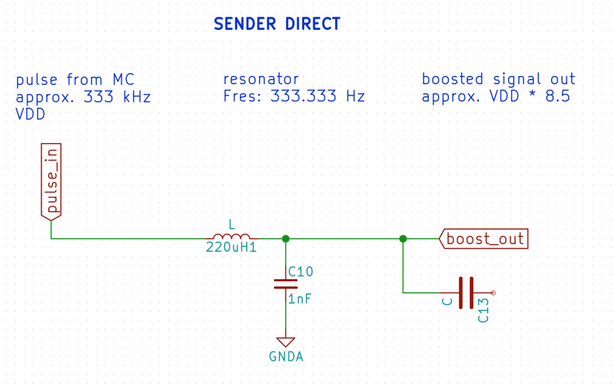


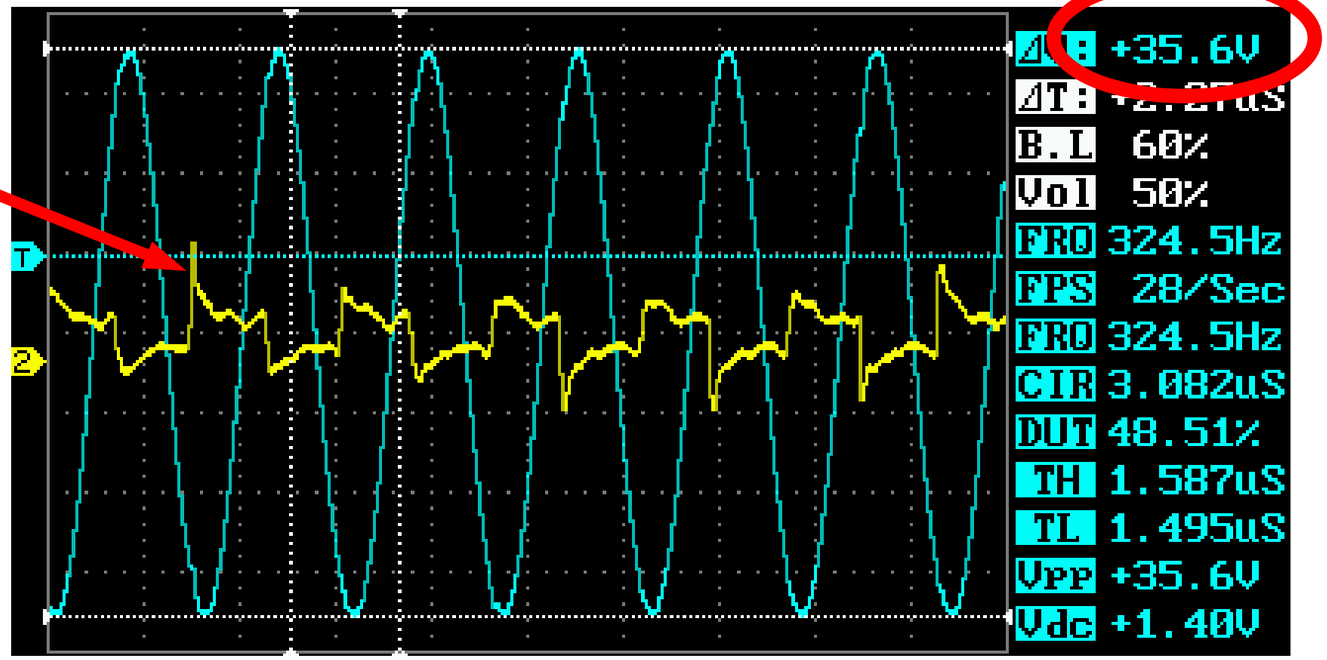
PAN Transmitter - Resonator

Output: 35.6 V

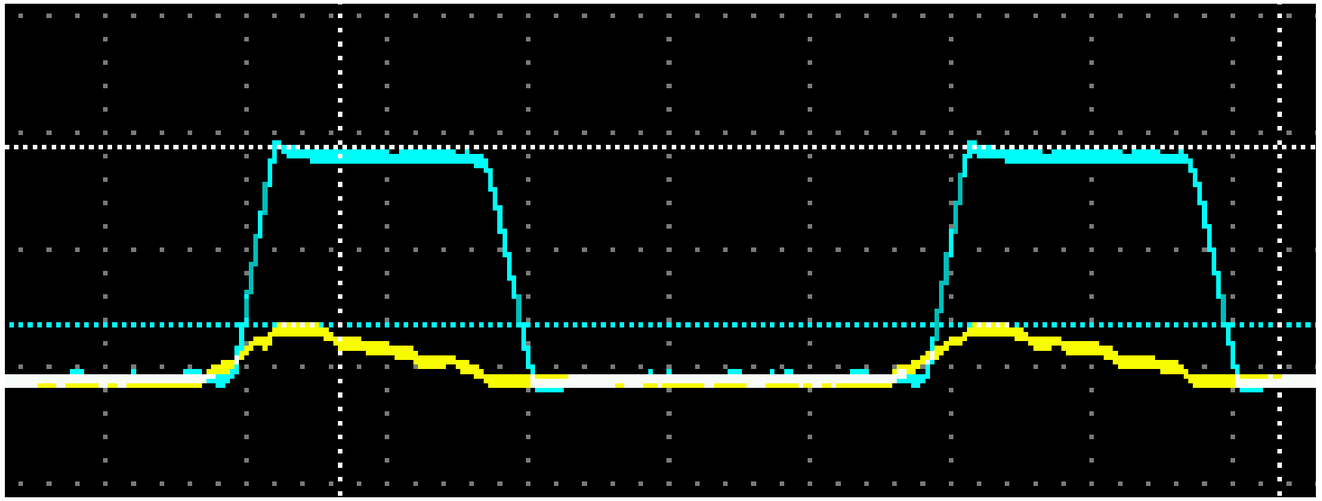
Directly from MC output:
deformed square wave

(This is what we expect)



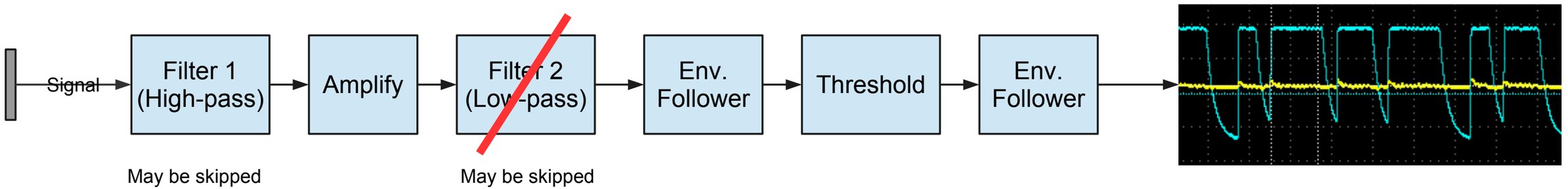


PAN Receiver



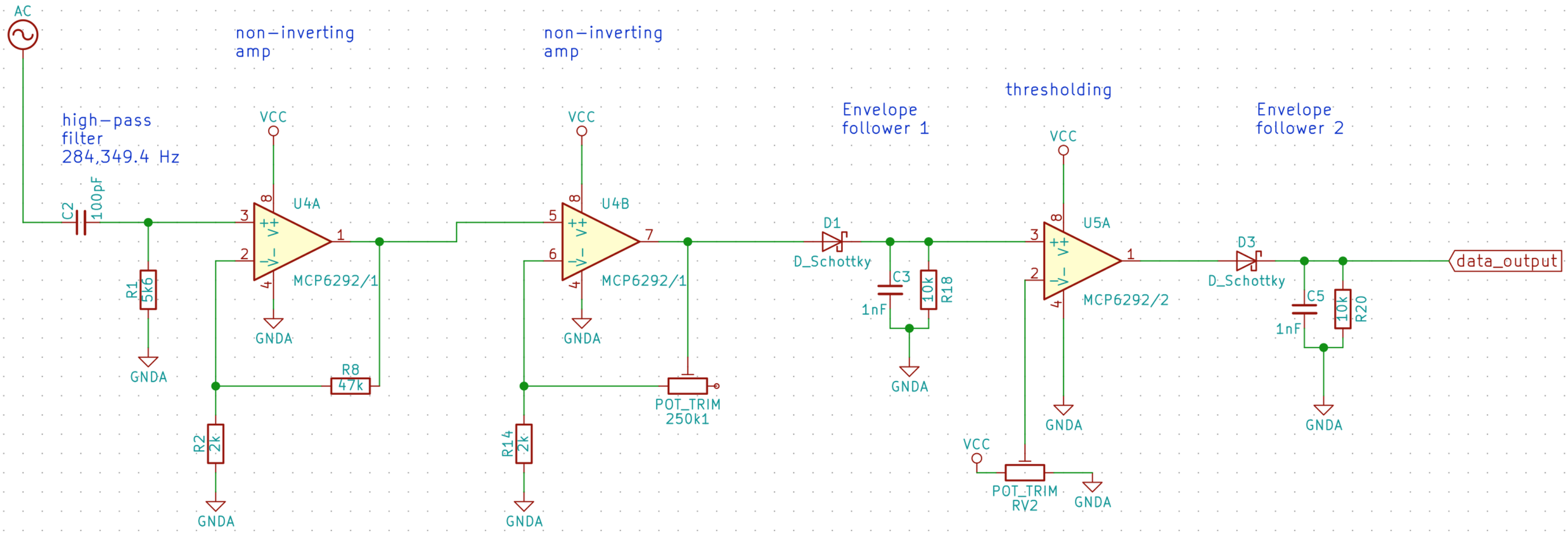
PAN Receiver

- Filter, amplify and threshold signal

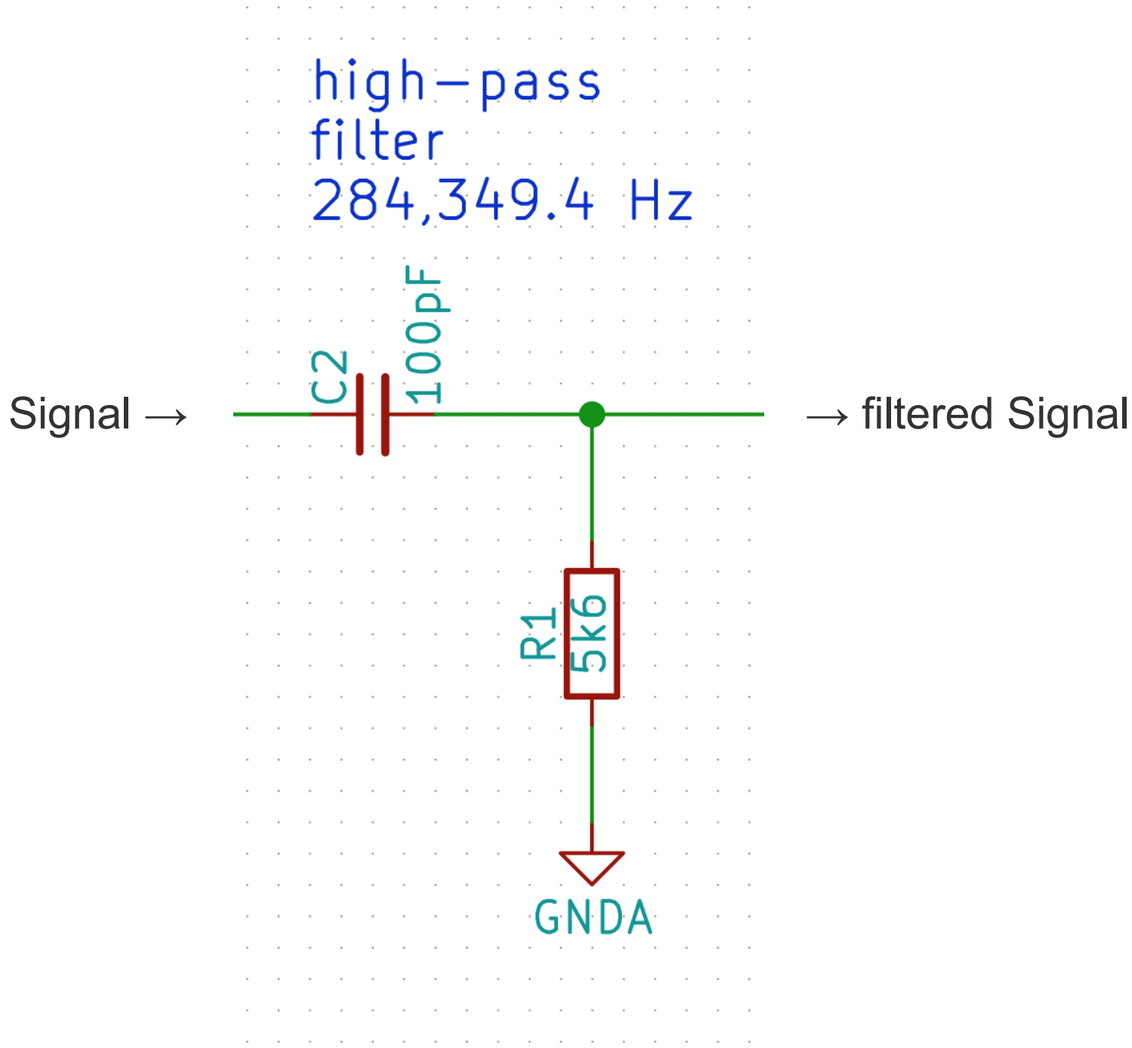


- Read amplified signal and decode (micro-controller)
- Process information

PAN Receiver



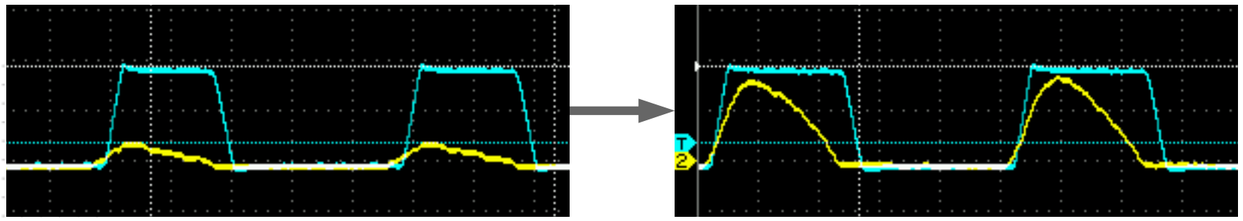
PAN Receiver



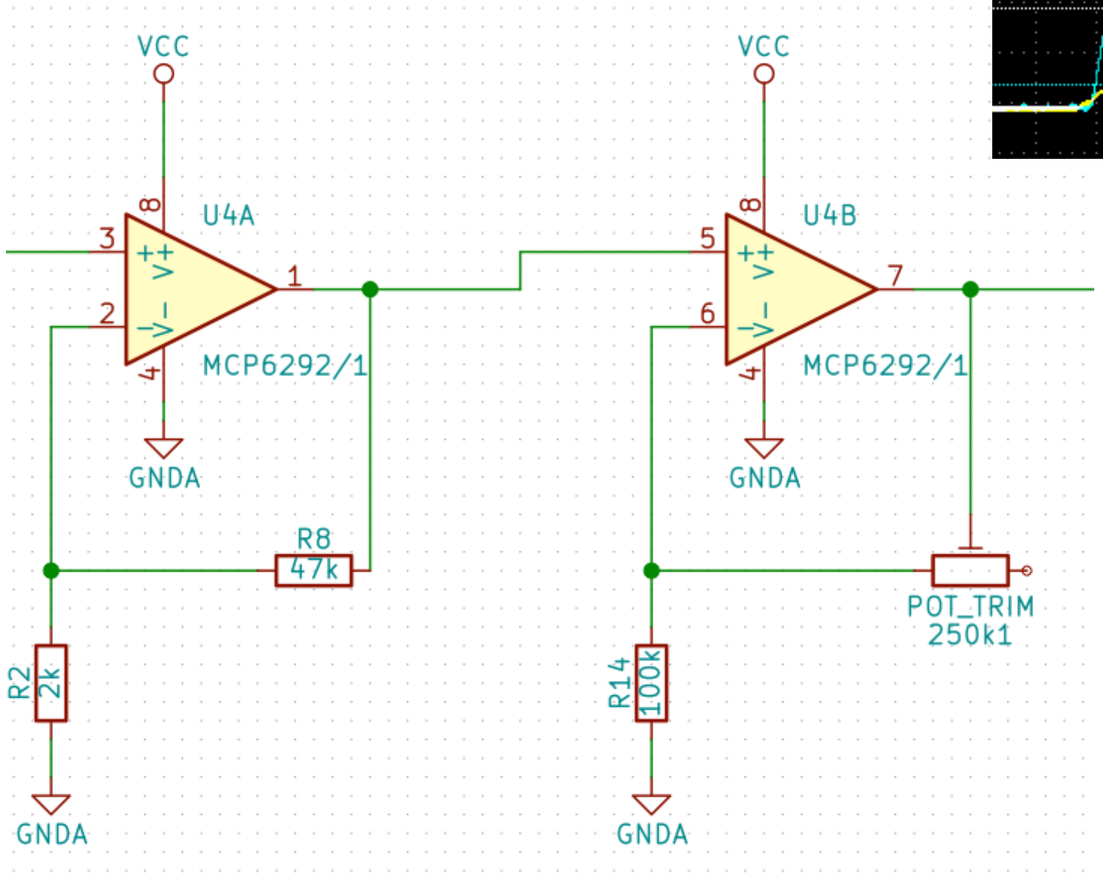
PAN Receiver

fixed gain of 23,5

variable gain



Filtered Signal →

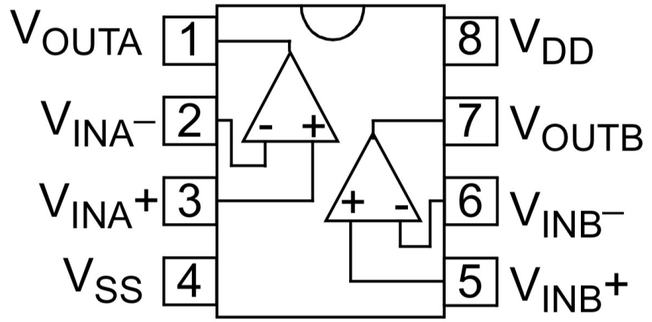


→ amplified Signal

MCP6292
Rail-to-Rail, Single-supply op-amp
(max gain for 333kHz: 30)

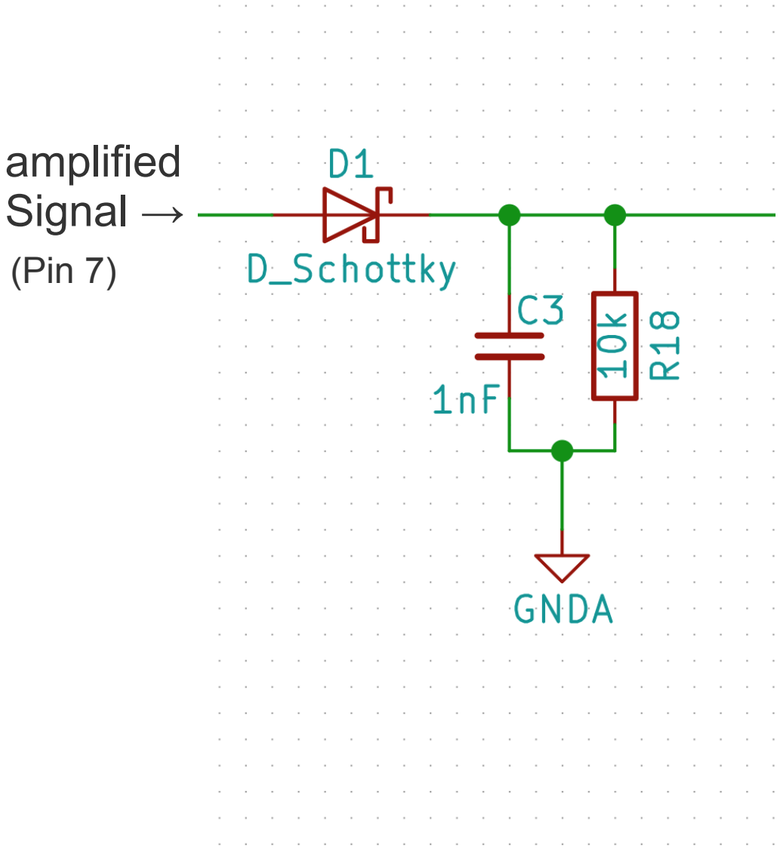
MCP6292

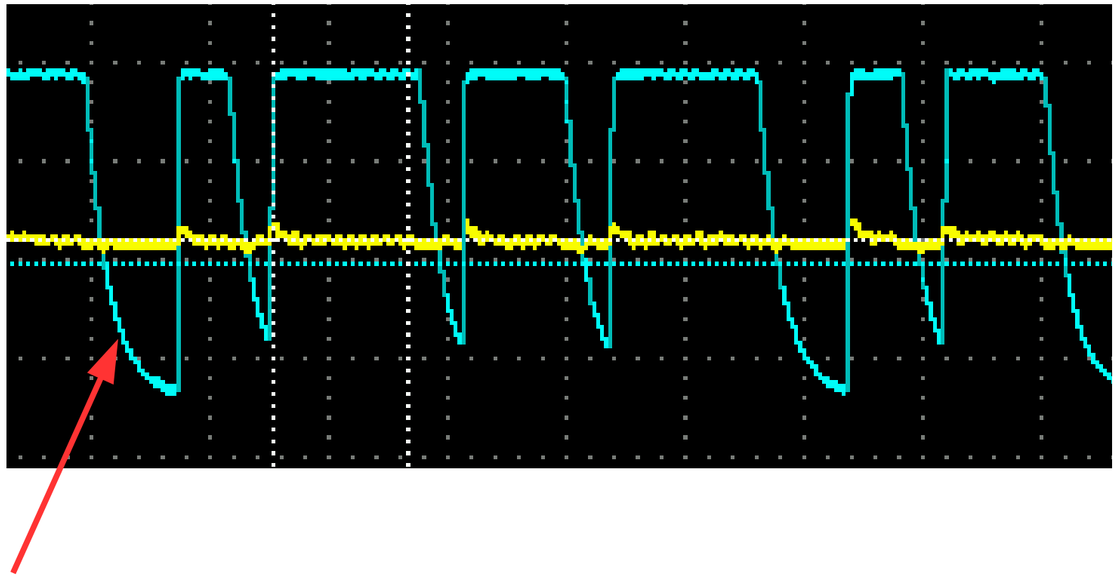
PDIP, SOIC, MSOP



PAN Receiver

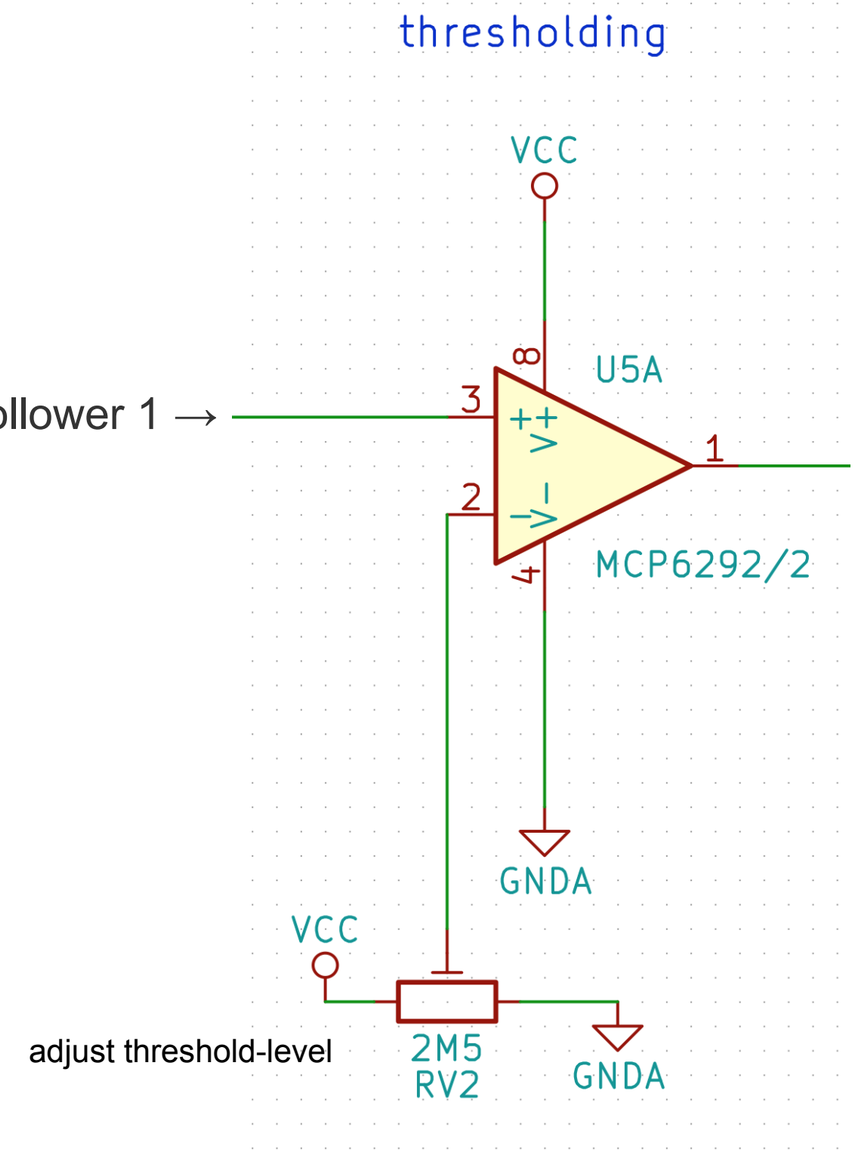
Envelope Follower 1





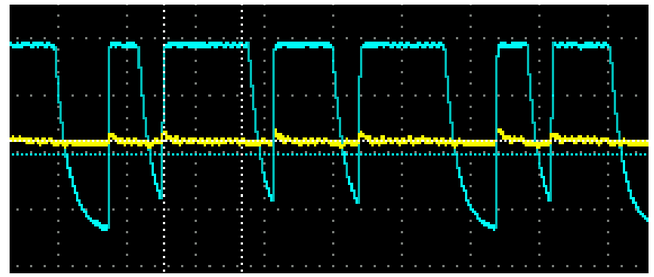
Follow envelope to smooth the signal

PAN Receiver

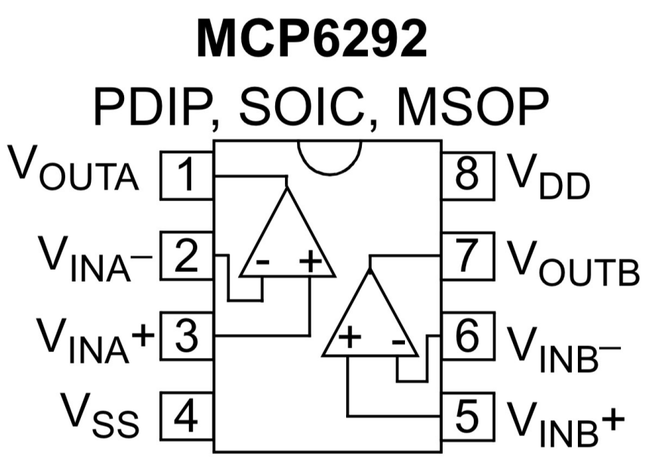


From
envelope follower 1 →

→ thresholded signal

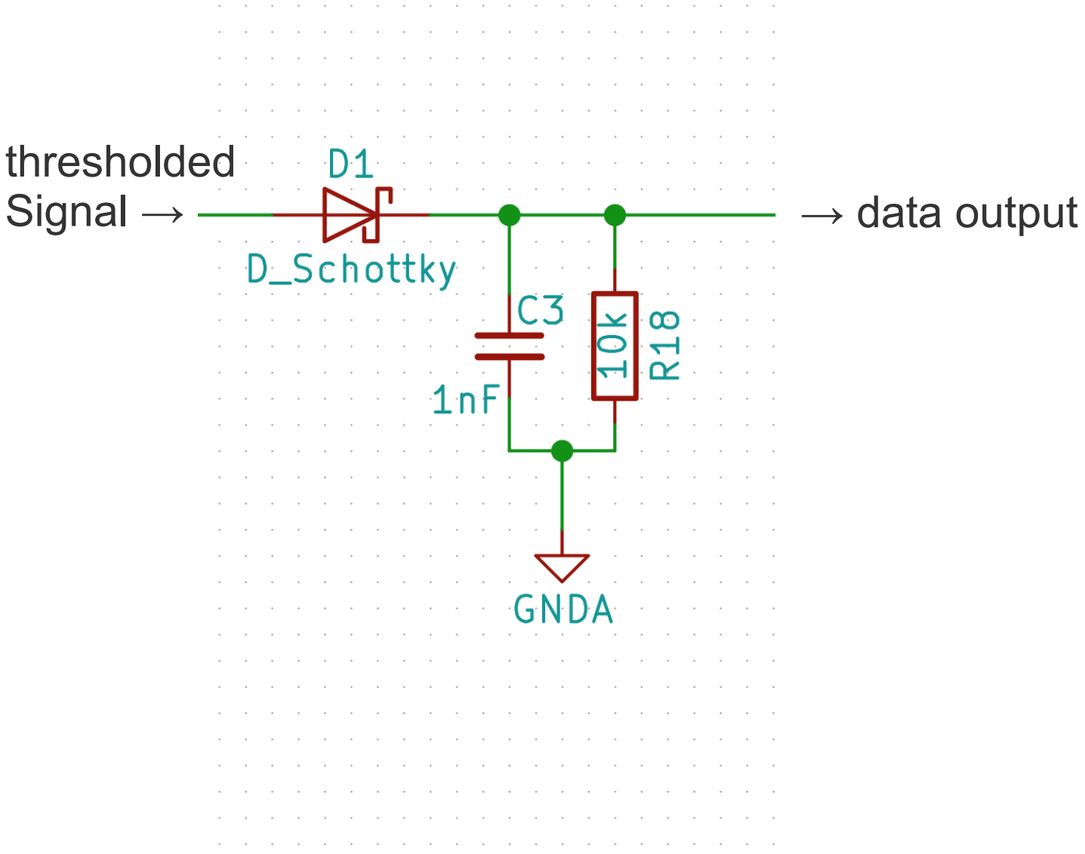


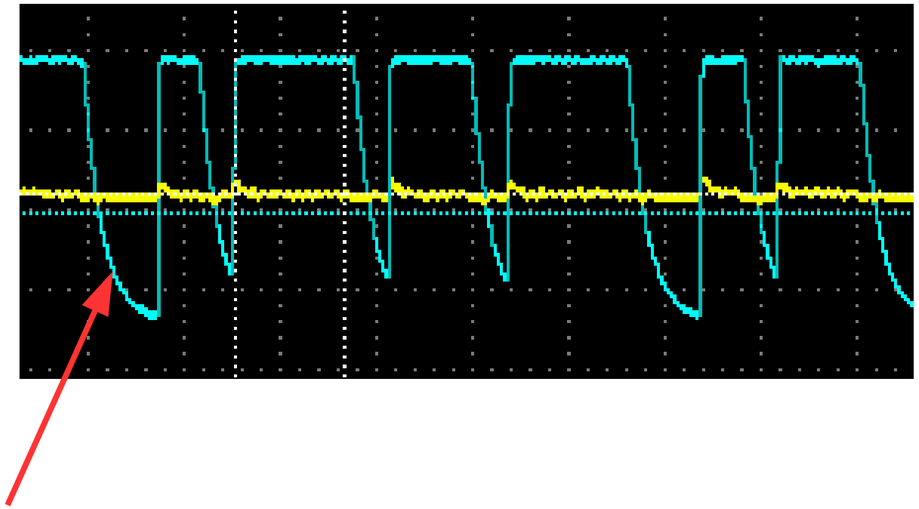
MCP6292
Rail-to-Rail, Single-supply op-amp



PAN Receiver

Envelope Follower 2





Follow envelope to smooth the signal

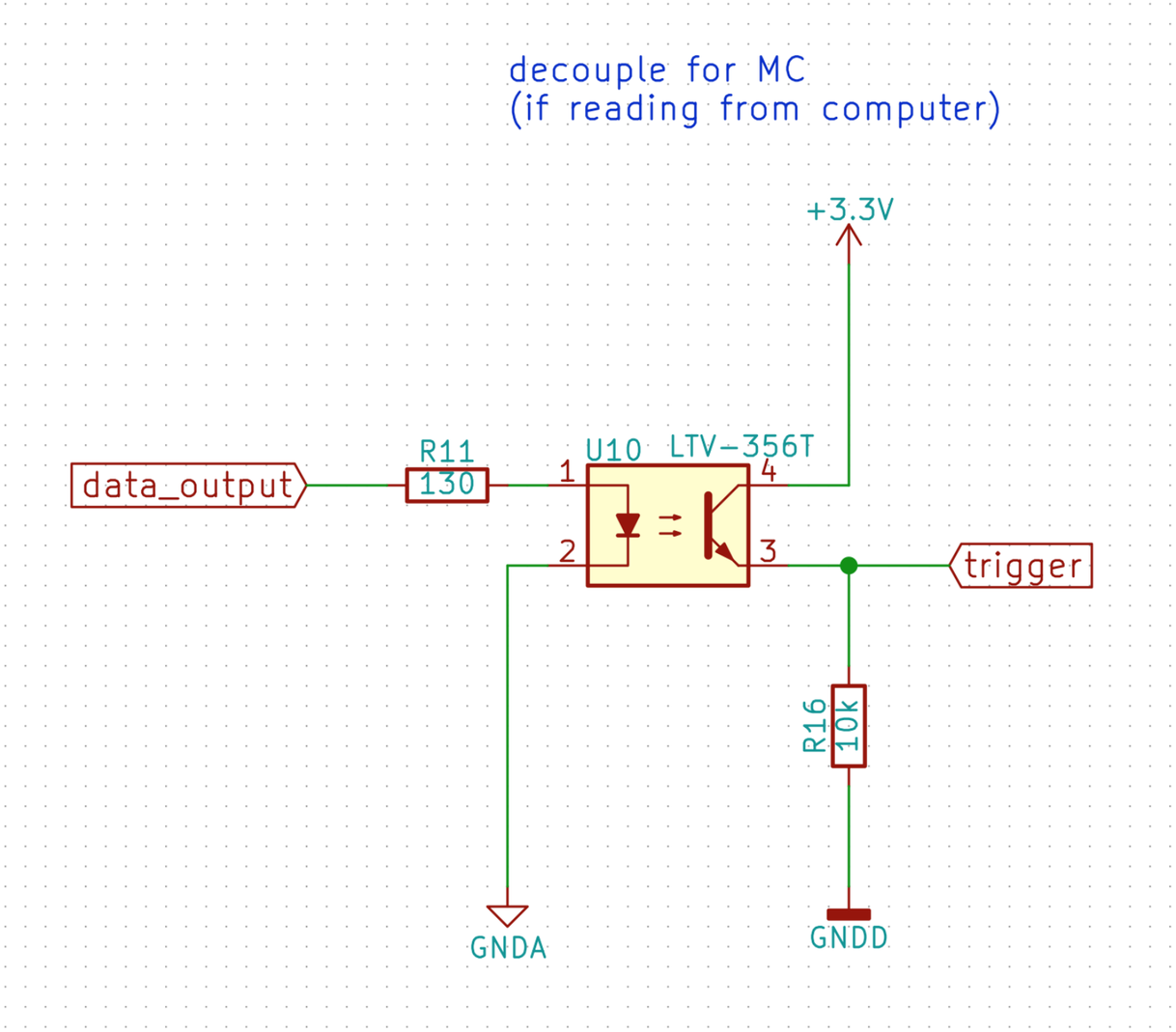
PAN Receiver - reader

Connecting data output to a device may change the earth-ground coupling of the circuit.

e.g.: reading data-output with an Arduino connected via USB to a computer adds a big capacitive-plate to the circuit. If the computer is connected to earth-ground (connected charger) the circuit directly grounds to earth and therefore changes its behavior (usually it becomes more sensitive)

The optocoupler may be skipped when reading data-output directly with a micro-controller (e.g. Attiny) with no other device connected.

In any way, decoupling the receiver circuit i a good idea.
(take care if you measure the circuit to use the correct ground)



PAN Encoding

- Data is encoded using OOK – On-Off-Keying
  - Logic 1: signal on
  - Logic 0: signal off
- Timings
  - 200 us / bit (~66 carrier cycles)
  - Allows ~5000 bit / sec
- 8-bit Preamble
  - 10101010
- Serial protocol
  - RS232 like
  - 8 data-bits
  - 1 parity-bit
  - 1 stop-bit

PAN Decoding

- Detect rising-edge (logic 1-bit)
- Start a timer for next expected bit in 200us (use a small offset)
- Listen for preamble
  - If preamble was received switch to data-receive-mode
- Bit-Banging: Push bit into one byte until we received 8-bit
- Deliver the byte
- Stop receive if error detected
- We may want to use Manchester encoding

Links

- Original Paper:
  - http://www.cba.mit.edu/docs/theses/95.09.zimmerman.pdf
- Resonance Circuit
  - http://hyperphysics.phy-astr.gsu.edu/hbase/electric/serres.html
  - http://www.1728.org/resfreq.htm
- Op-Amp:
  - https://www.scribd.com/document/68027370/Op-Amp-Experiment
- AM-Diode Detector:
  - http://www.radio-electronics.com/info/rf-technology-design/am-reception/diode-detector-demodulator.php
- High/Low-Pass Filter:
  - http://www.learningaboutelectronics.com/Articles/High-pass-filter-calculator.php
  - http://www.learningaboutelectronics.com/Articles/Low-pass-filter-calculator.php#answer1
- Other
  - www.ijcse.com/docs/INDJCSE12-03-05-072.pdf
  - https://www.scribd.com/presentation/313629677/Intrabody-communication-using-human-area-networking