Fault-tolerant Sensor Nodes with Erlang/ OTP and Arduino

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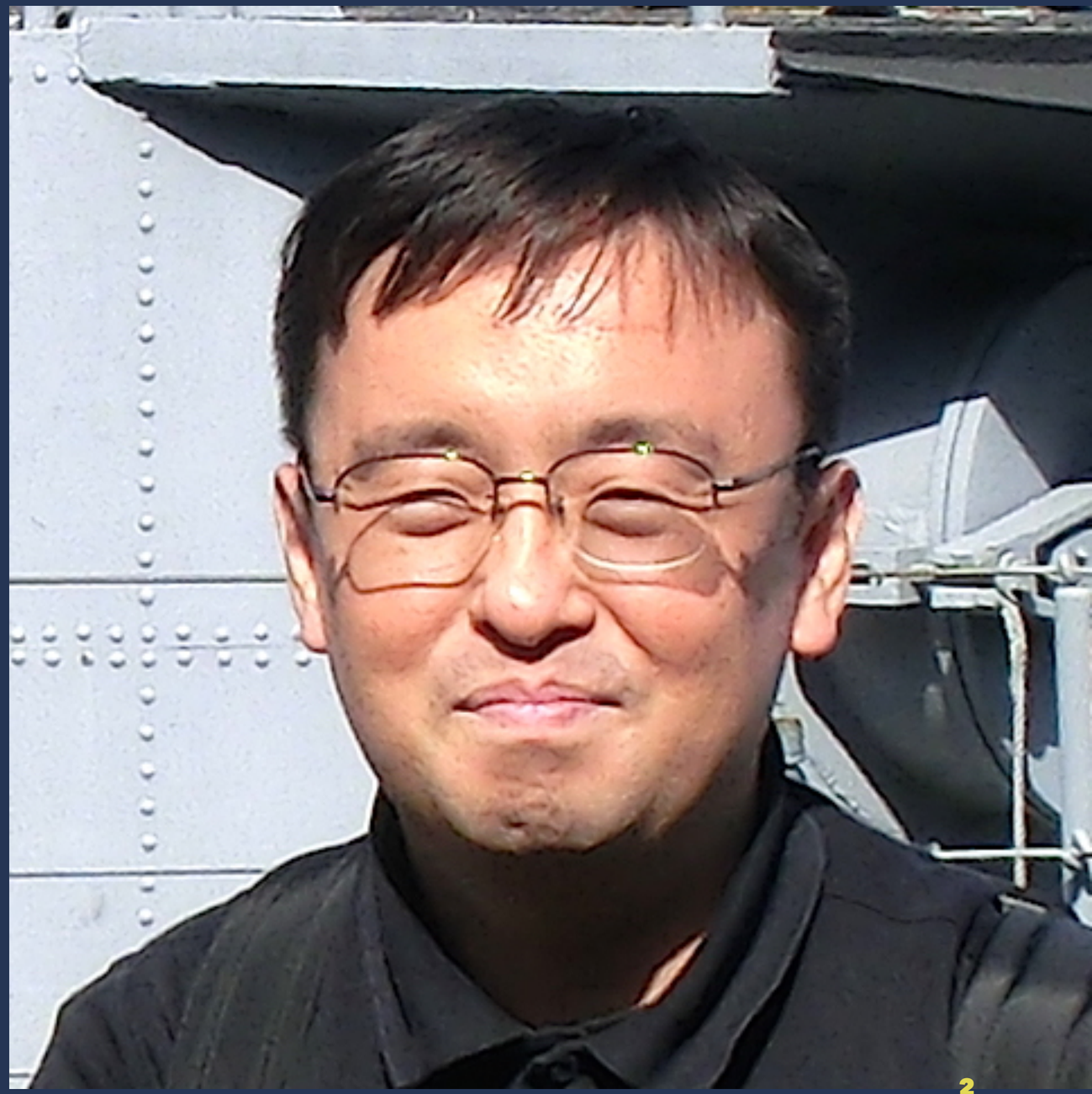


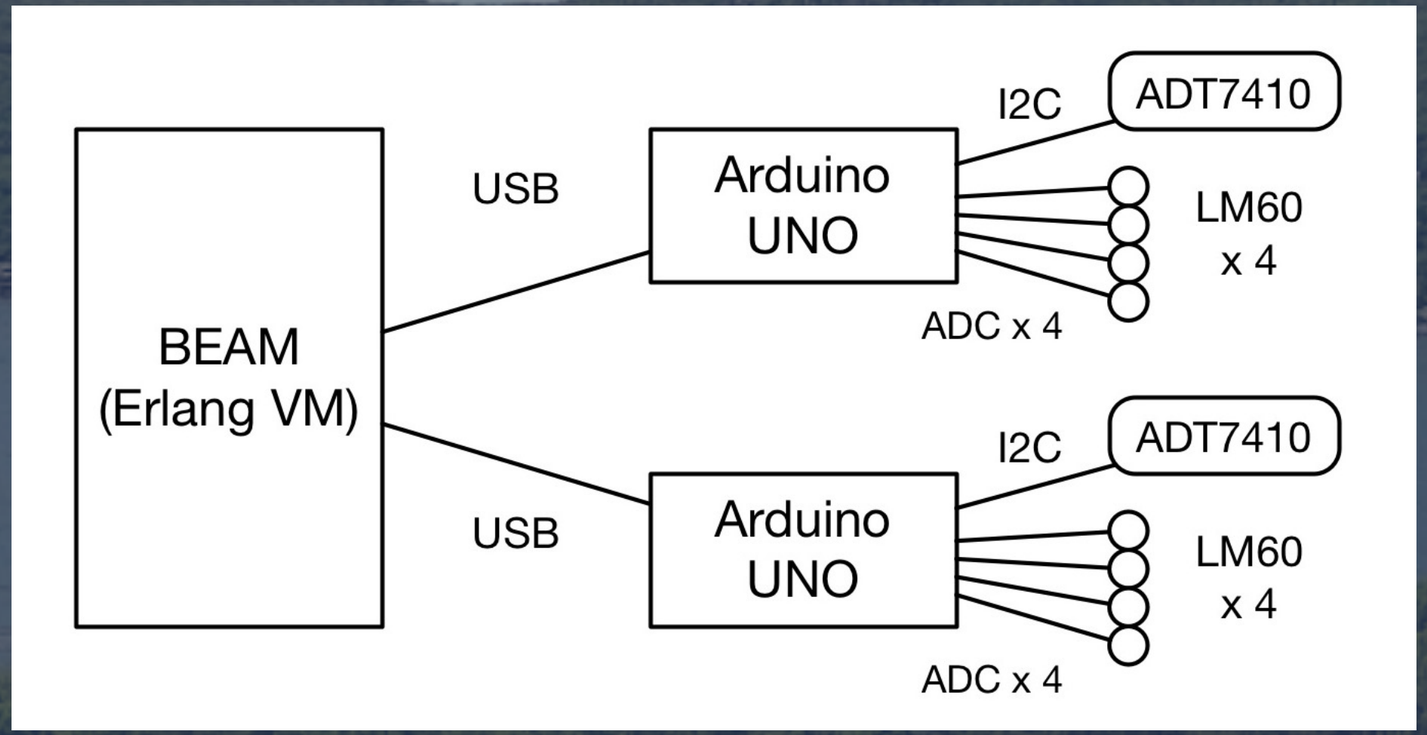
Basic principles

Stabilize
Simplify
"Let It Crash"
Dynamic Update

In this talk

Bearfort sensor shield
8-bit Arduino basics
Wire protocols
How Erlang talks with Arduino

Bearfort[1] system diagram



[1] Bearfort = {BEam, ARduino, FORTified} / Bearfort ridge, NJ, USA / Background photo: By Zeete - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=38798143

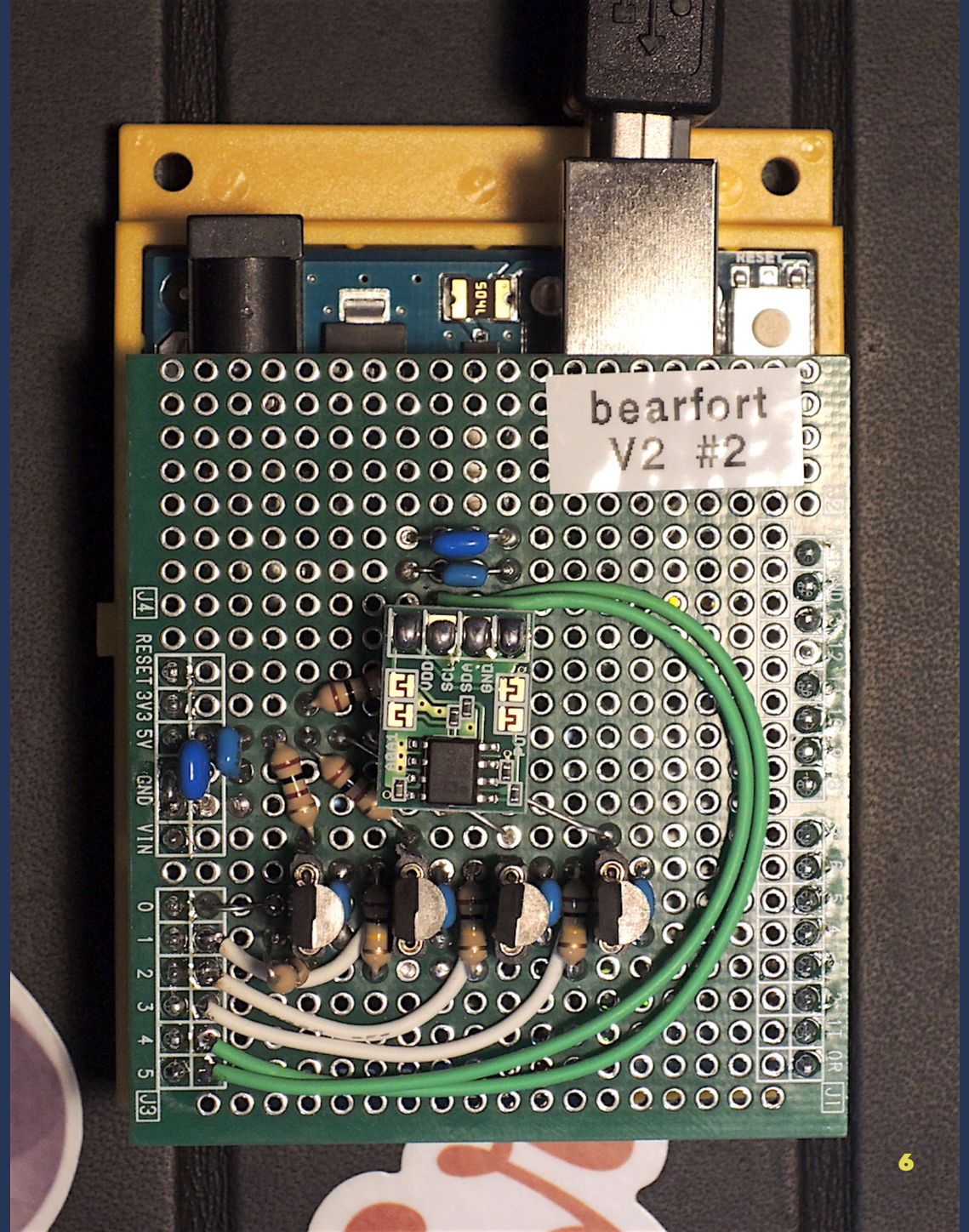
Bearfort sensor shield

Temperature sensors

Analog Devices ADT7410 on TWI/I2C

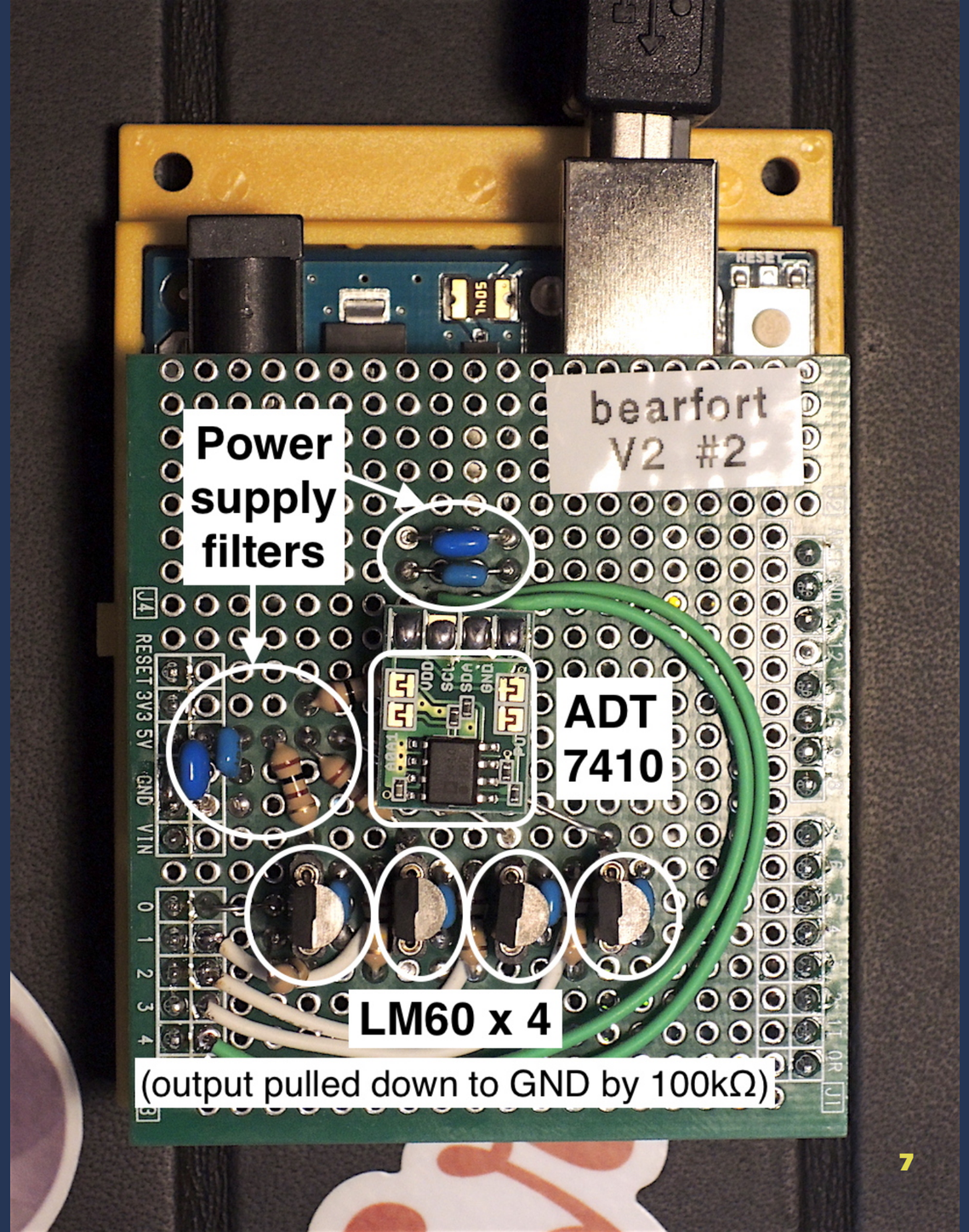
4 x Texas Instruments LM60s on ADC0-3

All sensors are powered by +5V
All sensors are replaceable



What Bearfort shield can do?

Fault tolerant temperature sensing
5 sensors
Robust against sensor failures



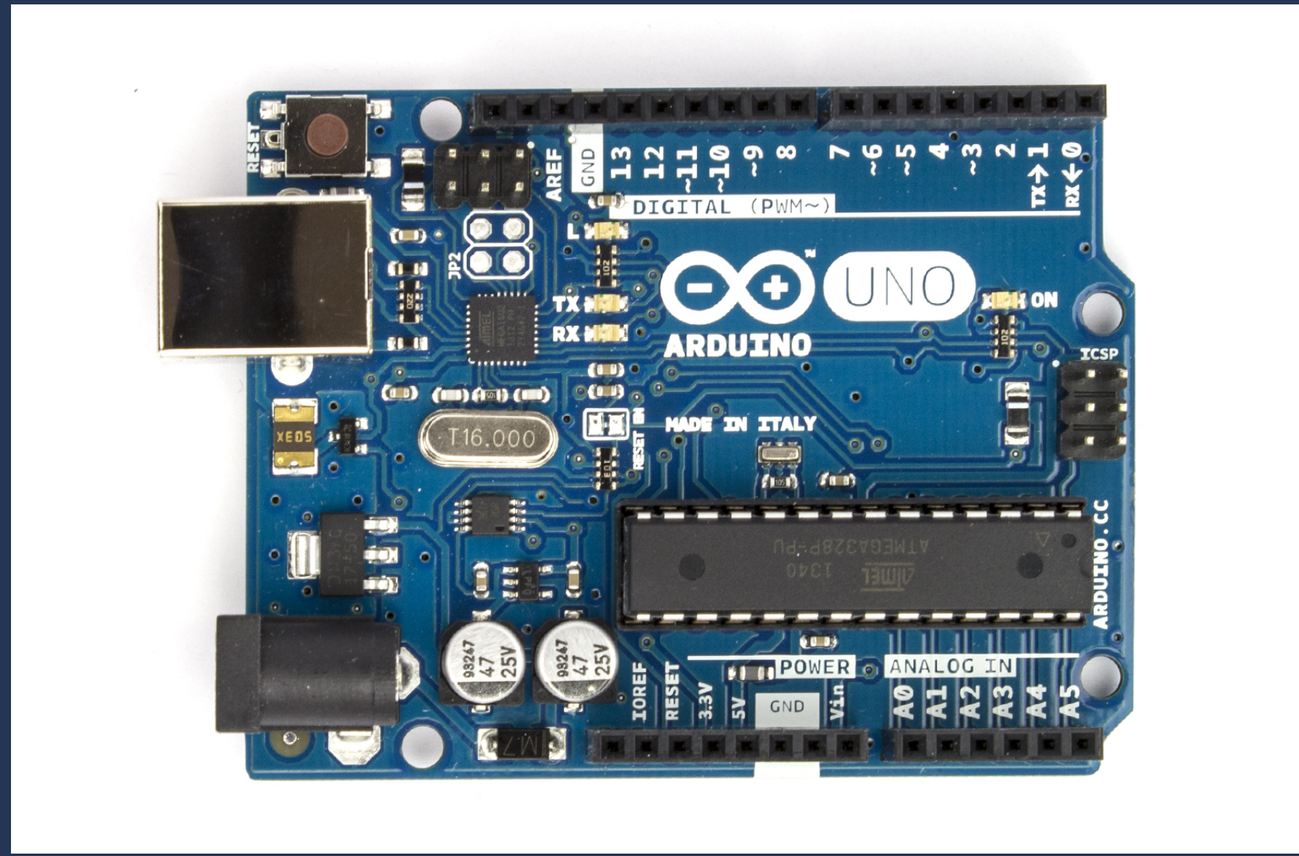
Arduino Uno R3

Atmel AVR ATmega328P

Powered by USB (5V) or external power supply (7~12V)

4 Analog Input + I2C + SPI

Price: USD24.95[2] as of March 2016 at SparkFun Electronics



[2] Photo: Wikimedia Commons, By oomlout - ARDU-UNO-03-Front, CC BY-SA 2.0, https://commons.wikimedia.org/w/index.php?curid=40551883

AVR development

Write C(++) and assembler

Event loop

Try and error

Interrupts: timer only

Chip programmer

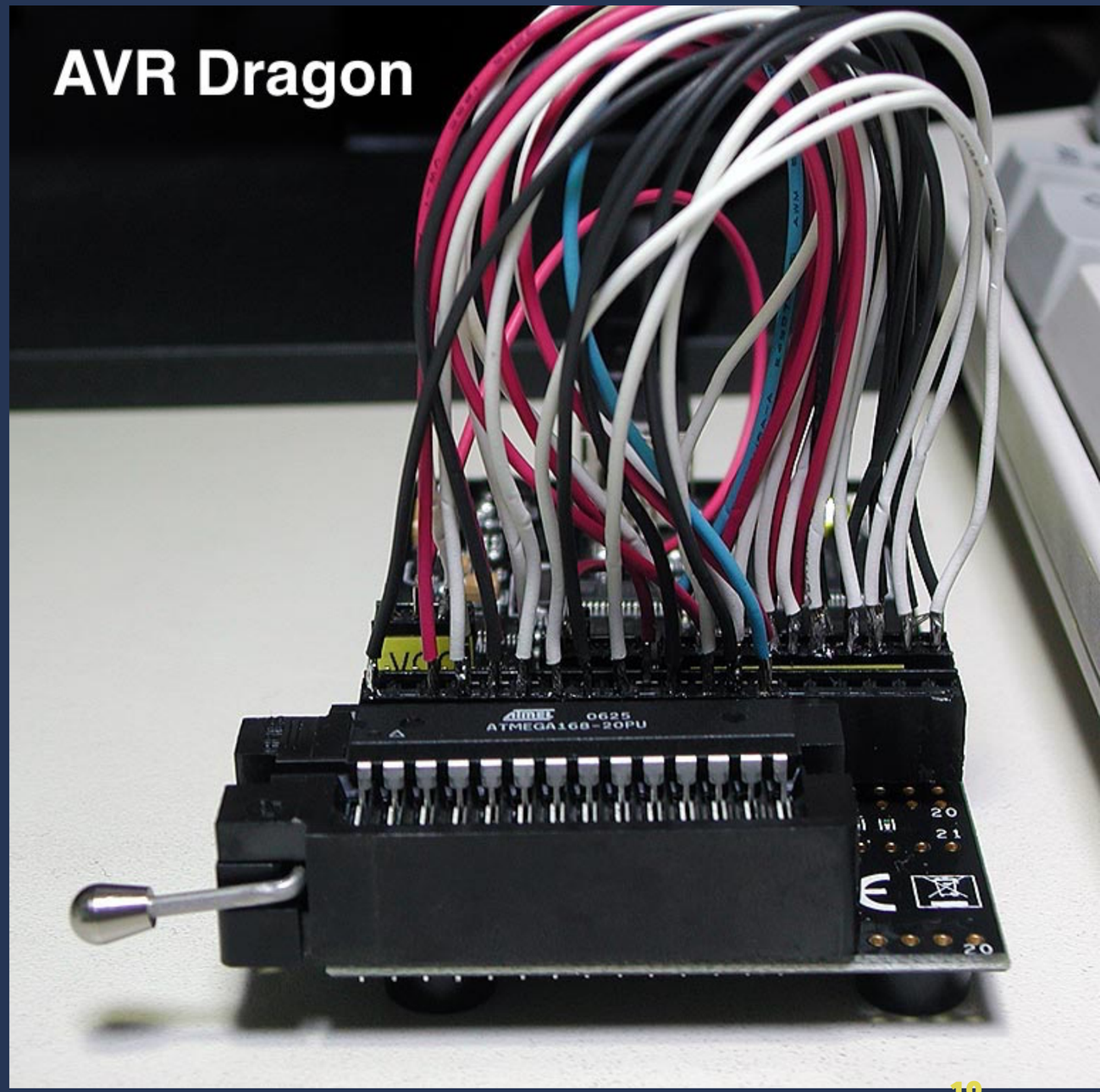
Essential for writing bootloader firmware

Hardware diagnostics

Hardware protection bit configuration

Replicating chips

Photo: AVR Dragon, circa 2008



Hardware principles

Stabilize
Simplify
"Let It Crash"

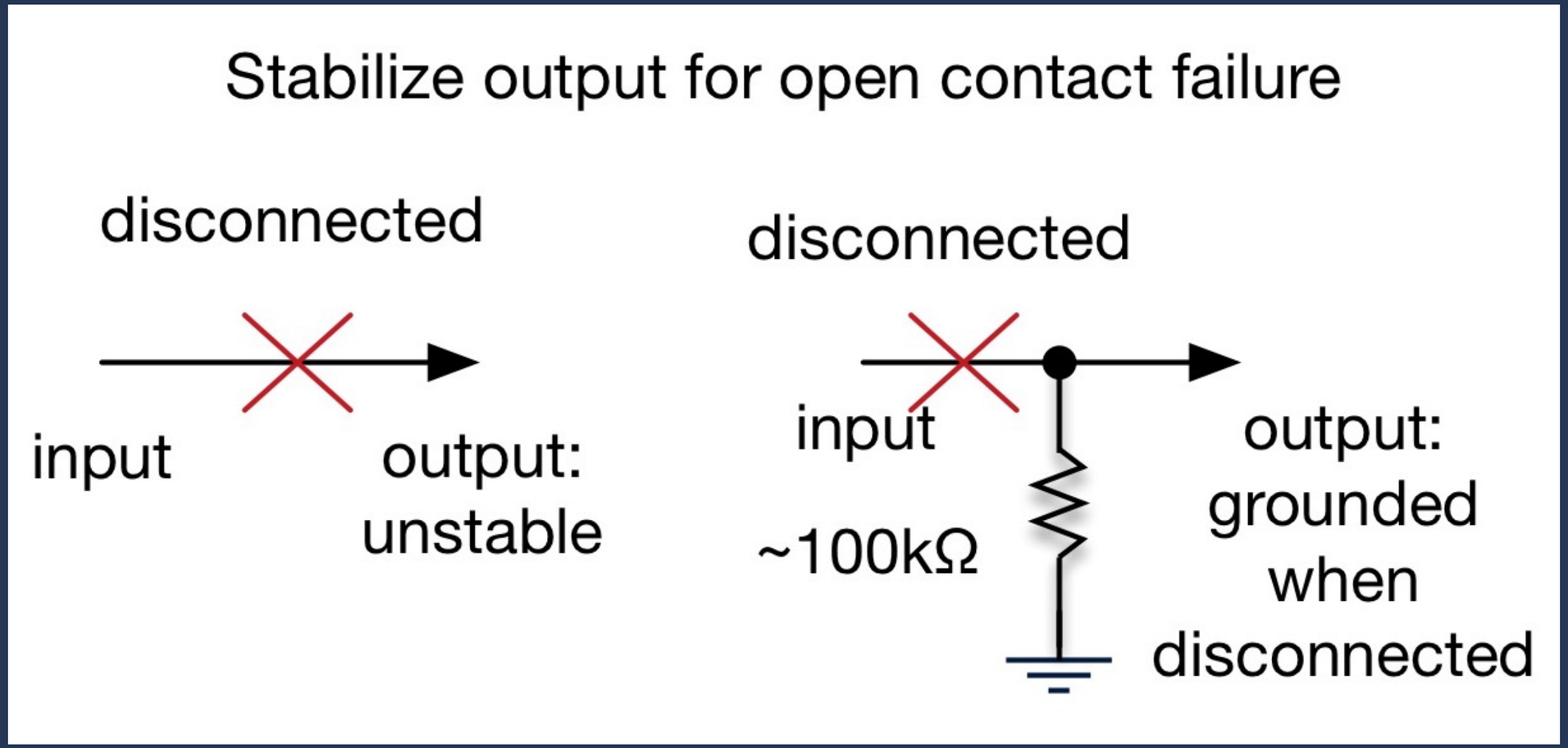
Stabilize hardware

Solder - do not use breadboards
Prepare for contact failures
"Keep it simple and stupid"

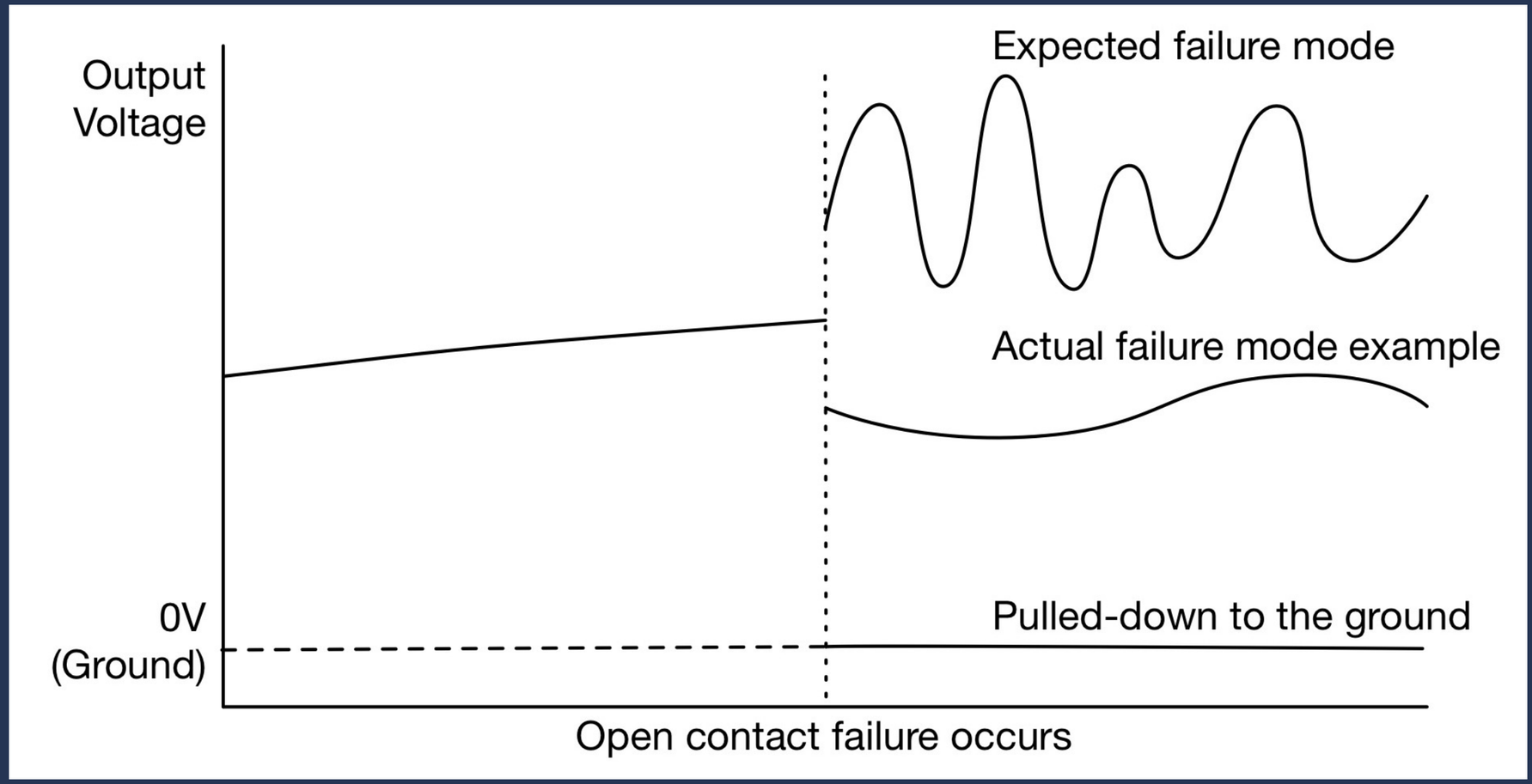
Contact failure modes

Open circuit
Short circuit
Intermittent failures

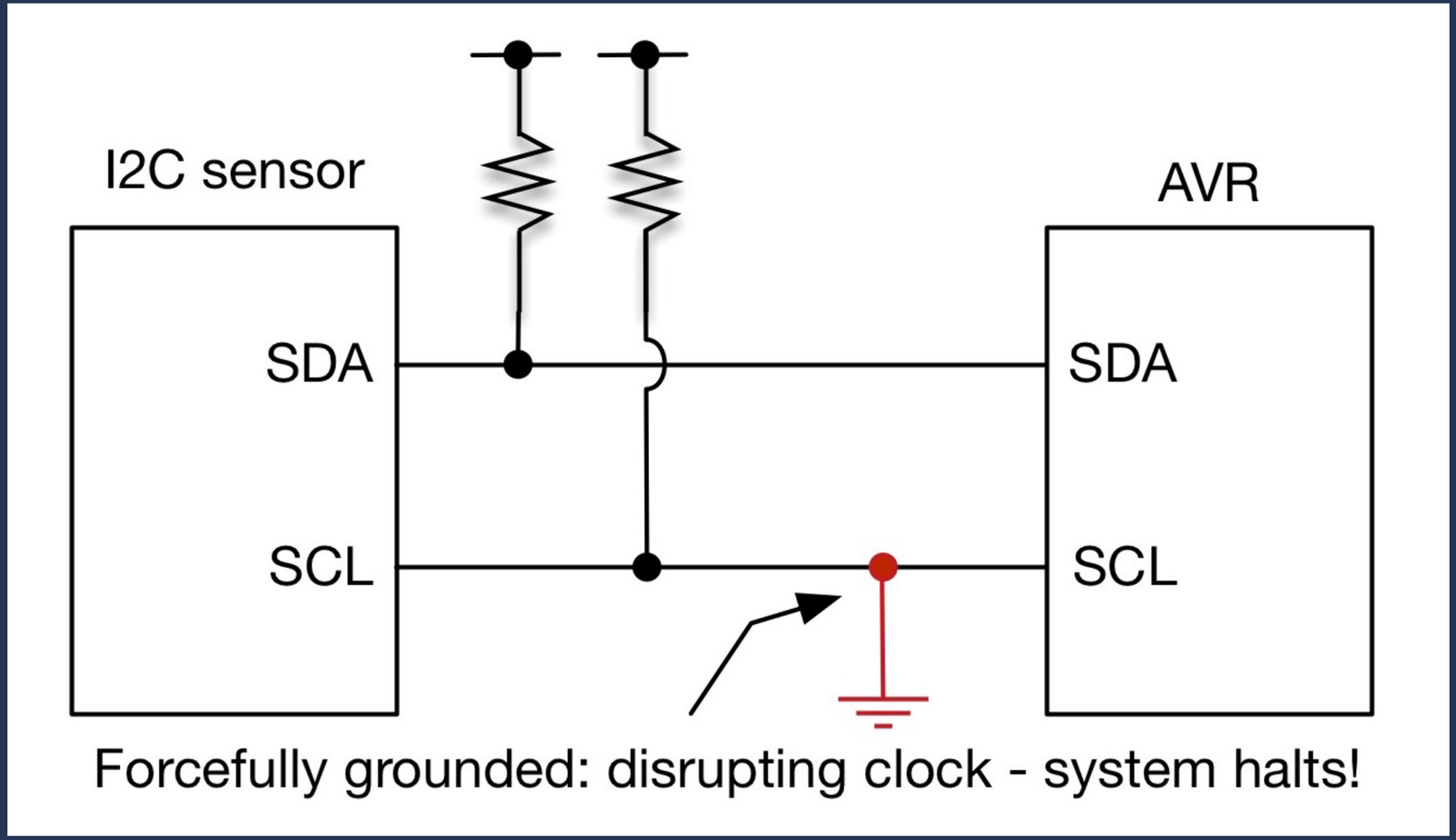
Open circuit



LM60 open circuit failure



Short circuit



Simplify hardware

8bit AVR is slow (16MHz)
Raw sensor values
No tunable parts

"Let It Crash"

Reset when hardware fails
Allow external reset
Use watchdog timer if needed

Resetting Arduino from USB

Turn off DTR/RTS for 50msec and turn back on

```
%%% Using Michael Santos'
%%% stk500 and srly repository code
{ok,FD} = serctl:open("/dev/cu.usbmodem1D11311"),
[begin dtrrts(FD, Status),
    timer:sleep(50) end || Status <- [off, on] ].
```

Yes, that's it!

Software principles

Simplify
"Let It Crash"
Dynamic update

Simplify wire protocol

Polling from host
Fixed-length output
No tunable parts

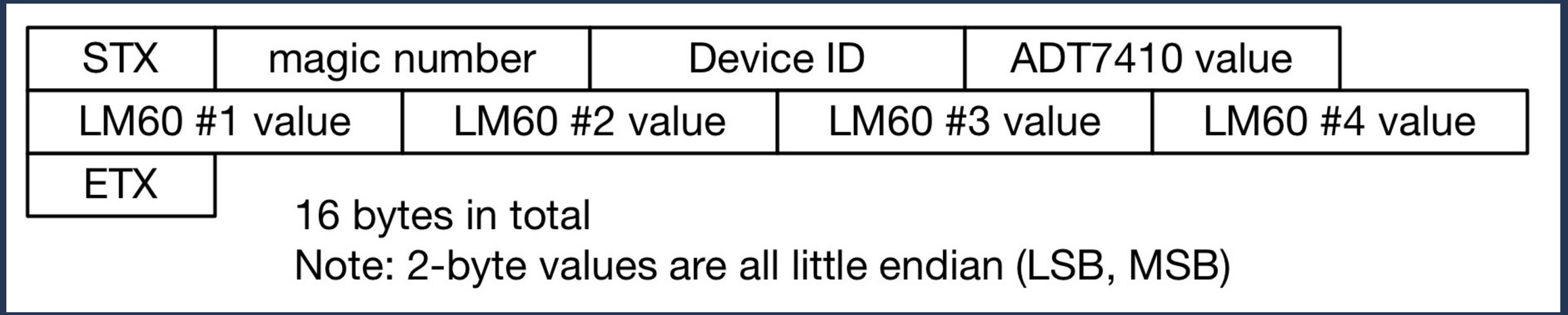
Serial line control from Erlang/OTP

Michael Santos' srly package

Control tty line principles with ioctl()

Fixed-length reading function is *extremely* useful

Wire protocol message format
16-byte fixed length



Wire protocol in Erlang

```
{ok, <<2, 16#51, 16#82,  % 2 == STX
 DevId:2/little-unsigned-integer-unit:8,
 ADT0:2/little-signed-integer-unit:8,
 A0:2/little-unsigned-integer-unit:8,
 A1:2/little-unsigned-integer-unit:8,
 A2:2/little-unsigned-integer-unit:8,
 A3:2/little-unsigned-integer-unit:8,
 3>>} = read_serial(FD). % 3 == ETX
```

"Let It Crash"

Erlang does it *very well*
Hardware reset control
Serial ioctl-capable API
Idempotent code

Dynamic update

Updating Arduino from Erlang
Use bootloader for code loading
Slow (5~10 seconds) but feasible

Update example

```
update() ->
    Hex = stk500:hex_file(
            "./arduino-uno/bearfort-arduino.hex"),
    Bytes = stk500:chunk(Hex, 128),
    {ok,FD} = stk500:open(
                "/dev/cu.usbmodem1D11311",
                [{speed, b115200}]),
    ok = stk500:load(FD, Bytes).
```

Issues

Slow USB connection transition
Automated sensor calibration
Modeling fault tolerant operation

Future directions

Indoor/outdoor field testing
Embedded Erlang node
Multiple sensors/nodes

Excluded from this talk

- TCP/IP: MQTT, CoAP, etc.
- Cryptographic security
- Host OS device drivers
- non-8bit Arduino boards
- Erlang/ALE = for Raspeberry Pi

Related work (1/2)

- Code and slides of this presentation
- srly: Erlang NIF serial API
- stk500: Erlang AVR bootloader API
- avr-libc, avr-binutils, avr-gcc
- avrdude: AVR program loader
- optiboot: AVR bootloader firmware

Related work (2/2)

- Omer Kiric's talk on EF SF Bay 2013
  - Erlang/ALE on GitHub
- Frank Hunleth's talk on EF SF Bay 2015
  - Robot running in Elixir
  - elixirbot on GitHub

Thanks to:

Michael Santos
Erlang Solutions
...and you all!

Thank you
Questions?