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 1995)

(Ingo Randolf – etextile-springbreak, etextile-summercamp – 2018)

http://etextilespringbreak.org
http://etextile-summercamp.org/

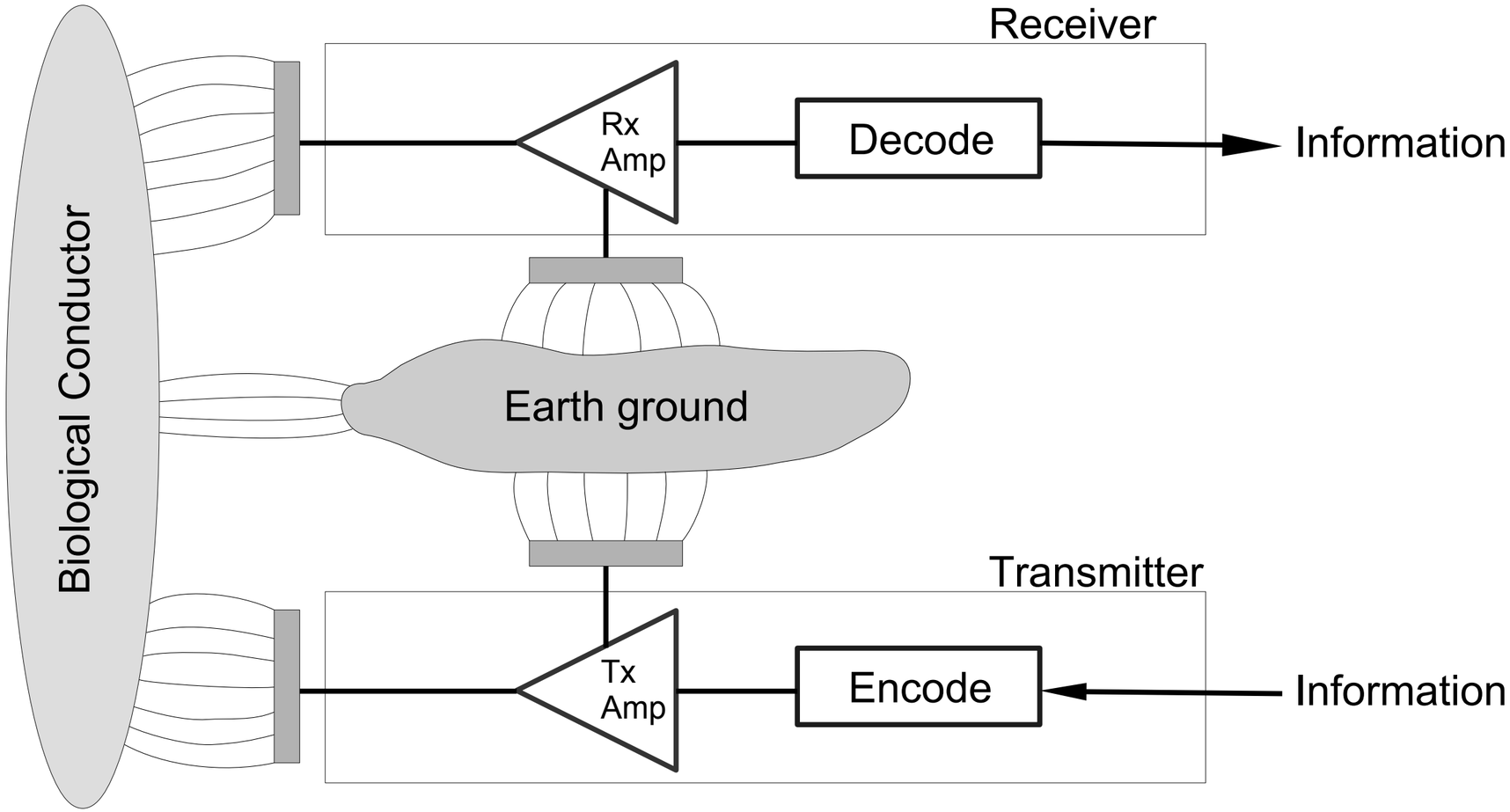
PAN – basic idea

- Use capacitive coupling to transmit data
- Use a biological-conductor as communication channel
  - Human Body
  - A plant (tree)
- Human body – a perfect conductor
  - internal resistance: ~250 Ohm / meter
  - Isolated with skin in order mega- to giga-ohms
  - Internal impedance can be considered negligible

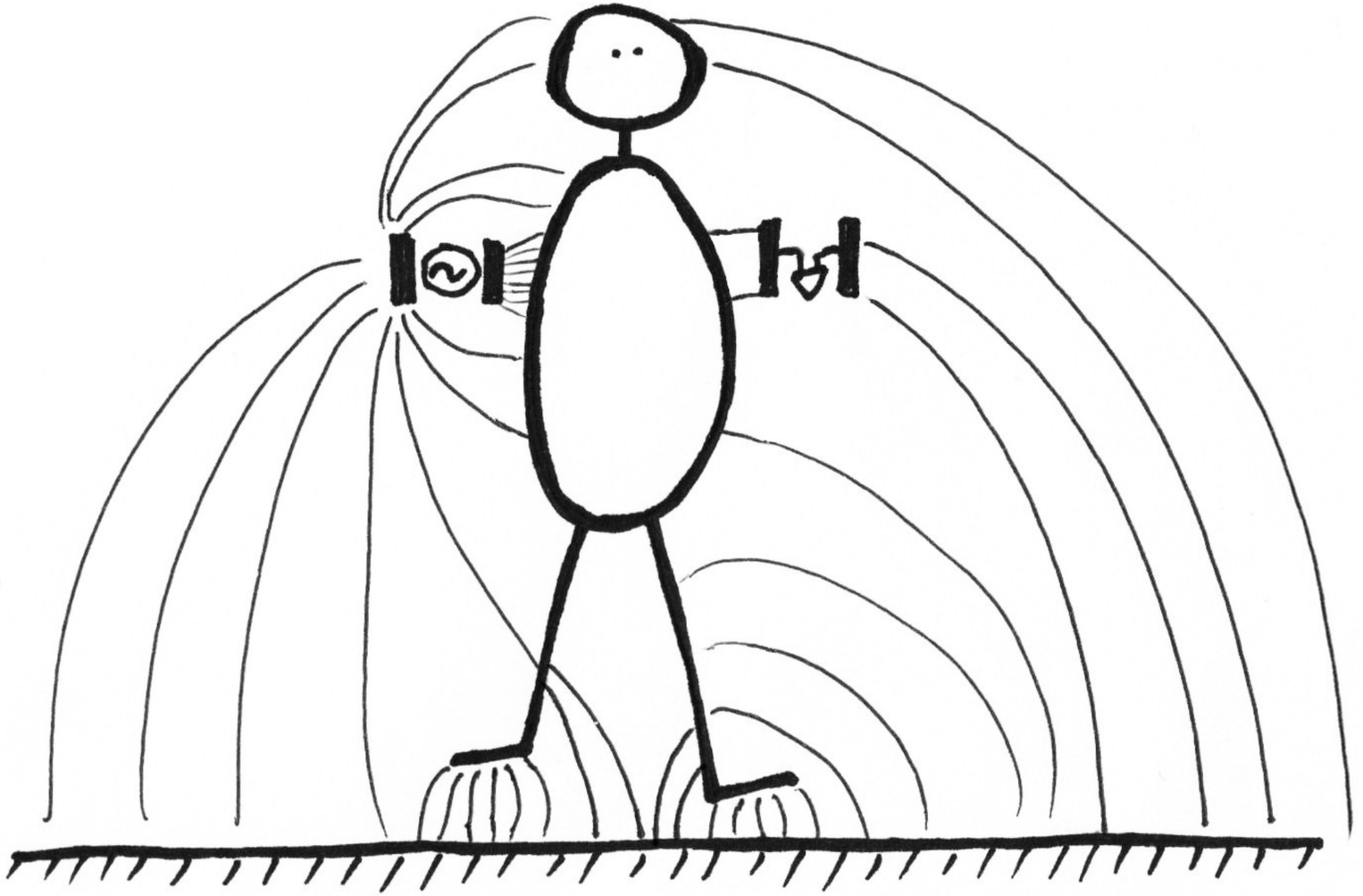
PAN – basic idea

- 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

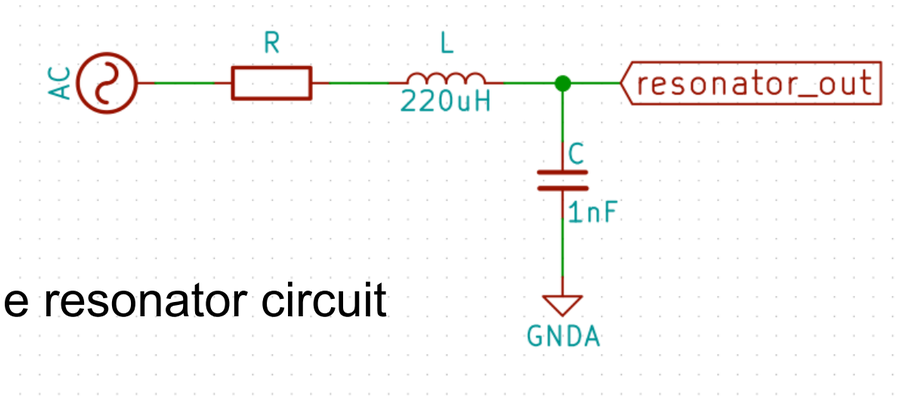


PAN Electric Field



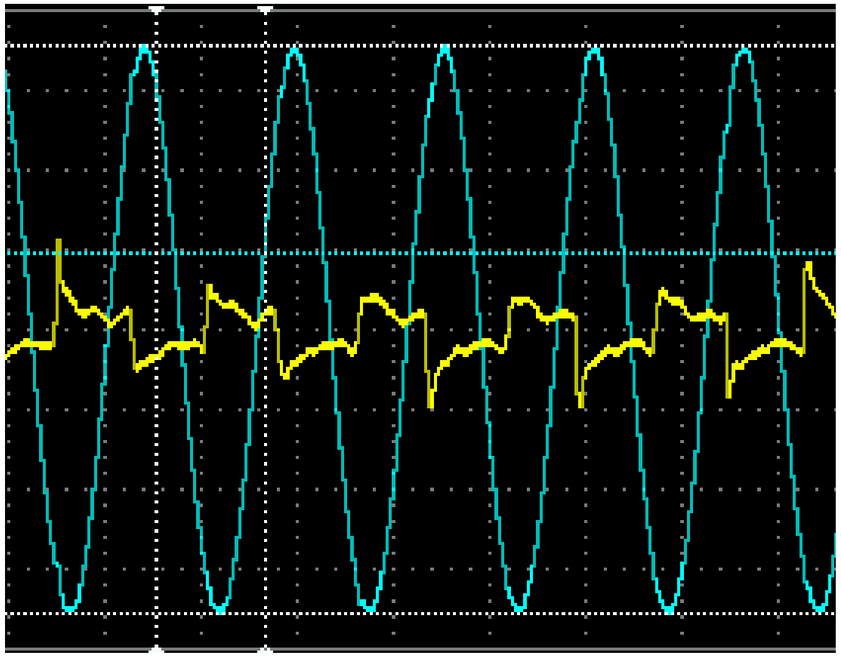
PAN Transmitter

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

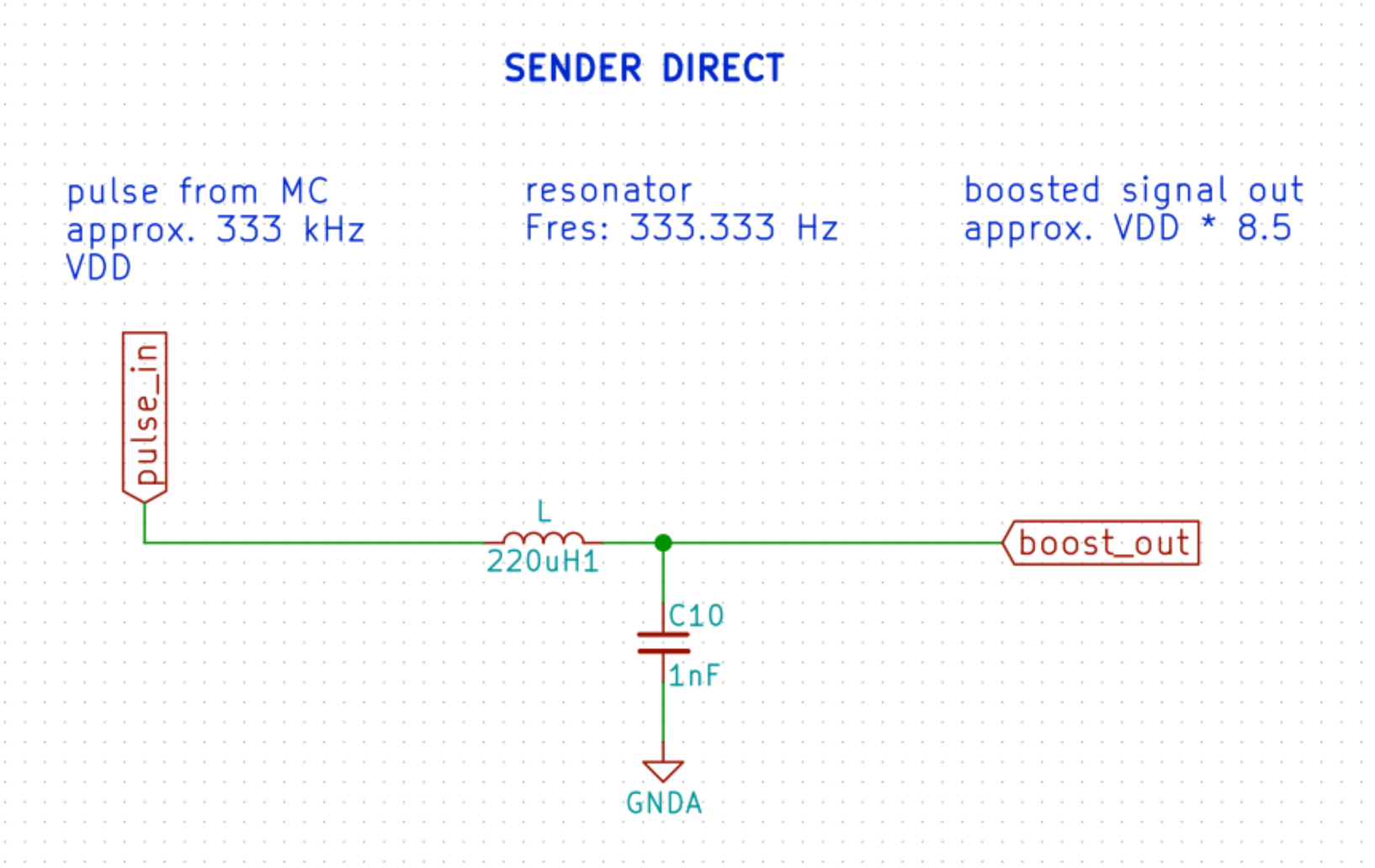


- Resonator Q
  - The "quality factor" Q, is a measure to the selectivity of the resonator circuit
  - $$Q = \frac{2 * \pi * F * L}{R}$$
  - For a given frequency, Q depends on the inductor L (inductance, coil) and R (resistance)
- Data-rate: ~5000 bit / sec

PAN Transmitter



PAN Transmitter - Resonator

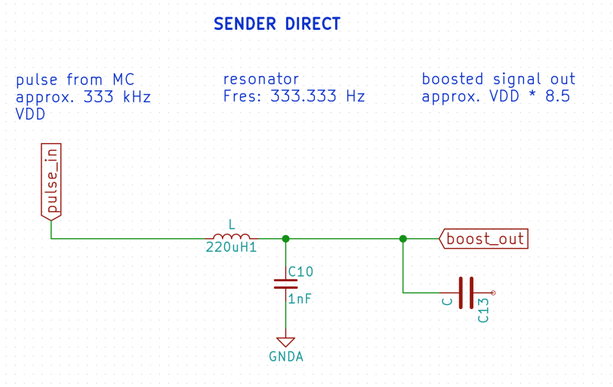


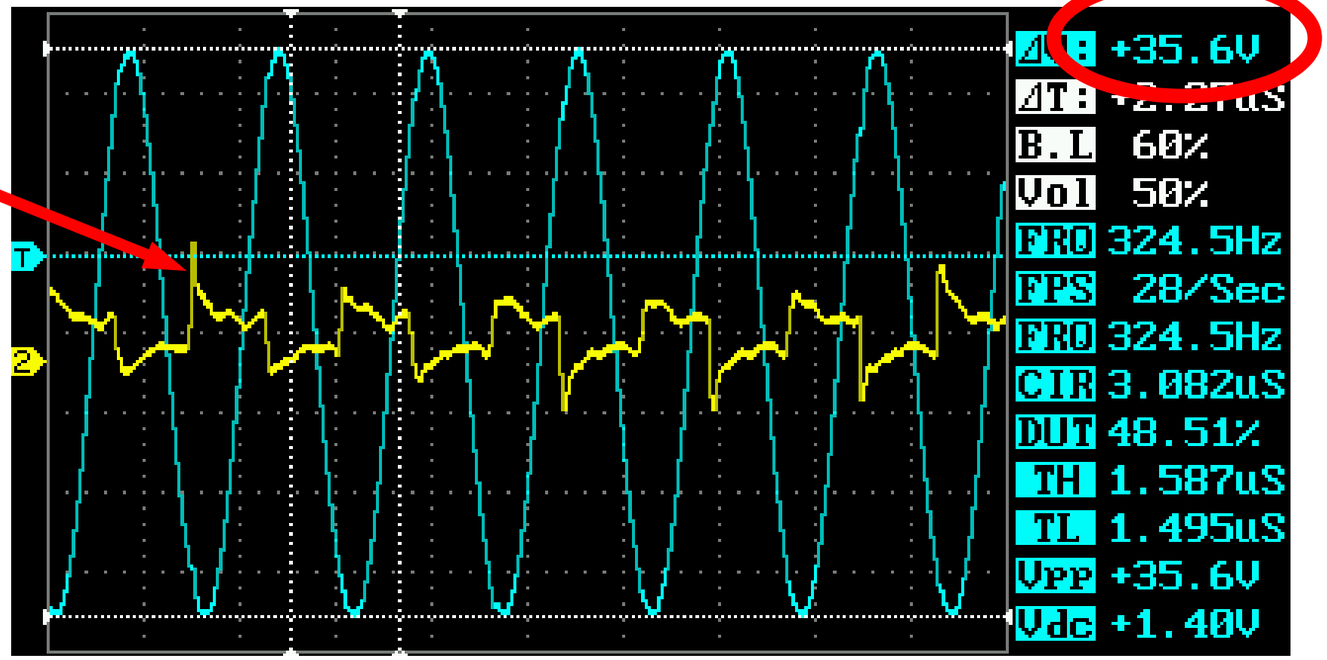
PAN Transmitter - Resonator

Output: 35.6 V

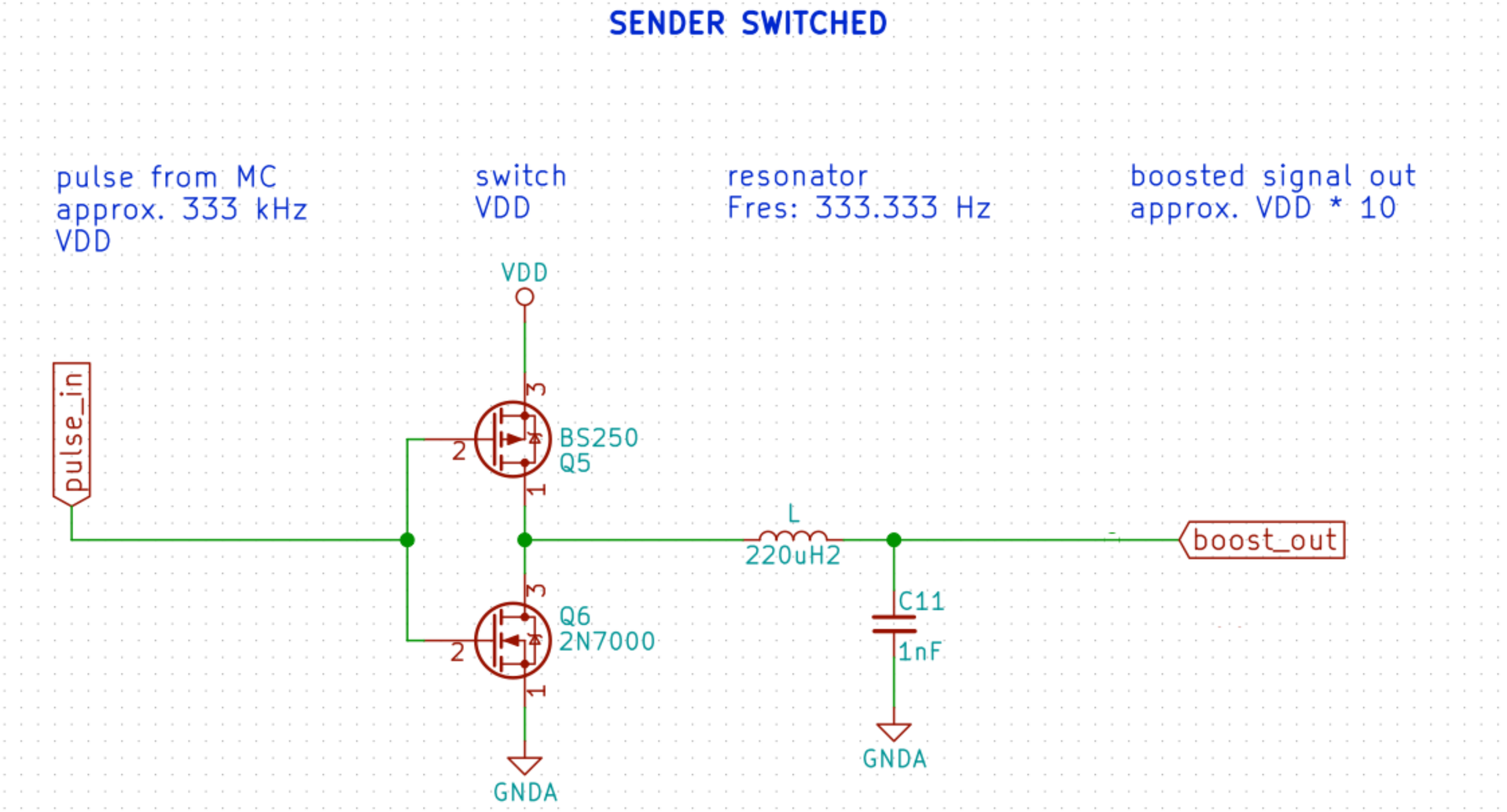
Directly from MC output:
deformed square wave

(This is what we expect)





PAN Transmitter – Resonator Switched



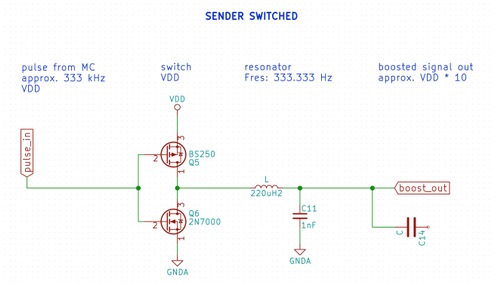
PAN Transmitter – Resonator Switched

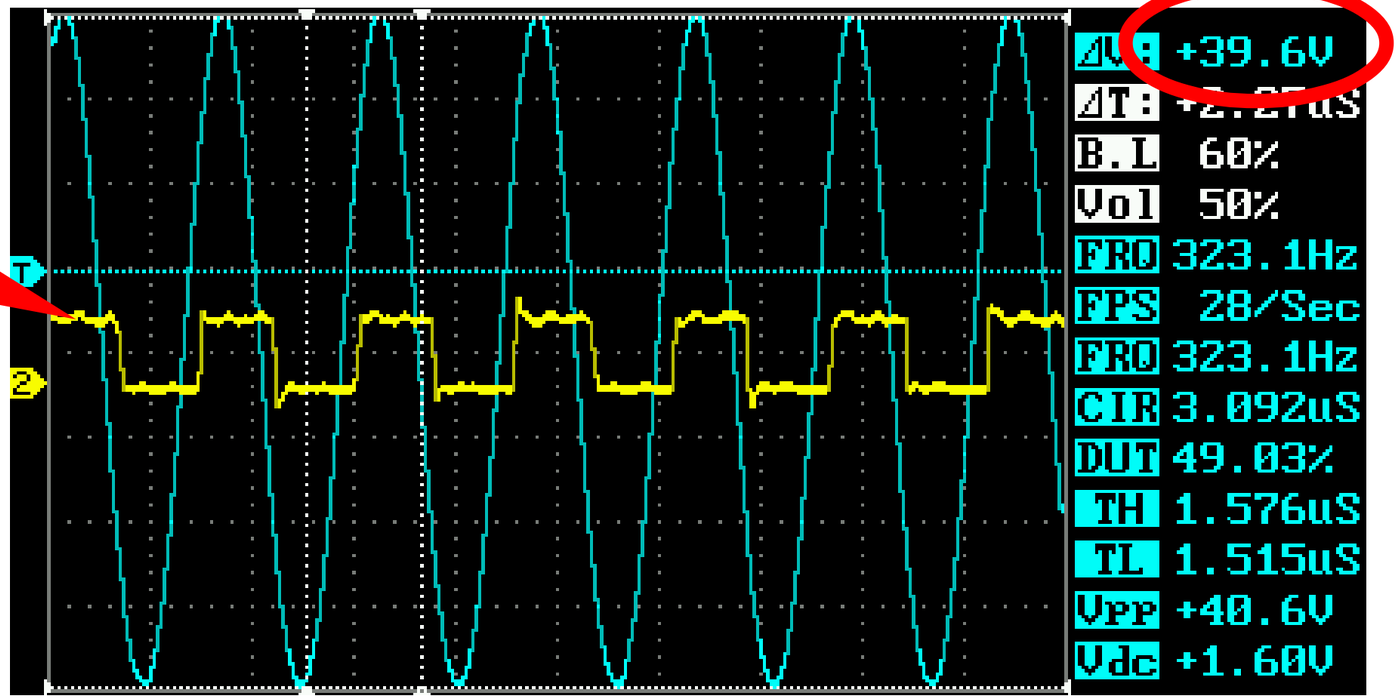
Drive oscillator circuit with a cleaner square-wave to protect the wave-generator and get better amplification

Output: 39.6 V

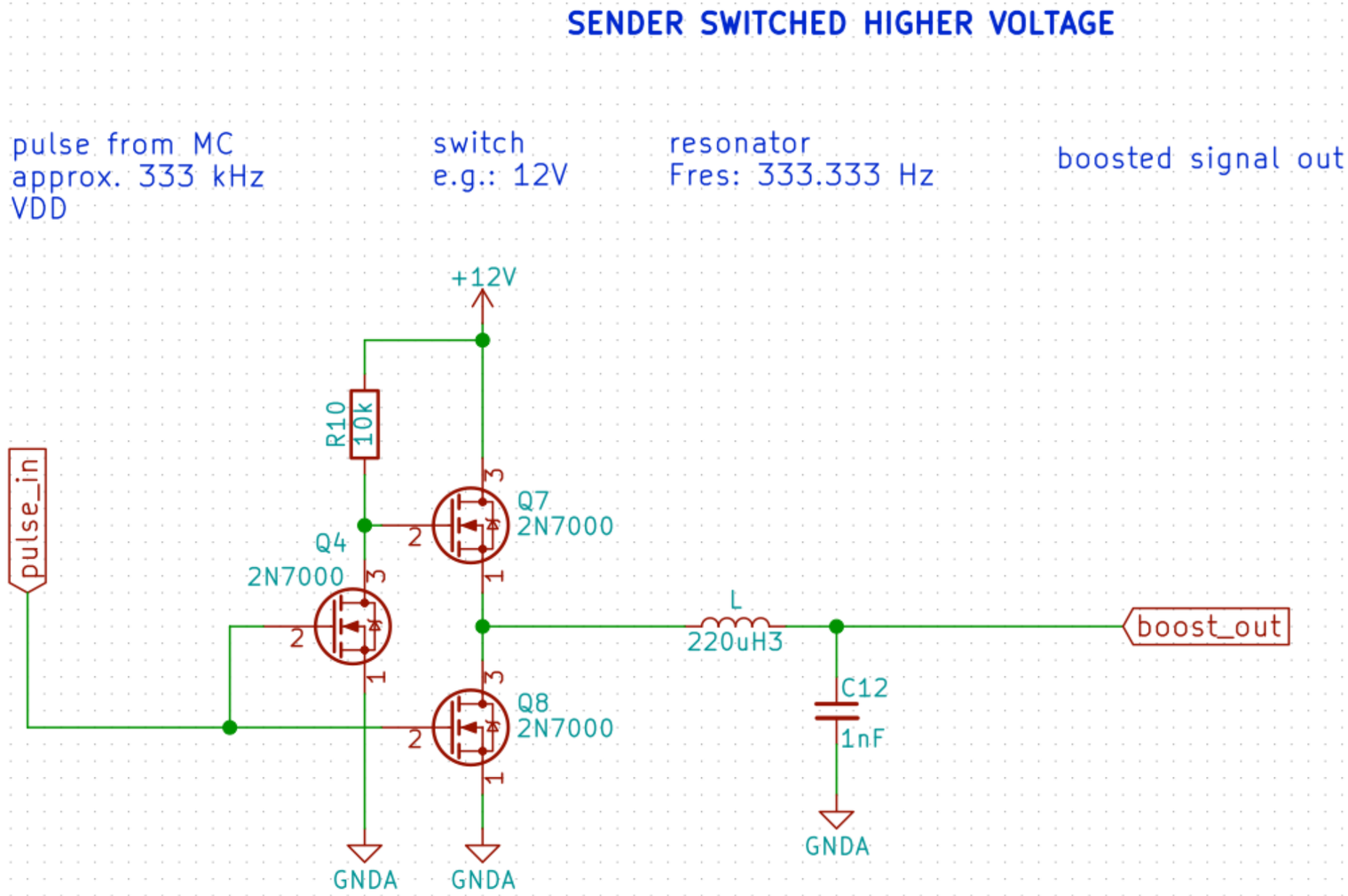
Input: 3.7 V

(transistor switched for cleaner input waveform)





PAN Transmitter – Resonator Switched 2



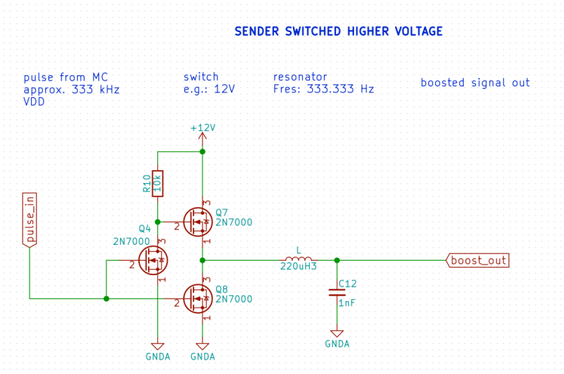
PAN Transmitter – Resonator Switched 2

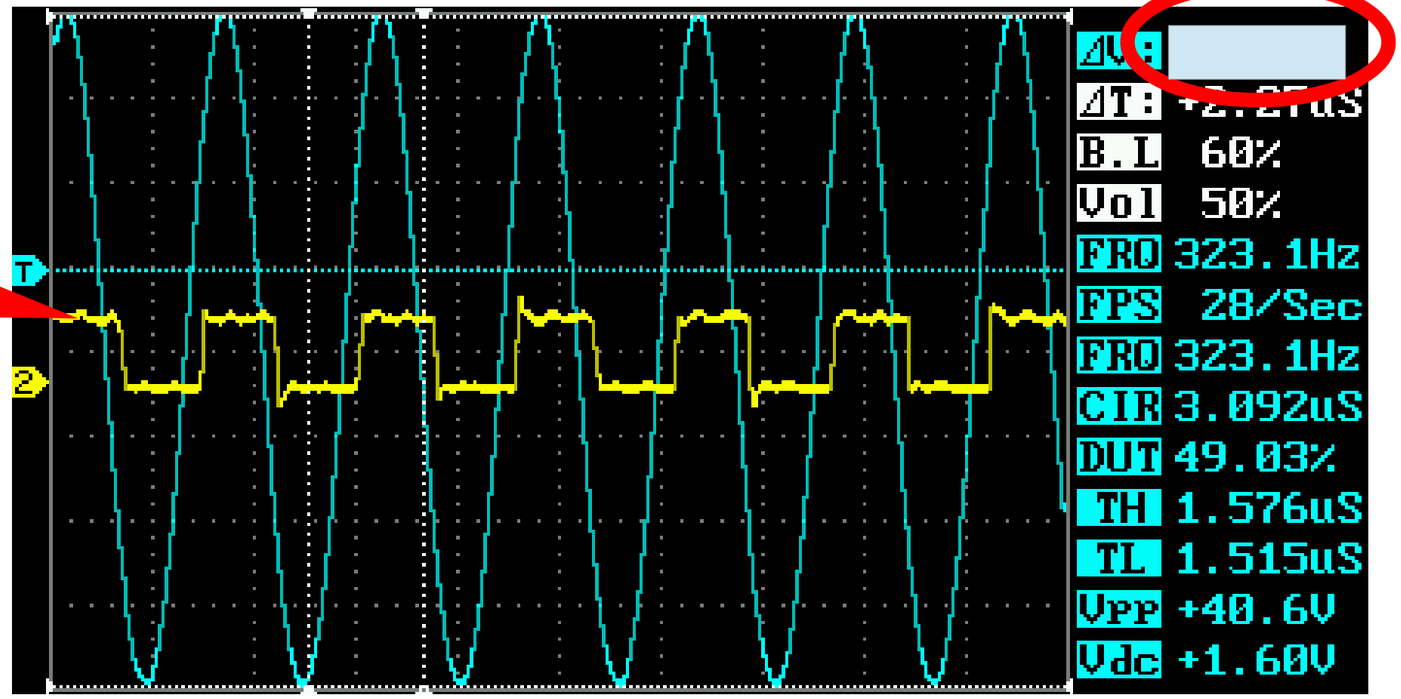
Drive oscillator circuit with a higher-voltage square-wave.
This allows an even higher output-voltage

Output: out of scope
> 100V p-to-p ?

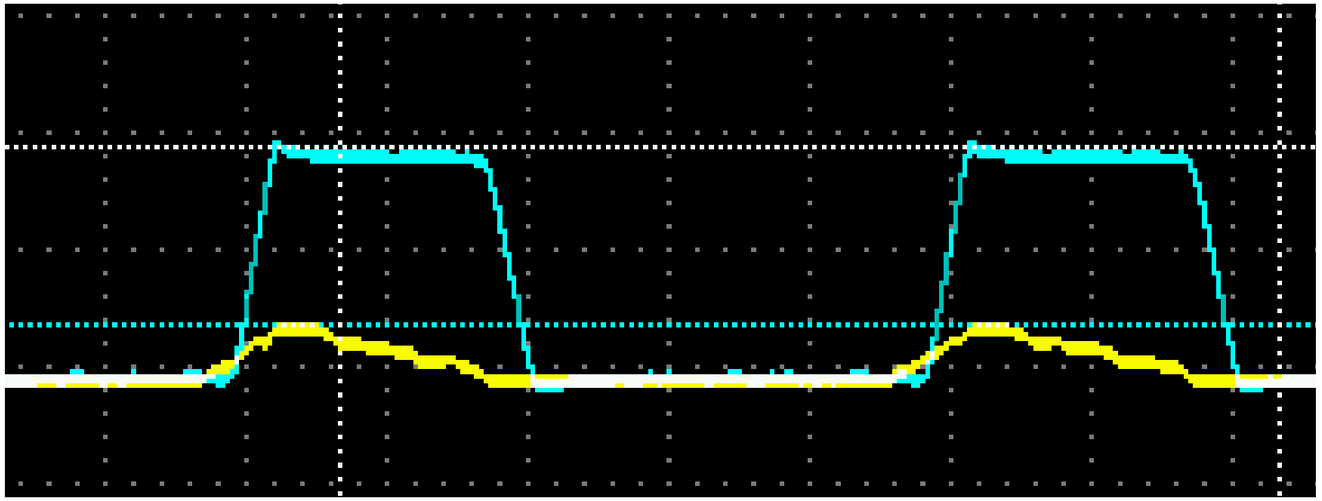
Input: e.g.: 18V

(transistor switching
higher voltage)



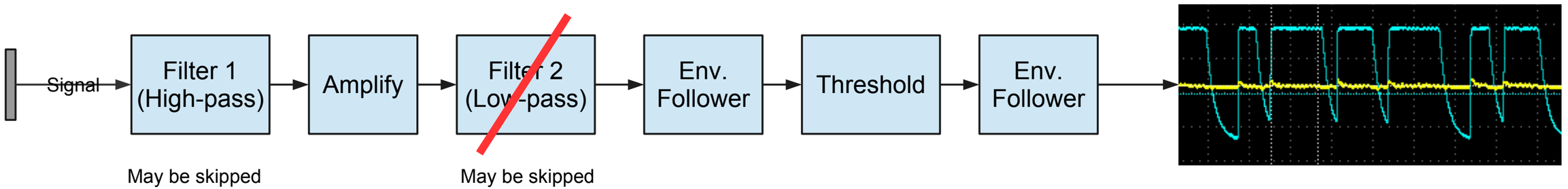


PAN Receiver



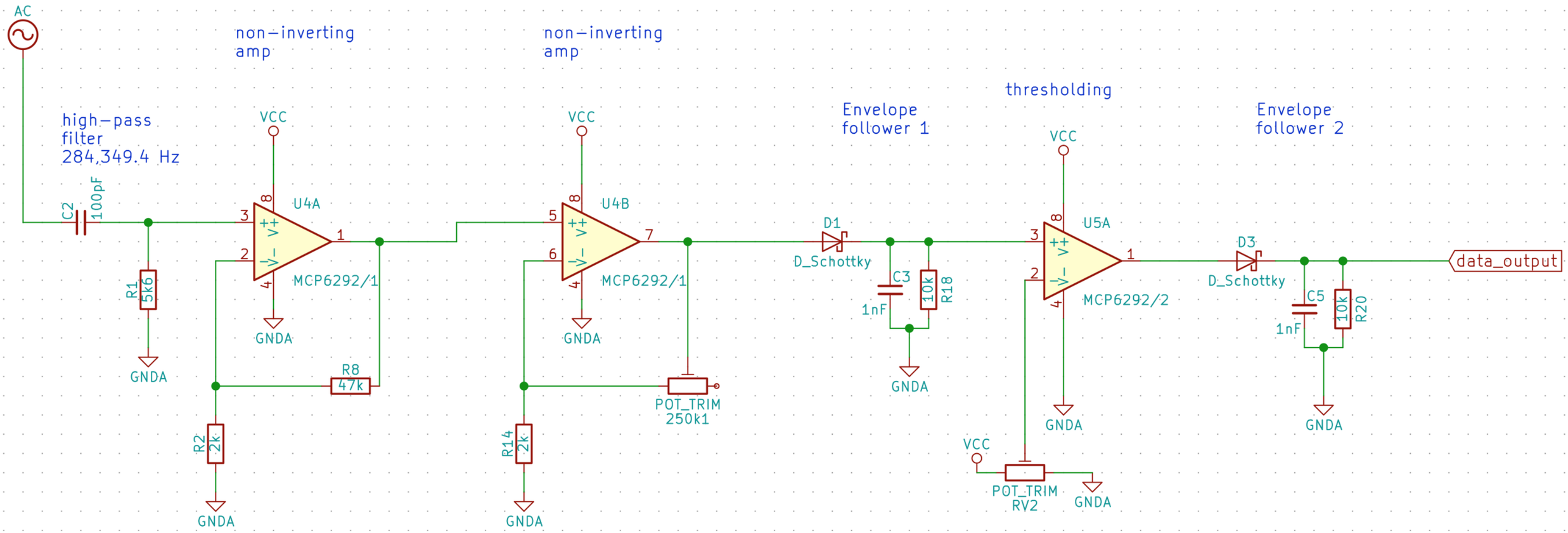
PAN Receiver

- Filter, amplify, threshold signal and smooth the signal

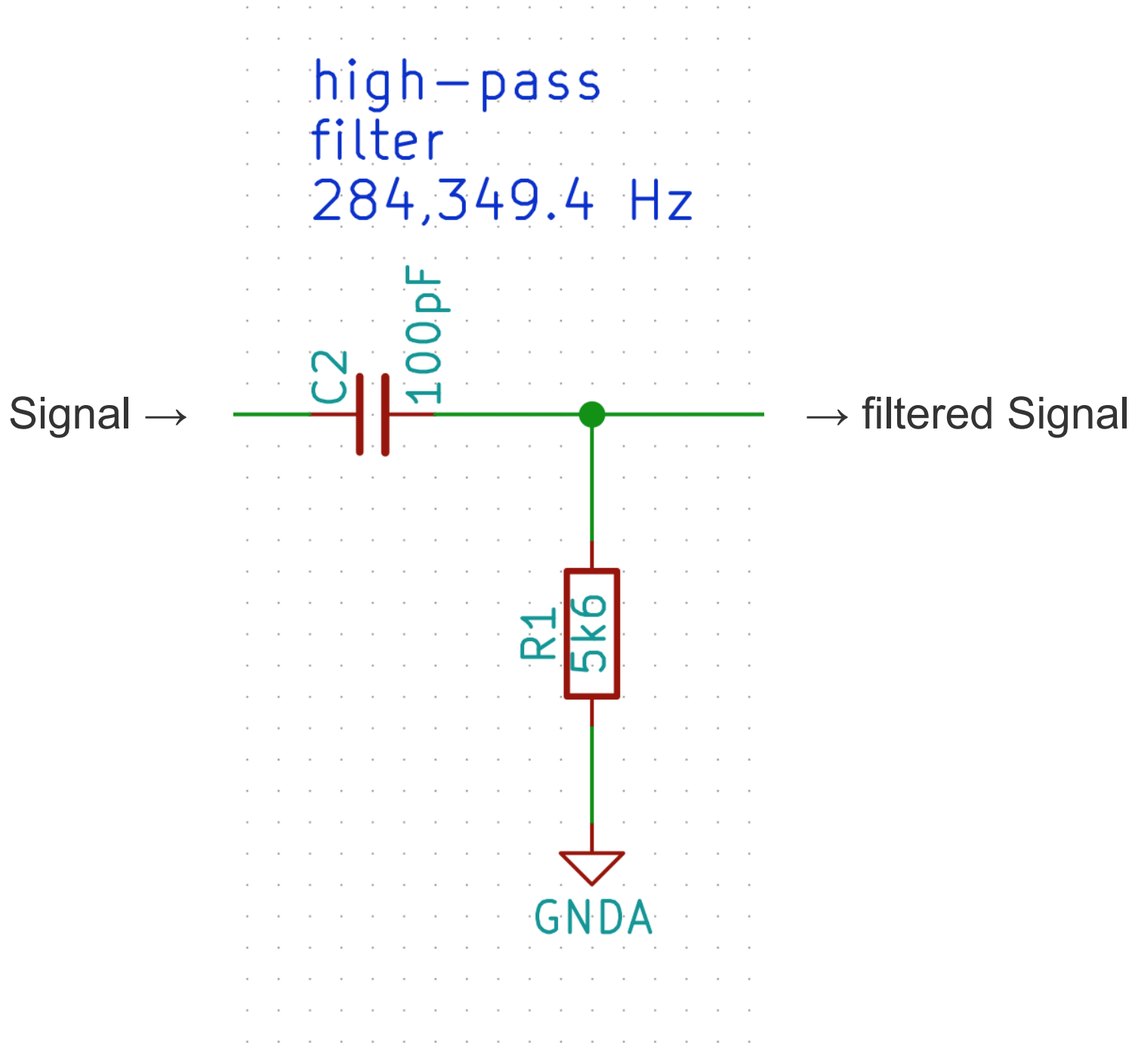


- Read amplified signal and decode (micro-controller)
- Process information

PAN Receiver



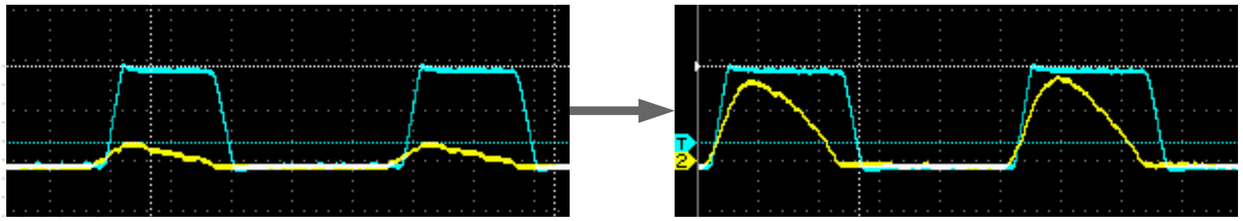
PAN Receiver



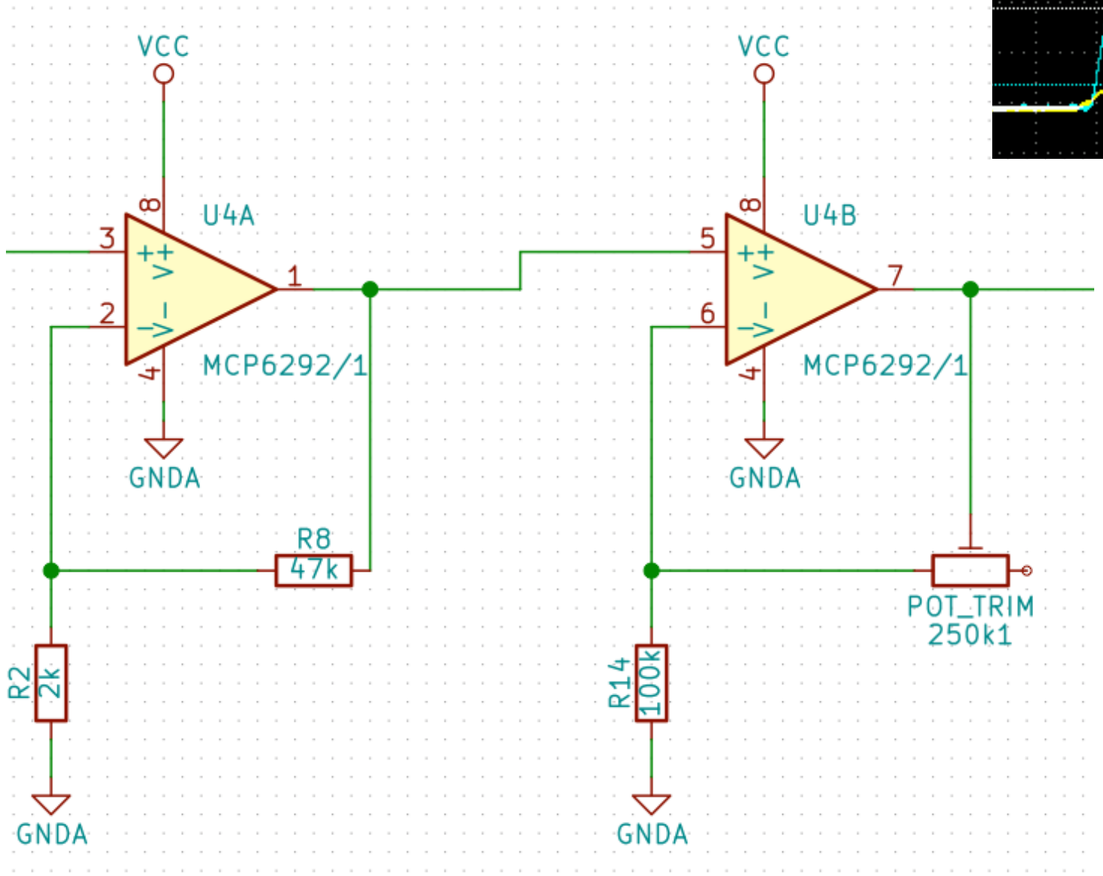
PAN Receiver

fixed gain of 23,5

variable gain



Filtered Signal →

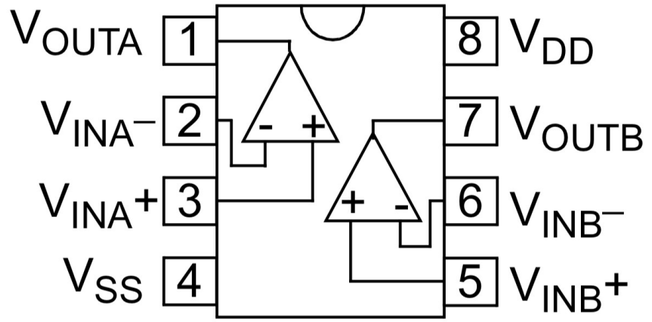


→ amplified Signal

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

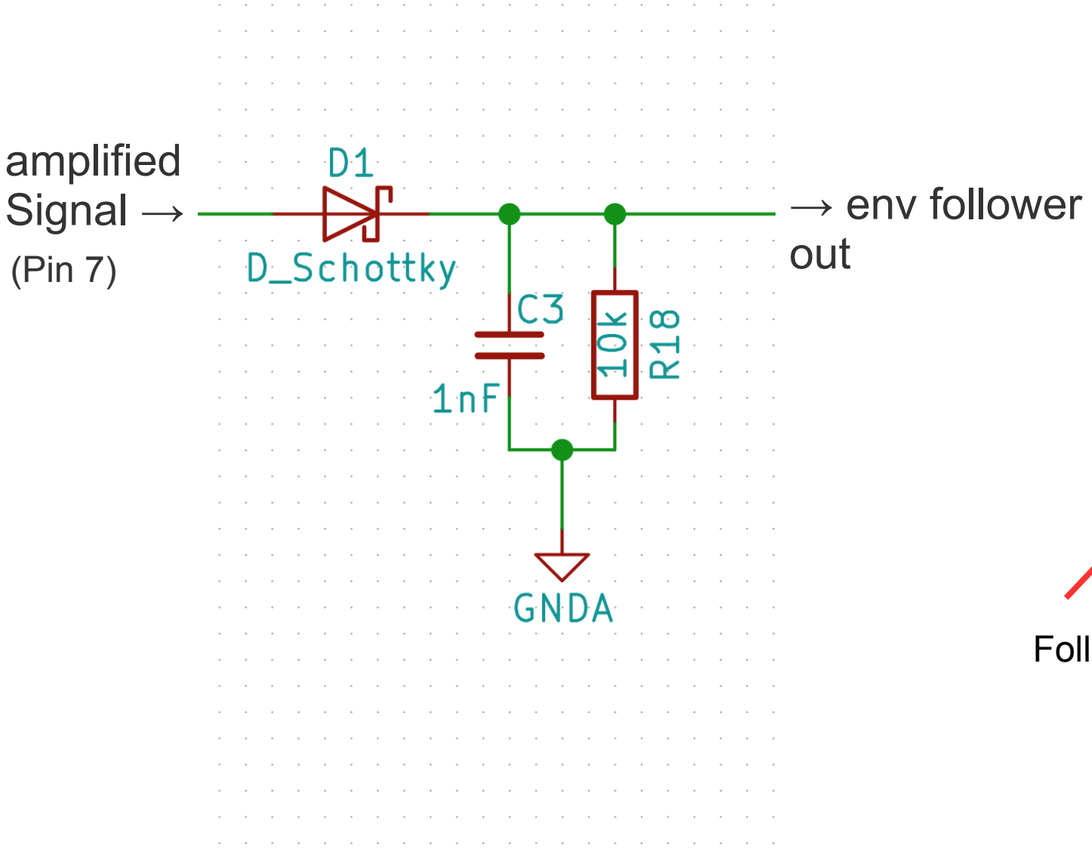
MCP6292

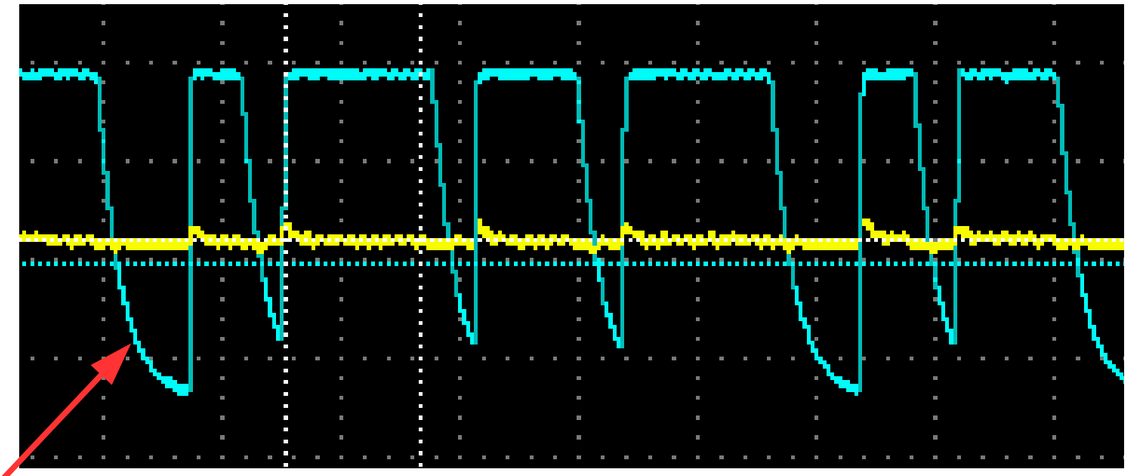
PDIP, SOIC, MSOP



PAN Receiver

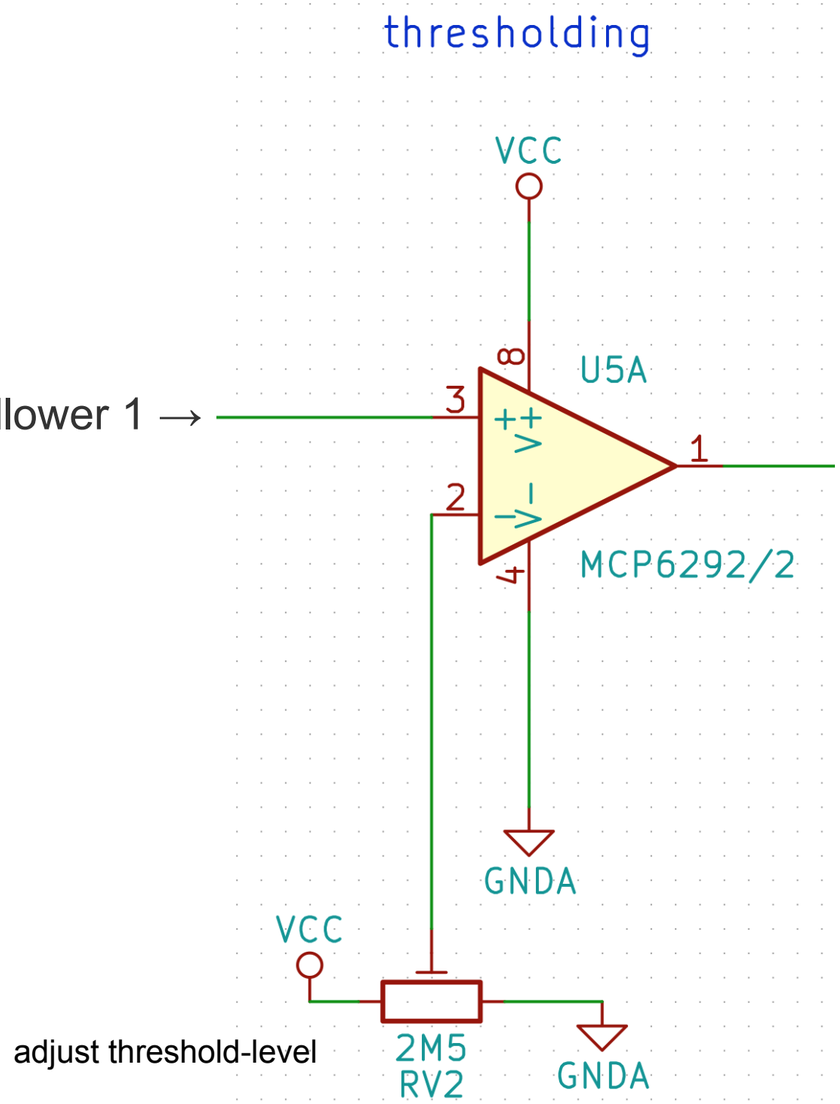
Envelope Follower 1

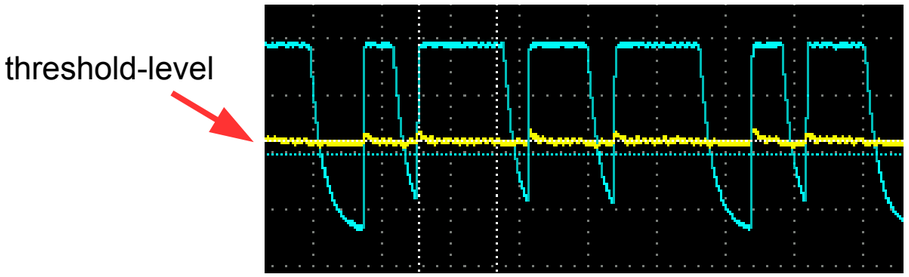




Follow envelope to smooth the signal

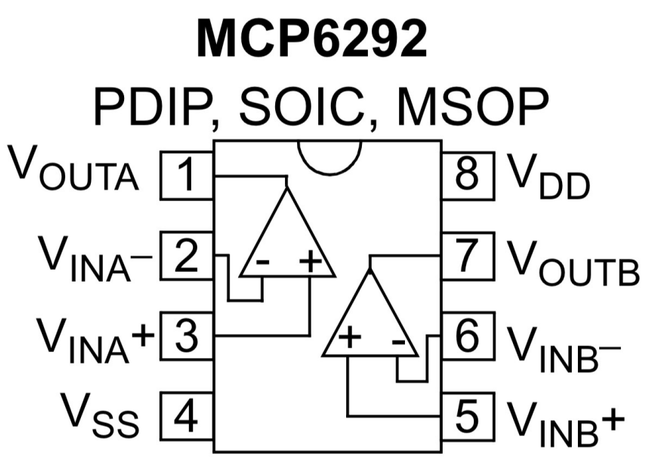
PAN Receiver





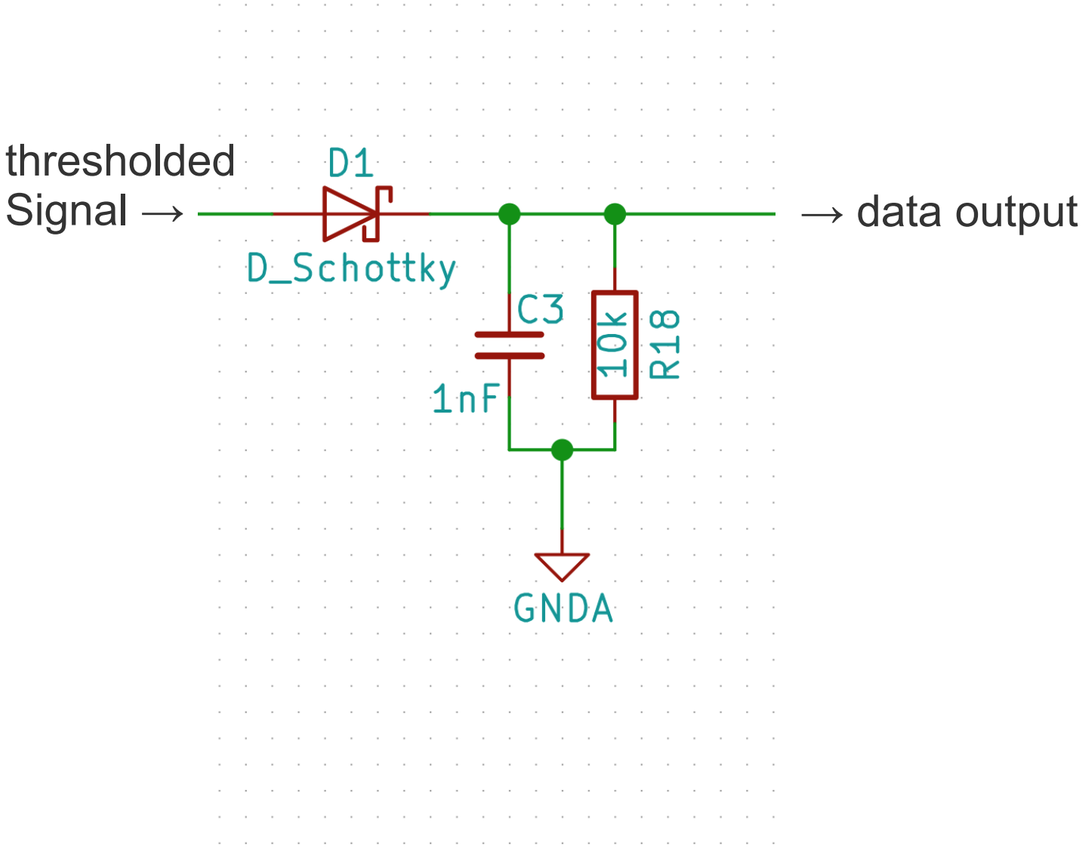
→ thresholded signal

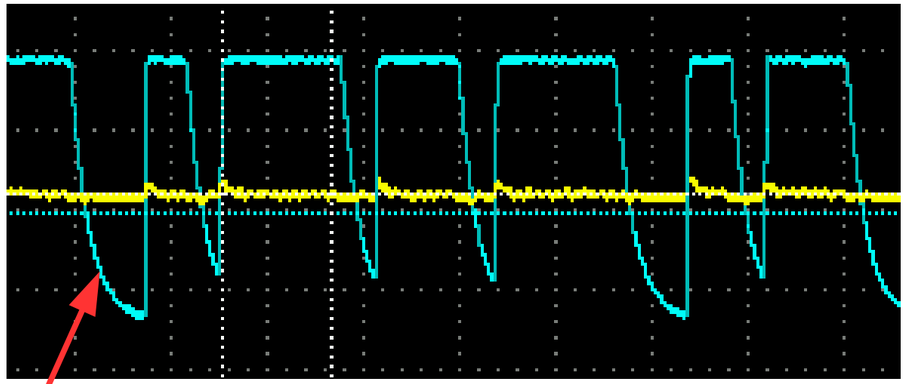
MCP6292
Rail-to-Rail, Single-supply op-amp



PAN Receiver

Envelope Follower 2





Follow envelope to smooth the signal
and remove “cracks” from bit-blocks

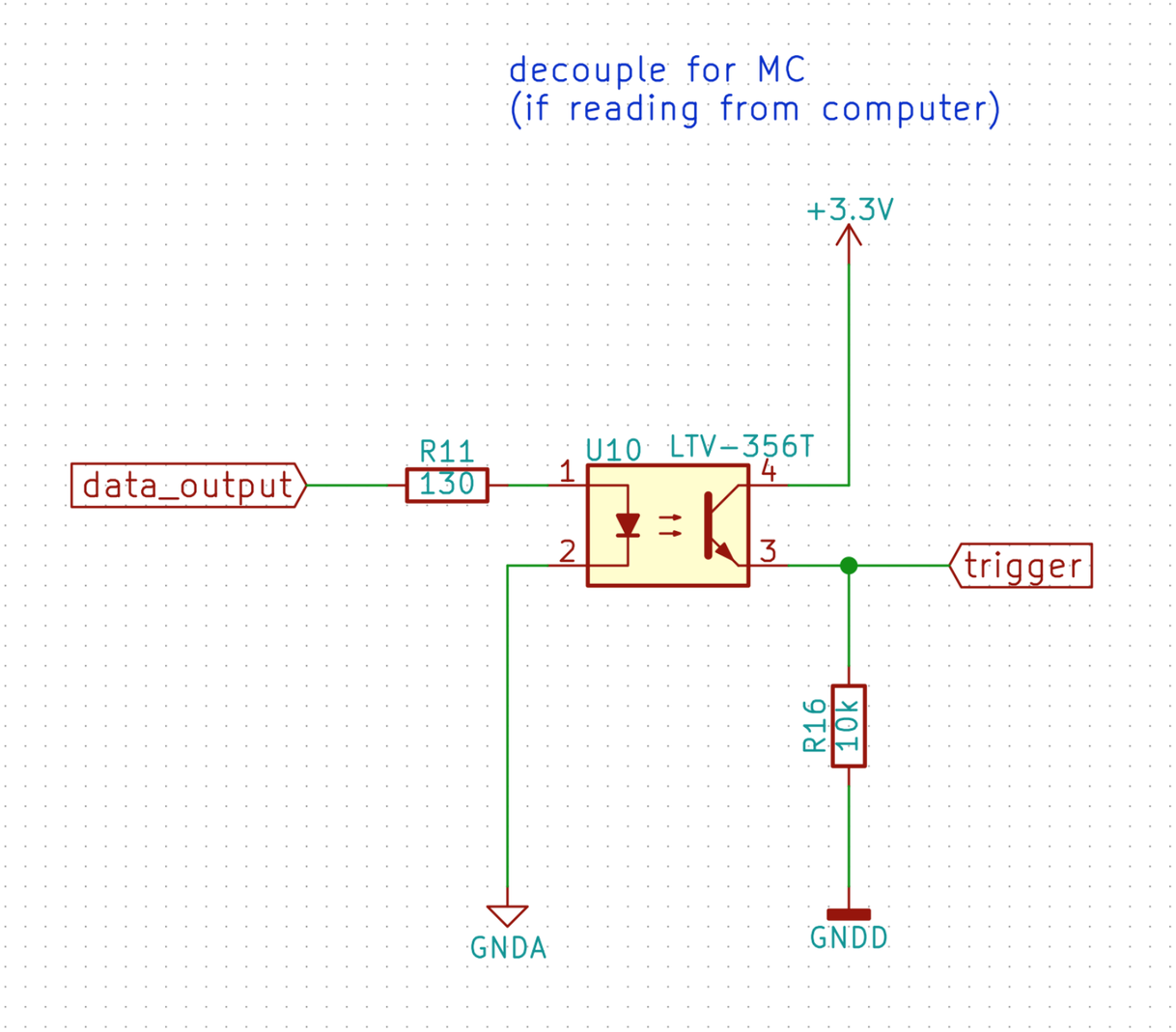
PAN Receiver - reader

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 short 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 receiving data if error detected and wait for a preamble
- 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