Linuxcon 2012

Sleep Monitoring with Linux and Arduino

http://marc.merlins.org/linux/talks/ArduinoSleepMonitoring/

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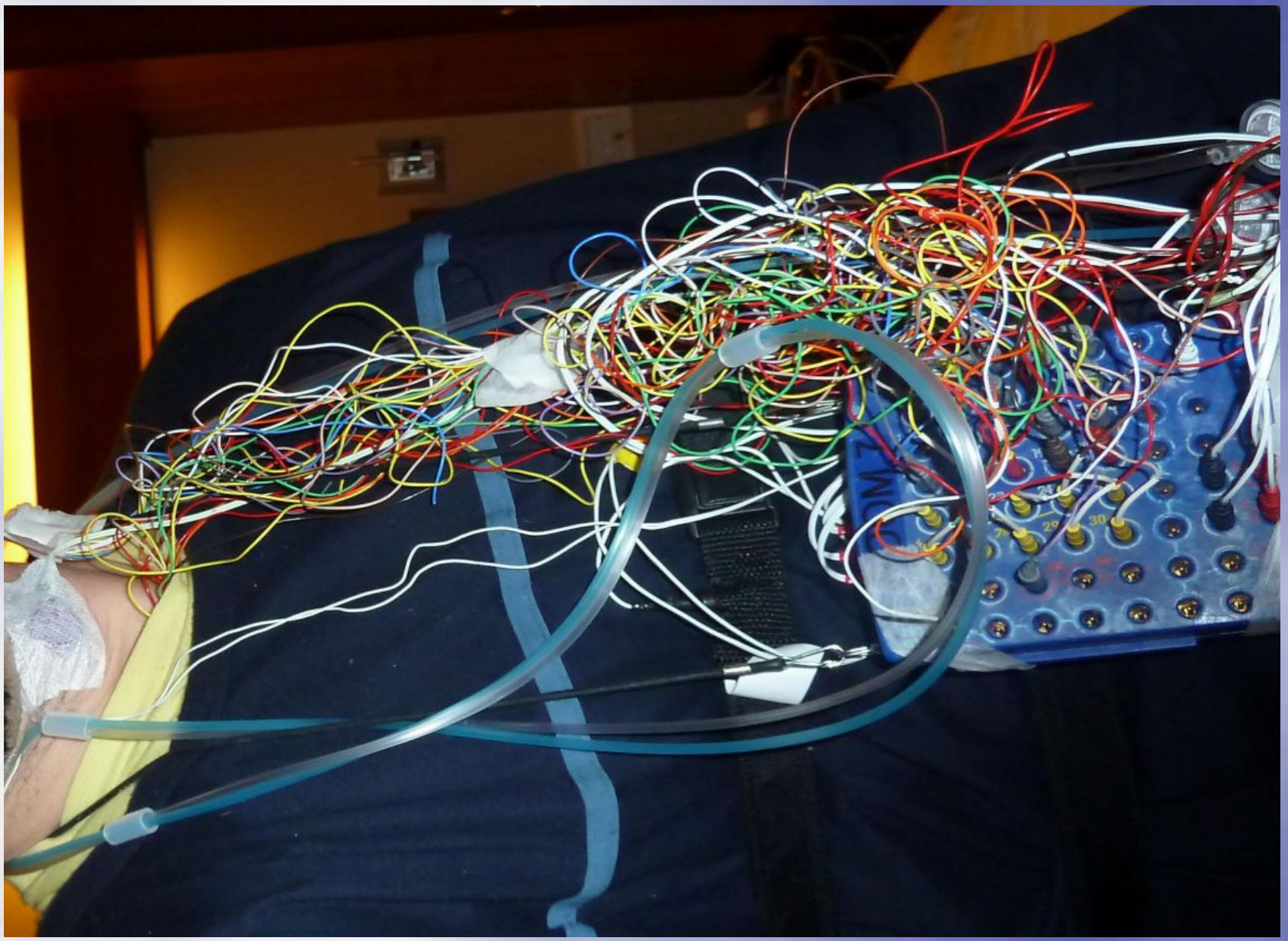
Sleep Apnea

- How restless are you at night?
- Do you snore?
- Do you know if you sleep on your back, and how much?
- Have you been told you stop breathing at night and then gasp for air?
- Do you wake up tired after a full night, need to take naps in the middle of the day?
- 5-10% of middle age men (half that for women) have sleep apnea.
- 80-90% of people are unaware and go undiagnosed.
- Sleep apnea is estimated to cost up to 5 life-years.

Sleep Apnea Diagnosis: Sleep Studies

- Expensive ($4000 before insurance is not uncommon)
- 6 week+ wait at Stanford
- Takes 2H to get setup with all the probes and test them before you can sleep
- You smell like ether when you come out, and get a free partial leg shave :)
- Schrödinger's cat problem: forcing me to sleep on my back for testing messes with my sleep (apnea is worse on my back).
- A split sleep study showed I was worse with a sleep appliance than without. It made no sense.

Good luck having a normal night with this



Take Home Sleep Study Devices

- A single sleep study isn't a pattern, it's a snapshot.
- How do you know if a mouth piece helps you sleeping?
- How about a “Don't sleep on your back” aid like the Rematee Bumper Belt
- Find out if sleeping with ear plugs and/or facemask helps
- Study how caffeine and alcohol affect your sleep.
- Medical devices are expensive ($300-$500/night, or $5000 for a Watermark Ares and Itamar Medical PAT 200.

Watermark Medical Ares

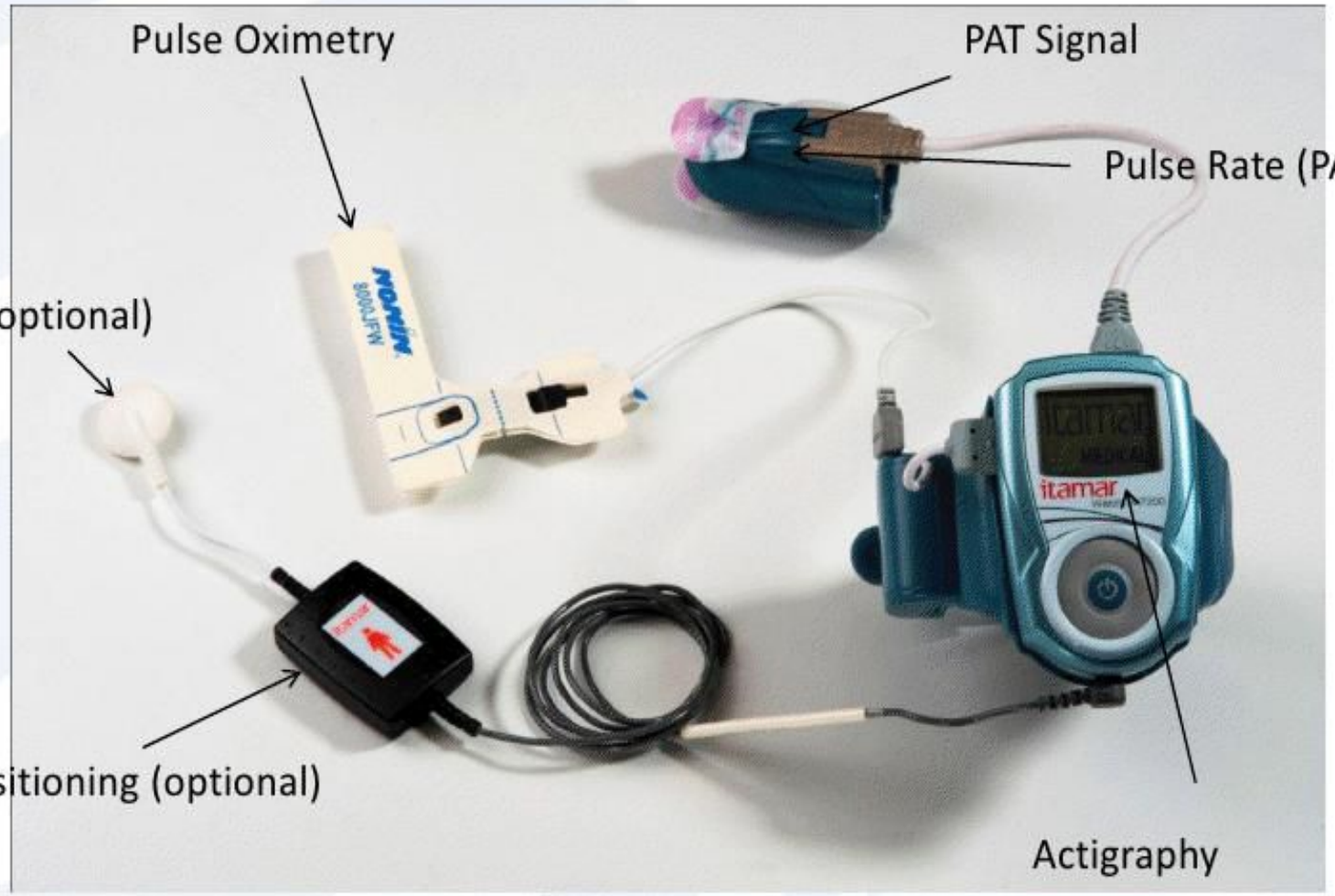
- Looks well integrated, but not ideal for tummy sleepers.
- Too many ways it can slip off, so need to be tight and uncomfortable

Itamar Medical PAT 200

- Better integrated, nothing in your nose or on your head, but expensive one use throw away PAT monitor.

Sleep sensors

- Oximeter, airflow, body position, microphone, EEG for phases of sleep (light, REM, deep).



How about making my how? It can't be that hard, right?

- Itamar Medical PAT 200:
- “The peripheral arterial tone (PAT) signal measures the arterial pulsatile volume changes of the finger that are regulated by the α-adrenergic innervation of the smooth muscles of the vasculature of the finger, and thus reflects sympathetic nervous system activity. The WP100 indirectly detects apnea/hypopnea events by identifying surges of sympathetic activation associated with the termination of these events.”

Pulse Oxymetry can't be that hard, right?

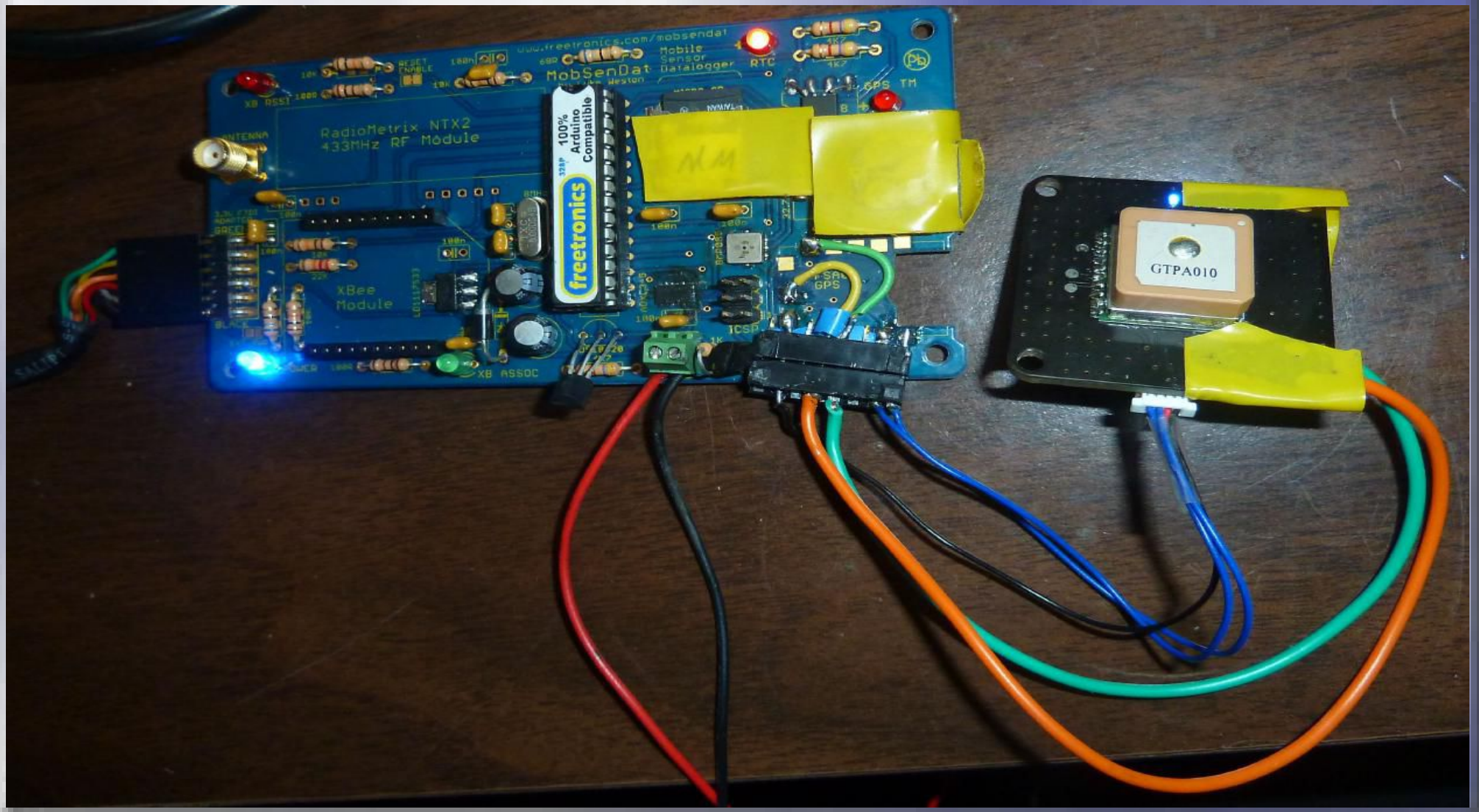
- http://www.pulse-meter.com/oximetry.html
- http://www.equipmentexplained.com/physics/respi_measurements/oxygen/oximeter/pulse_oximeter.html
- http://www.robots.ox.ac.uk/~neil/teaching/lectures/med_elec/notes6.pdf
- “For the purposes of signal amplification, the photocurrent must be transformed into a voltage with moderate output impedance; this is achieved with the circuit shown in Figure 43, the op−amp being configured as a current−to−voltage converter. Because of the high junction resistance of the reverse−biased photodiode, the op−amp should be an FET type with a very high input impedance. Since the negative input of the op−amp acts like a virtual earth, the output voltage of the circuit is vo = −I RL. A very large feedback resistance may be used, values as high as several tens of MΩ being typical in practice.”

Tips to cure or diminish sleep apnea

- CPAP (forced air into your nose from a machine) is commonly used. Doesn't work well for me, I would strangle myself with those air hose
- Mouth piece that moves your bottom jaw forward is reasonably easy to use and convenient.
- Multiple surgery options (removing tonsils, improving your nose airway, sawing your jaws from your skull and moving them forward, especially the bottom one, etc...).
- Devices to encourage you not to sleep on your back.
- Go see a real medical professional, don't get advise from me :)

Starting simple

- First, you have a solution looking for a problem :)
- I had the mobsendat arduino board I built at LCA2011

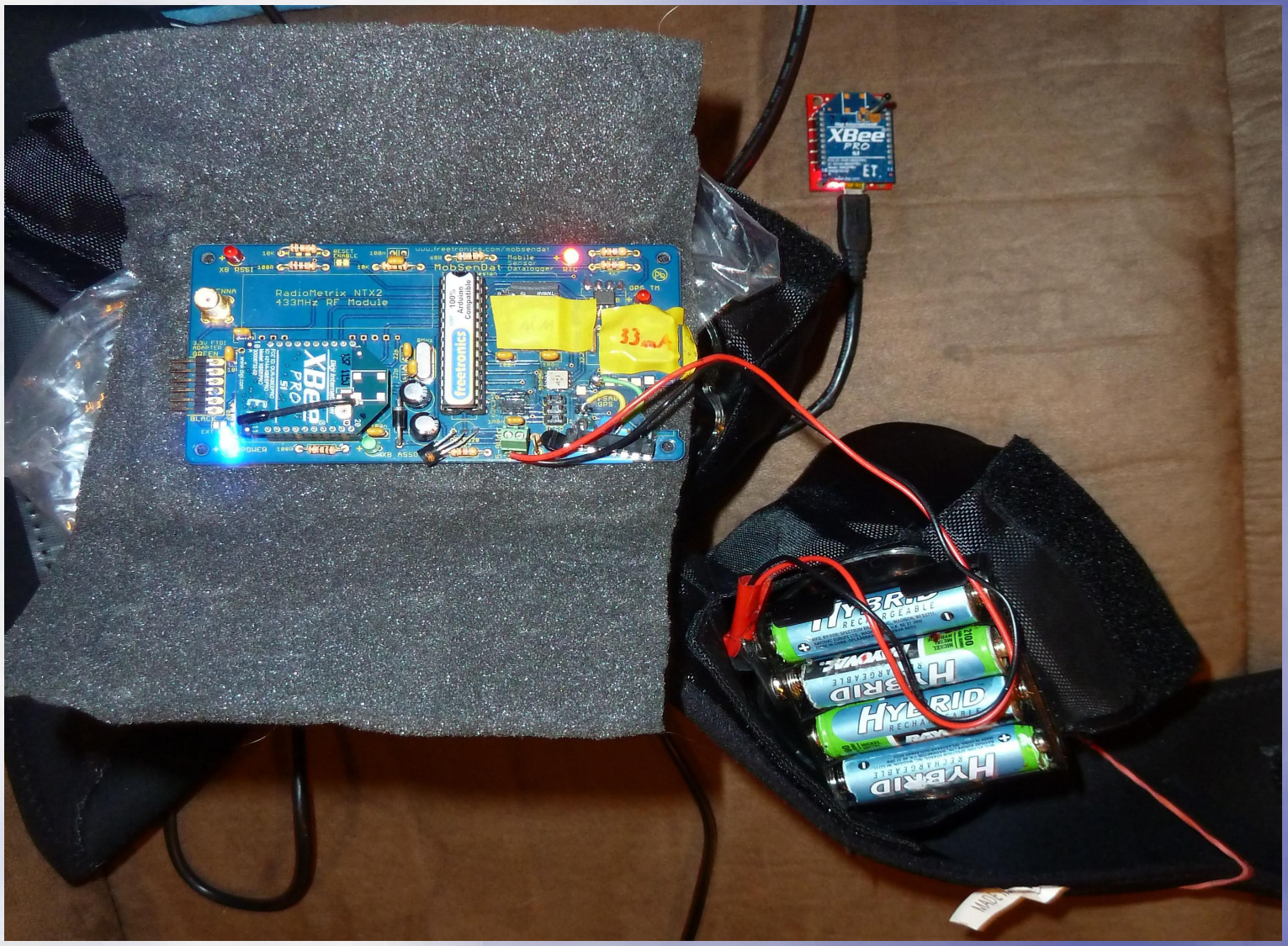


Find a matching problem for your solution

- I wanted to know if my rematee bumper belt really stopped me from sleeping on my back (back sleeping makes sleep apnea worse).

Arduino to the rescue!

- The mobsendat has many sensors. The altimeter or 2 temperature sensors may not come in handy, but the accelerometer will :)



Arduino sleep position logs

```
[1] Using logfile 2012-08-18 23:56:05 instead of 2012/08/12 20:25:24 from arduino
to compute epochoffset
[1] At 2012/08/12 20:31:37 (67), new position is now right (from unknown)
[1] At 2012/08/12 20:33:47 (93), new position is now down (from right)
[1] At 2012/08/12 23:33:13 (2021), new position is now left (from down)
[1] At 2012/08/12 23:55:33 (2289), new position is now down (from left)
[1] At 2012/08/13 00:31:58 (2726), new position is now left (from down)
[1] At 2012/08/13 00:49:08 (2932), new position is now right (from left)
[1] At 2012/08/13 00:54:58 (3002), new position is now down (from right)
[1] At 2012/08/13 01:43:28 (3584), new position is now left (from down)
[1] At 2012/08/13 01:55:48 (3732), new position is now down (from left)
[1] At 2012/08/13 02:06:58 (3866), new position is now left (from down)
[1] At 2012/08/13 02:58:28 (4484), new position is now right (from left)
[1] At 2012/08/13 03:03:43 (4547), new position is now down (from right)
[1] At 2012/08/13 03:13:28 (4664), new position is now left (from down)
[1] At 2012/08/13 03:28:38 (4846), new position is now down (from left)
[1] At 2012/08/13 03:49:43 (5099), new position is now left (from down)
[1] At 2012/08/13 04:09:33 (5335), new position is now right (from left)
[1] At 2012/08/13 04:34:13 (5631), new position is now down (from right)
[1] At 2012/08/13 04:52:58 (5854), new position is now right (from down)

up,    down,  left,  right, unkwn,  hours sleep, pos changes
00.1%, 63.1%, 28.2%, 07.6%, 01.1%,  8.2 H sleep,  18 pos chg
```

Immediate improvements: going wireless

- The proof of concept worked
- Getting logs off the sdcard onto my laptop every day was tedious
- This was supposed to be an excuse to hack and learn about arduino
- The next obvious step was to make the device wireless and use Zigbee/Xbee radios

Zigbee / Xbee


XBee Modules
XBee PRO
Series 2
MaxStream
XBee
Series 2
Digi
XBee
Series 2

Zigbee / Xbee

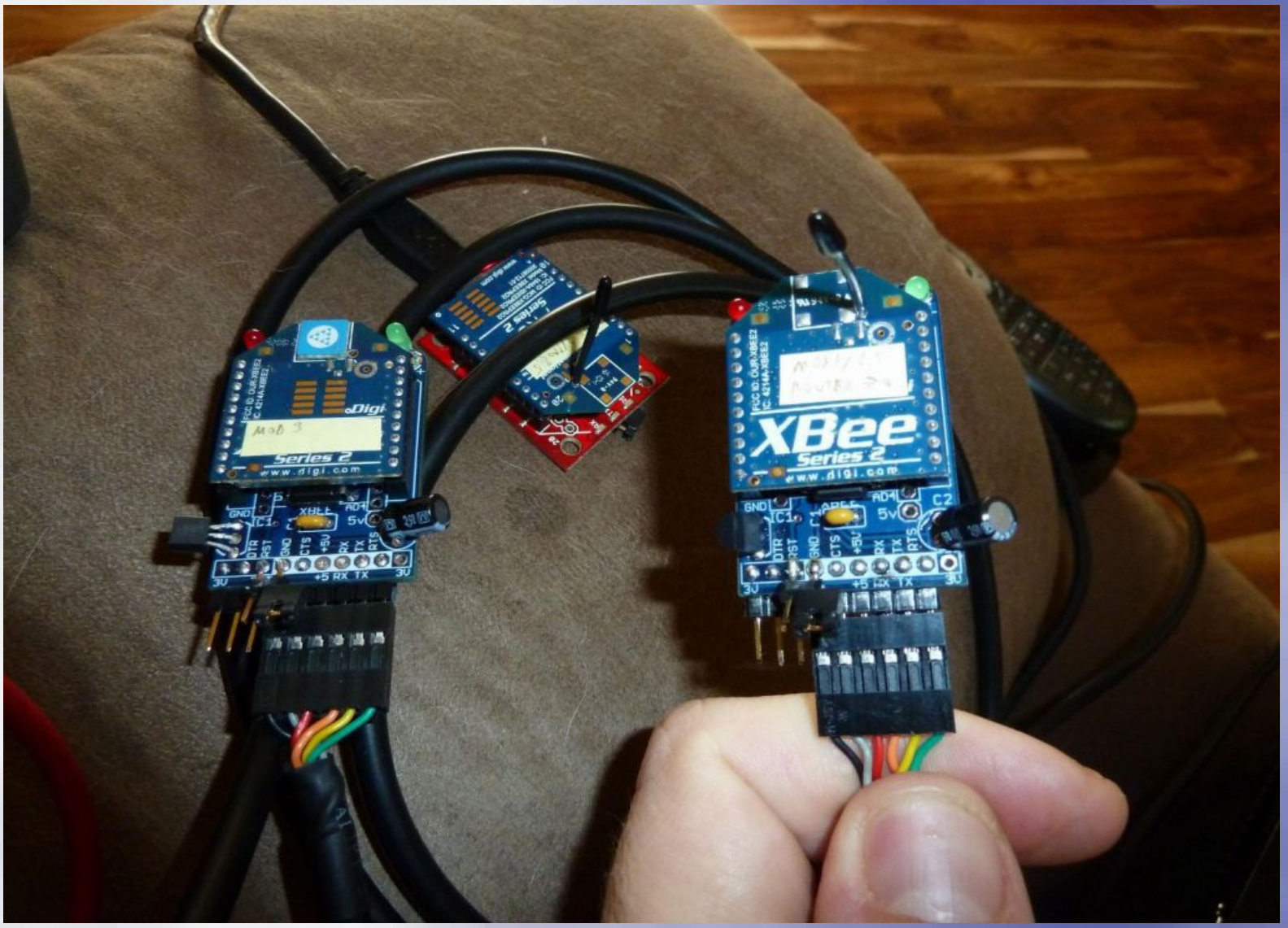
- Simple, small and cheap serial radios
- RS232 interface
- Analog and digital IO can be sampled and transmitted
- Can be run independently (without a computer or arduino).
- Series 1 modules are Point to Point or Broadcast
- Series 2 (aka 2.5) support Mesh Networking for greater range.
- Coordinator, Routers, and End device modules as determined by which firmware you flashed.

Zigbee / Xbee

- Module takes care of routing in mesh networks and retransmission of lost data (up to a buffer size).
- Analog and digital IO can be sampled and transmitted
- Low power use (10mA when not sleeping)
- Xbee Pro modules transmit at 60mW instead of 1mW
- Can run on 3.3V or somewhat less
- Perfect for embedded use
- Default radio used with android projects

Xbee receiving on PC

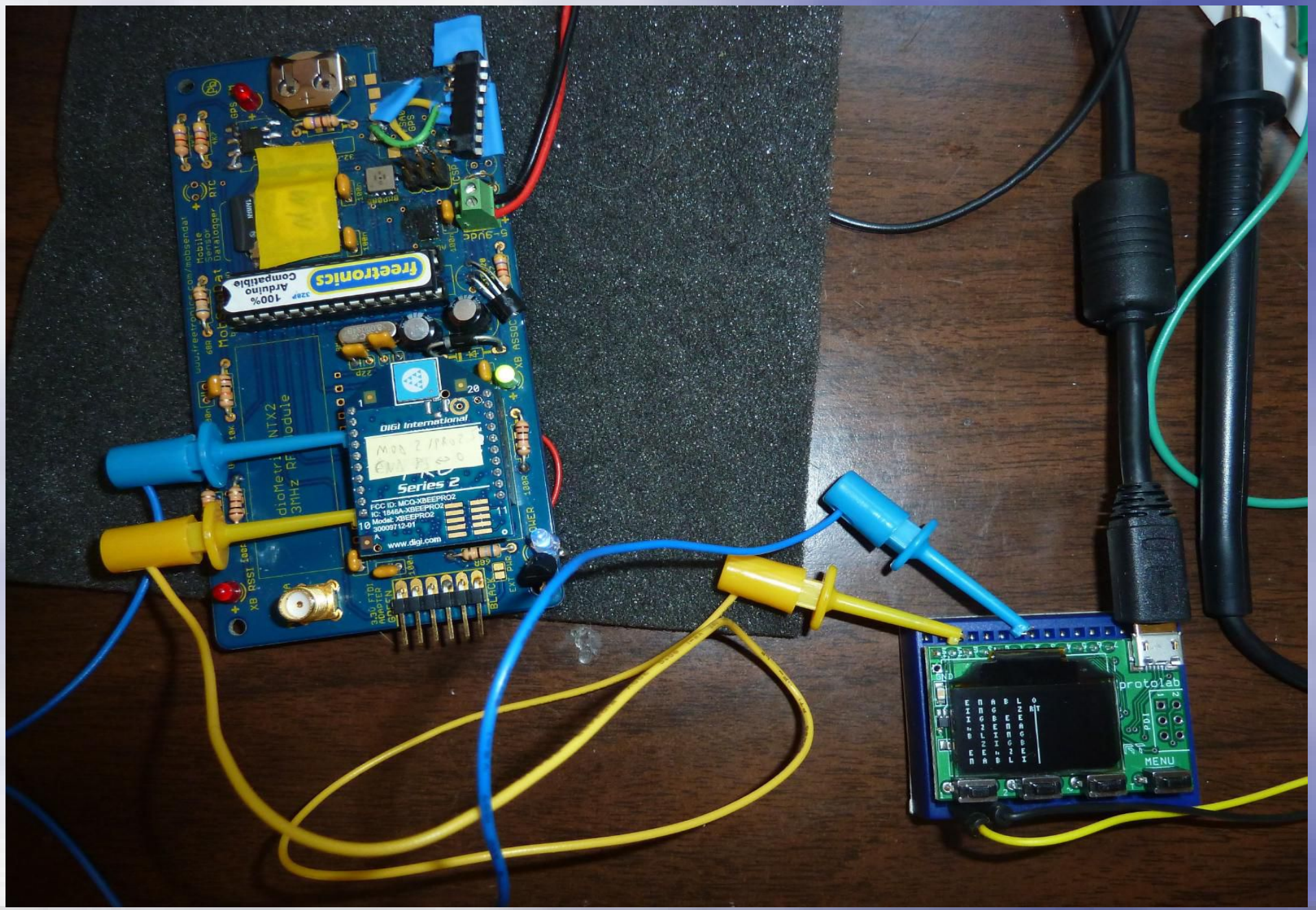
- PC USB/serial interface from sparkfun or adafruit



First problem: Xbee garbage

- Everything was working peachy, until...
- One day I started getting garbage on my PC for the data sent by my arduino board.
- Spent time figuring radio problems, it's kind of opaque.
- Then, I made sure that the Xbee was getting proper serial data by using the excellent xprotolab to do serial decoding with its logic analyzer
- http://www.gabotronics.com/development-boards/xmega-xprotolab.htm

Xbee serial debugging



Xbee garbage explained

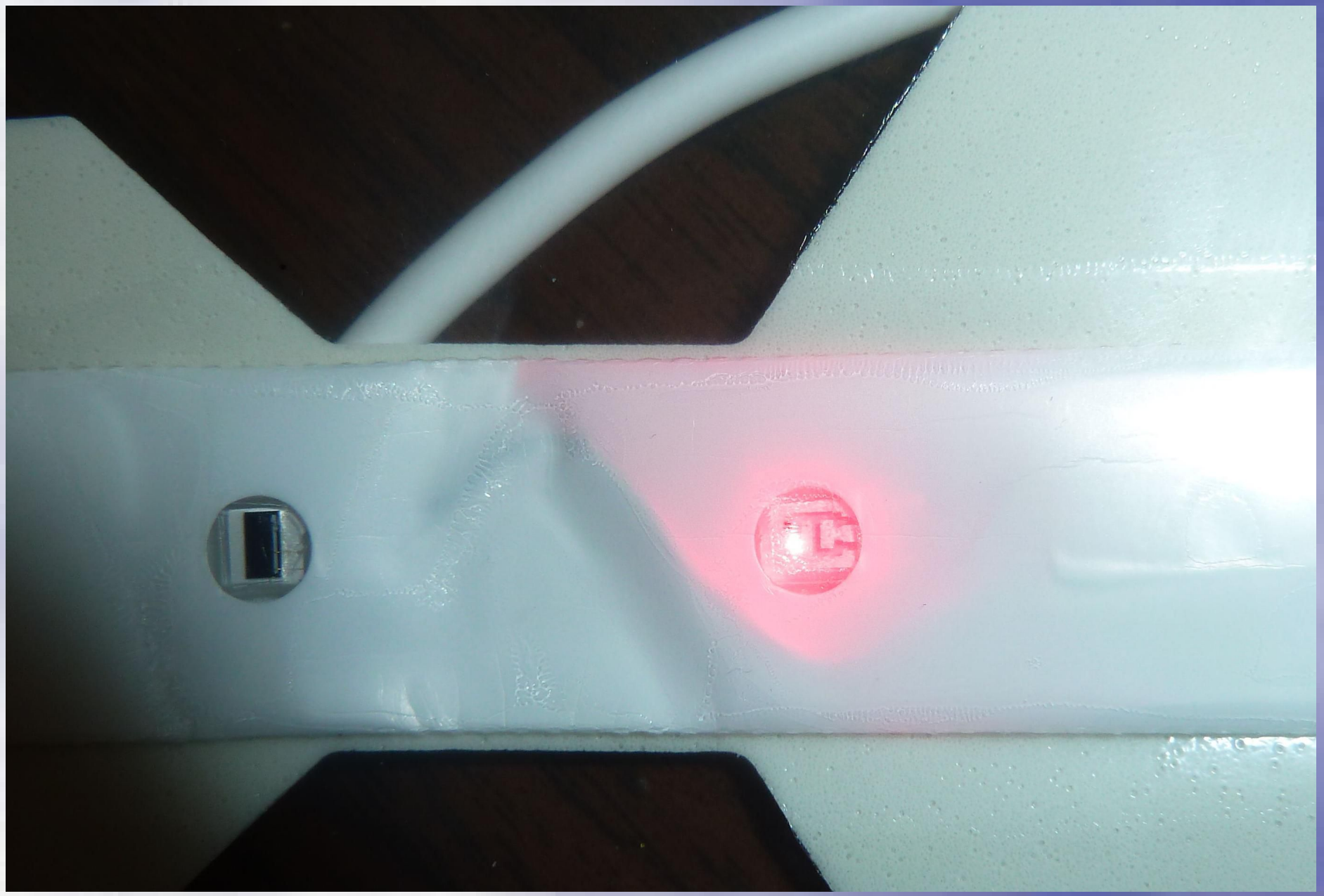
- My Xprotolab had two decoding lines, one was able to get data from my arduino, the other was not.
- The very helpful Gabriel Anzziani who designed the Xprotolab, pointed out that one UART decoding line was done in software, and one in hardware.
- That was enough for me to guess there was a timing problem in the NewSoftSerial arduino library
- Eventually I traced it down to the new avr-gcc optimizing NewSoftSerial enough that it was just too fast
- http://marc.merlins.org/perso/arduino/post_2011-12-12_GCC-AVR-4_5_3-2-Breaks-Arduino-NewSoftSerial.html

Detecting Apnea with an SPO2 sensor

- When you stop breathing, eventually your blood O2 saturation goes down, and that's generally bad.
- Reading SPO2 and logging it was the obvious thing to do after logging sleep positions.
- But it's actually hard to do for the neophyte EE that I am
- Actually commercial sensors do require a lot of engineering work to be precise.
- Turns out, it's even harder with a cheap SPO2 probe: infrared and red are on the same 2 wires in opposite current direction, and I couldn't get anything out of the photo transistor :(

Attempts to get SPO2 on arduino (infrared)

Attempts to get SPO2 on arduino (red)



Getting SPO2: CMS50EW

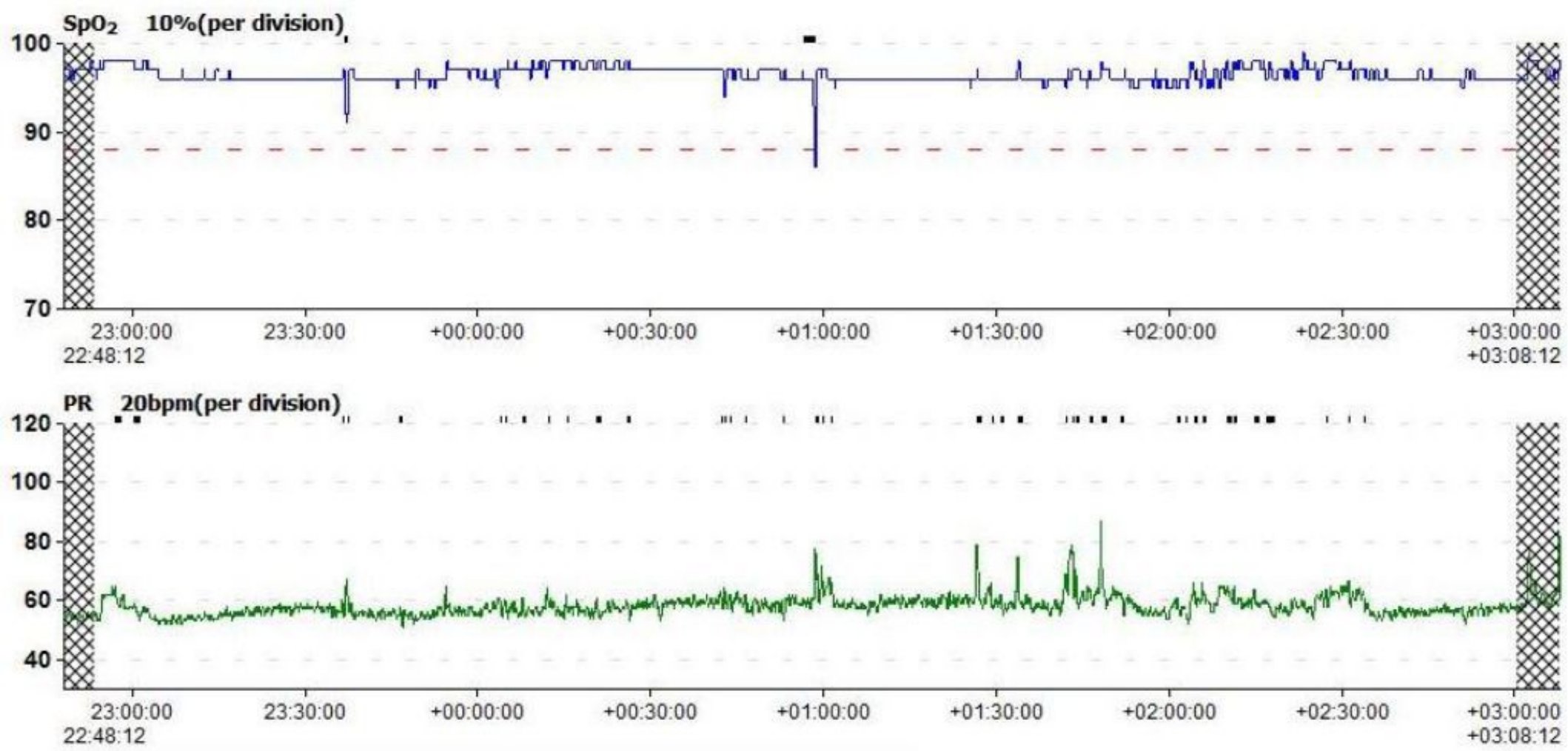
- So, I found this little guy online for $115. It stores data overnight and transmits it real time over bluetooth.

Getting SPO2 is actually hard

- Was the CMS50EW too good to be true?
- Unfortunately yes, the protocol is not open, the bluetooth stack is so bad that it didn't work with 3 out of my 4 windows machines (some VMs) and did not work with any VM .
- Once the data is in the software, there is no data export mode, just graphs.
- It's bulky and awkward to wear at night, it has to be carefully secured with tape to prevent bad readings from exposing the wrong part of the nail (better probes work around that).
- I wasn't too interested in having to do syncs and downloads each night and hand synchronize streams from multiple sources.
- Generally, I found it not workable for my project, and have not yet found other options I can use real time.

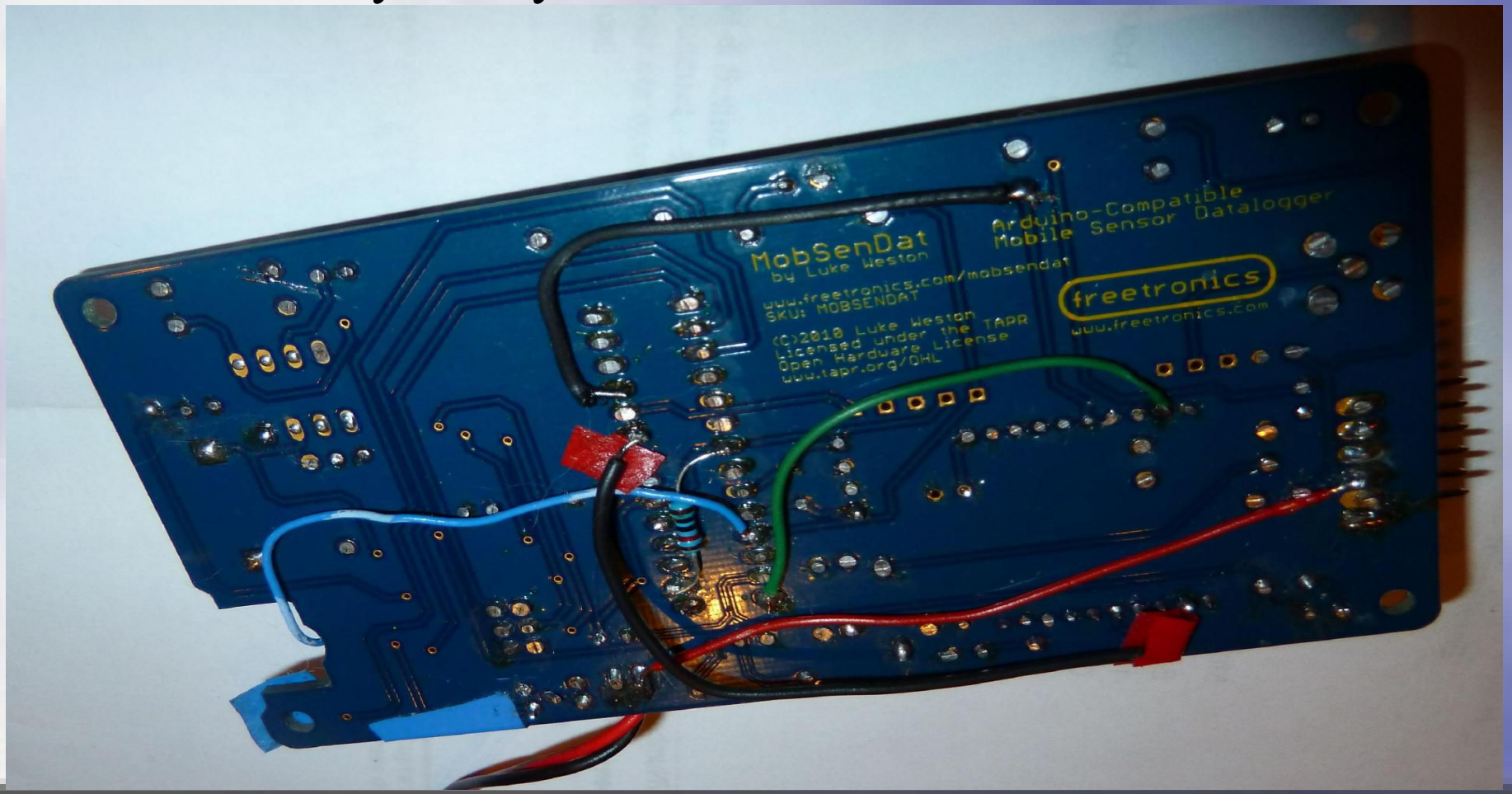
Getting SPO2 is actually hard (3)

- While it was actually hard to get reliable and convenient data from it, it does work, see the apnea event at 01:00 and the heart rate going up when I moved to recover.



Other hacking: putting the Xbee to sleep

- I hacked my mobsendat to send sleep to Pin9/DTR/SleepRQ
- http://itp.nyu.edu/~jl2515/sustain/xbee.htm
- Saves 30-90mA compared to the radio being on all the time, extends battery life by 2-3x.

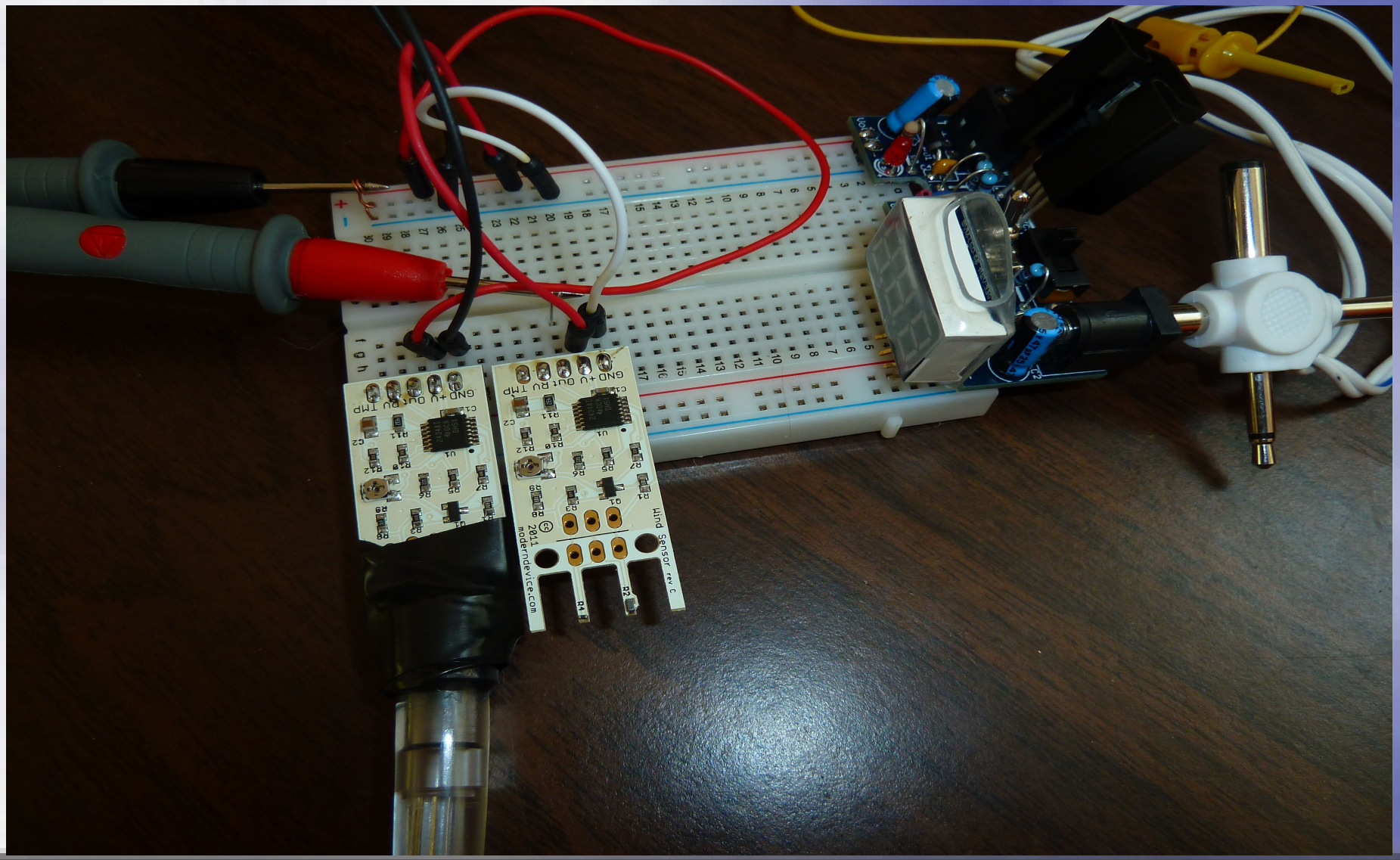


Adding more sensors: breathing detection

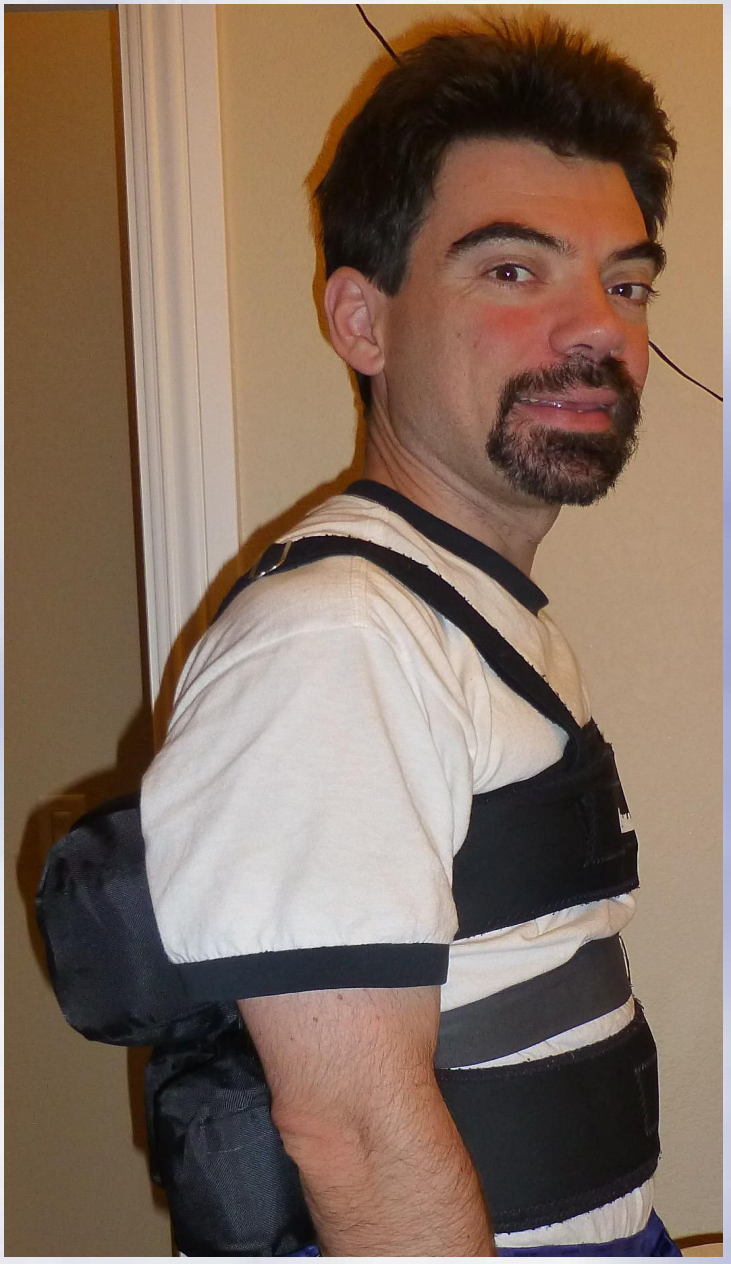
- SPO2 seemed doomed, so I looked into detecting breathing.
- Measuring airflow from the nose seemed like the obvious way to go.
- The wind sensor from modern devices is actually sensitive enough that it can be made to work.
- http://shop.moderndevice.com/products/wind-sensor
- I got some nose cannula online, and technically they are medical instruments with sale restrictions. At least it's not as bad as trying to find syringes to refill cartridges.
- While I'm not fond of nose cannula, I figured I had to try that first.
- The modern devices output could conveniently be tuned to output between 0 and Vcc, trivial to read on an arduino analog pin.

Modern Devices Wind Sensor

- The sensor is based on measuring temperature changes as affected by wind blowing through the sensor.



Looking “good” in the name of science :)



Ready for a “good” night :)

- Two different zeo probes taped so that they don't move off, and the cannula also needs to be pretty tight and taped so that it doesn't slip out of my nose at night.

Zeo Bedside Sleep Manager

- Zeo made a headband that picks up electrical signals from the brain and computes what sleep status you're in (Light, REM, deep, or awake).

http://www.myzeo.com/sleep/shop/featured-products/zeo-sleep-manager-bedside.html

Zeo Bedside Hacking

- What the Zeo folks really did well was to publish full hacking specs, an open firmware, and a demo library
- http://zeorawdata.sourceforge.net/starting.html
- Hacking an arduino USB-Serial 3.3V cable does the trick.

Zeo Bedside Hacking (2)

- Thanks for that little plug in the back of the unit.

Arduino + Zeo output

```
Arduino + Zeo output:
2012-08-26 05:07:48: AF|17830264:9496969797969695969596979A9B9B9B9B9998989795959695959799 9B9B9E9E9F9D9D9B9D9D9D9D9C9C9D9D9C9C9C9C
2012-08-26 05:07:53: POS|17835046:"2012/08/25 17:53:58",,X:0.11,Y:-1.01,Z:0.09,V:5.27,left,rssi:901(DC:0),assoc:838(avg:670|ANS)
2012-08-26 00:00:00: AF|17835124:989A9A9A9A999797989B9D9E9E9E9C9B9B9B9A999897979A9C9E9F9F9F9F9F9F9E9E9C9C9B9B9B9C9C9C9D9D9D9C9C9C
2012-08-26 05:07:53: POS|17840050:"2012/08/25 17:54:03",,X:0.11,Y:-1.00,Z:0.09,V:5.29,left,rssi:901(DC:0),assoc:837(avg:670|ANS)
2012-08-26 05:07:58: AF|17840197:9A9A9C9B9A9A9A9A9A9C9D9F9F9F9E9E9D9D9B9A9B9D9FA0A0A0A1A09E9E9E9E9D9D9C9C9C9B9B9C9E9FA09E9E9D9E9E9D
2012-08-26 05:07:58: POS|17845049:"2012/08/25 17:54:08",,X:0.10,Y:-1.00,Z:0.08,V:5.26,left,rssi:901(DC:0),assoc:838(avg:670|ANS)
2012-08-26 05:08:03: AF|17845125:999A999A9C9E9E9FA0A0A0A09FA0A1A1A1A1A1A0A09F9F9E9E9F9E9E9E9E9E9E9D9C9C9D9EA09F9D9D9B9C9D9D9C9B9A98
2012-08-26 05:08:03: POS|17850050:"2012/08/25 17:54:13",,X:0.09,Y:-1.01,Z:0.09,V:5.31,left,rssi:901(DC:0),assoc:0(avg:670|ANS)
2012-08-26 05:08:08: AF|17850195:9A9C9D9E9E9F9E9D9E9E9E9F9E9E9D9D9C9C9C9C9B9B9B9C9C9C9C9B9A9A9A9A9A9C9E9E9D9B9B9C9B9A9B9A989897989B
2012-08-26 05:08:08: POS|17855047:"2012/08/25 17:54:18",,X:0.10,Y:-1.00,Z:0.09,V:5.26,left,rssi:901(DC:0),assoc:0(avg:502|ANS)
2012-08-26 05:08:10: Zeo Sleep state: REM
```

```
2012-08-26 05:07:43: AF|17825341:9897989896979496969696969797999A
9B9A9A9A99989798989795959 89A9C9D9E9F9F9E9D9C9C9B9A9A9A99999898
98 97 98 9A: breathing input samples (ADC is 0 to 1023 shrunk to 8 bits: 384 to 640)

2012-08-26 05:07:43: POS|17830189:"2012/08/25 17:53:53",,
X:0.10,Y:-1.00,Z:0.10,V:5.27,left,rssi:901(DC:0),assoc:838(avg:502|ANS)
2012-08-26 05:07:43: Time logged on server
POS|17830189: position sample at 17830,189 seconds from boot.
"2012/08/25 17:53:53": Time on the arduino RTC clock (can be off if not reset)
X:0.10,Y:-1.00,Z:0.10: accelerometer values
V:5.27: input voltage from battery
left: sleeping position derived from the accelerometers
rssi: analog value of signal strength received from coordinator or nearest router
DC: disconnect count, how many samples RSSI was 0, used to cancel the Xbee sleep
Assoc: analog value of assoc output from zigbee (usually 0 or 838-ish)
Avg: average of the last 10 assoc samples to know if we're talking to the coordinator
ANS: Average No Sleep (don't sleep when the association LED is blinking

2012-08-26 05:08:10: Zeo Sleep state: REM
Logs the sleep state gathered by Zeo, and band on my head, or back in the doc
```

Graphing Airflow

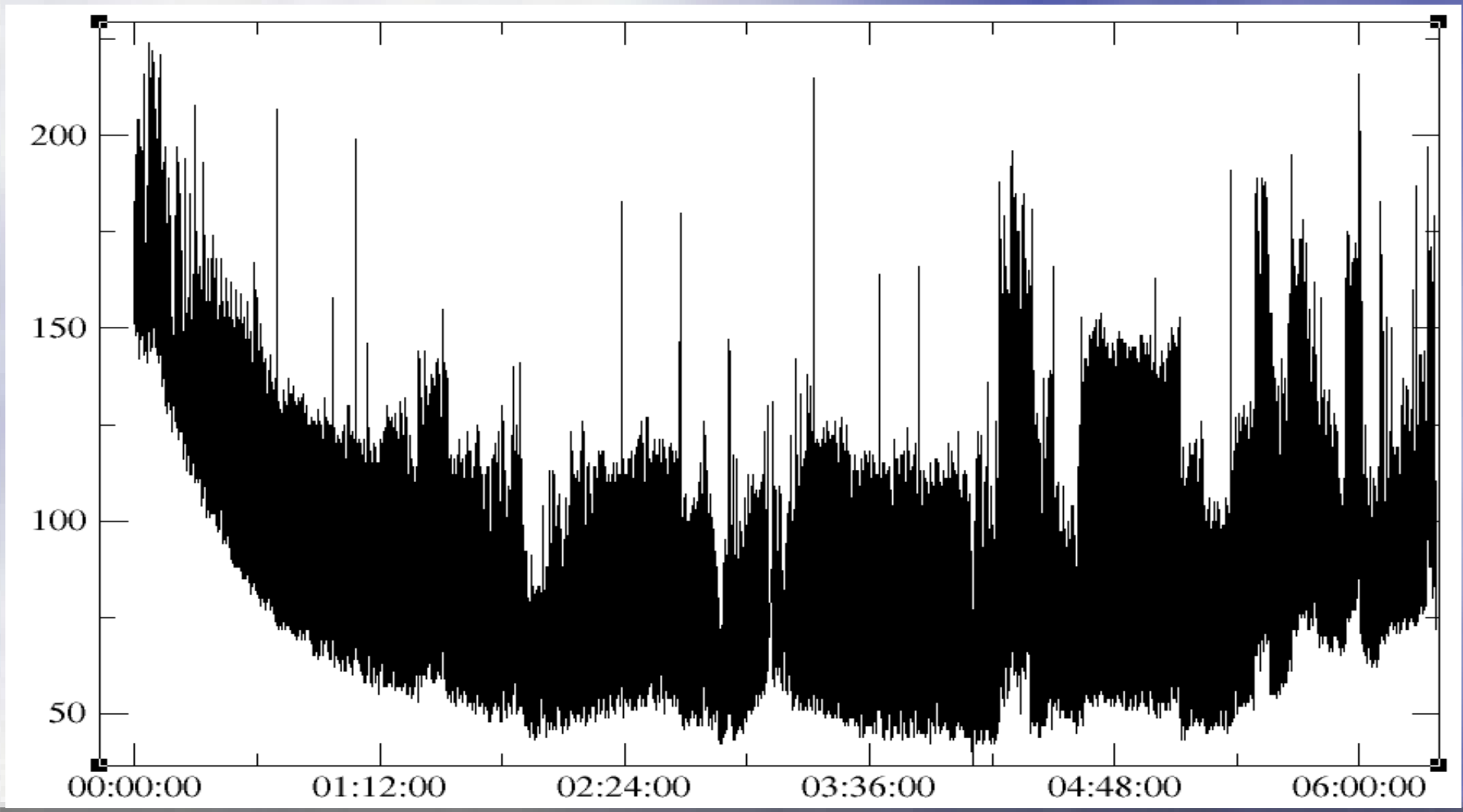
- Every time you want to graph on linux, you hear about gnuplot,
- Unfortunately gnuplot does not deal with sub second data, and breathing should be sampled at 10Hz at least.
- Grace/xmgrace did the job once input data dates are converted:

```
Arduino + Zeo output:
2012-08-26 05:07:43: AF|17825341:9897989896979496969696969797999A9B9A9A9A99989798989795959 89A9C9D9E9F9F9E9D9C9C9B9A9A9A99999898
2012-08-26 05:07:43: POS|17830189:"2012/08/25 17:53:53",,X:0.10,Y:-1.00,Z:0.10,V:5.27,left,rssi:901(DC:0),assoc:838(avg:502|ANS)
2012-08-26 05:07:48: AF|17830264:9496969797969695969596979A9B9B9B9B99989897959596959597999B9B9E9E9F9D9D9B9D9D9D9C9C9D9D9C9C9C9C
2012-08-26 05:07:53: POS|17835046:"2012/08/25 17:53:58",,X:0.11,Y:-1.01,Z:0.09,V:5.27,left,rssi:901(DC:0),assoc:838(avg:670|ANS)
2012-08-26 00:00:00: AF|17835124:989A9A9A9A999797989B9D9E9E9E9C9B9B9B9A999897979A9C9E9F9F9F9F9F9F9F9E9E9C9C9B9B9B9C9C9C9D9D9D9C9C9C
2012-08-26 05:07:53: POS|17840050:"2012/08/25 17:54:03",,X:0.11,Y:-1.00,Z:0.09,V:5.29,left,rssi:901(DC:0),assoc:837(avg:670|ANS)
2012-08-26 05:07:58: AF|17840197:9A9A9C9B9A9A9A9A9A9C9D9F9F9F9E9E9D9D9B9A9B9D9FA0A0A0A1A09E9E9E9E9D9D9C9C9C9B9B9C9E9FA09E9E9D9E9E9D
2012-08-26 05:07:58: POS|17845049:"2012/08/25 17:54:08",,X:0.10,Y:-1.00,Z:0.08,V:5.26,left,rssi:901(DC:0),assoc:838(avg:670|ANS)
2012-08-26 05:08:03: AF|17845125:999A999A9C9E9E9FA0A0A0A09FA0A1A1A1A1A1A0A09F9F9E9E9F9E9E9E9E9E9E9D9C9C9D9EA09F9D9D9B9C9D9D9C9B9A98
2012-08-26 05:08:03: POS|17850050:"2012/08/25 17:54:13",,X:0.09,Y:-1.01,Z:0.09,V:5.31,left,rssi:901(DC:0),assoc:0(avg:670|ANS)
2012-08-26 05:08:08: AF|17850195:9A9C9D9E9E9F9E9D9E9E9E9F9E9E9D9D9C9C9C9C9B9B9B9C9C9C9C9B9A9A9A9A9A9C9E9E9D9B9B9C9B9A9B9A989897989B
2012-08-26 05:08:08: POS|17855047:"2012/08/25 17:54:18",,X:0.10,Y:-1.00,Z:0.09,V:5.26,left,rssi:901(DC:0),assoc:0(avg:502|ANS)
2012-08-26 05:08:10: Zeo Sleep state: REM

Xmgrace input:
2012-08-26T00:18:30.1 84
2012-08-26T00:18:30.2 82
2012-08-26T00:18:30.3 79
2012-08-26T00:18:30.4 76
2012-08-26T00:18:30.5 73
2012-08-26T00:18:30.6 69
2012-08-26T00:18:30.7 65
2012-08-26T00:18:30.8 62
2012-08-26T00:18:30.9 59
2012-08-26T00:18:31.0 56
2012-08-26T00:18:31.1 54
2012-08-26T00:18:31.2 52
```

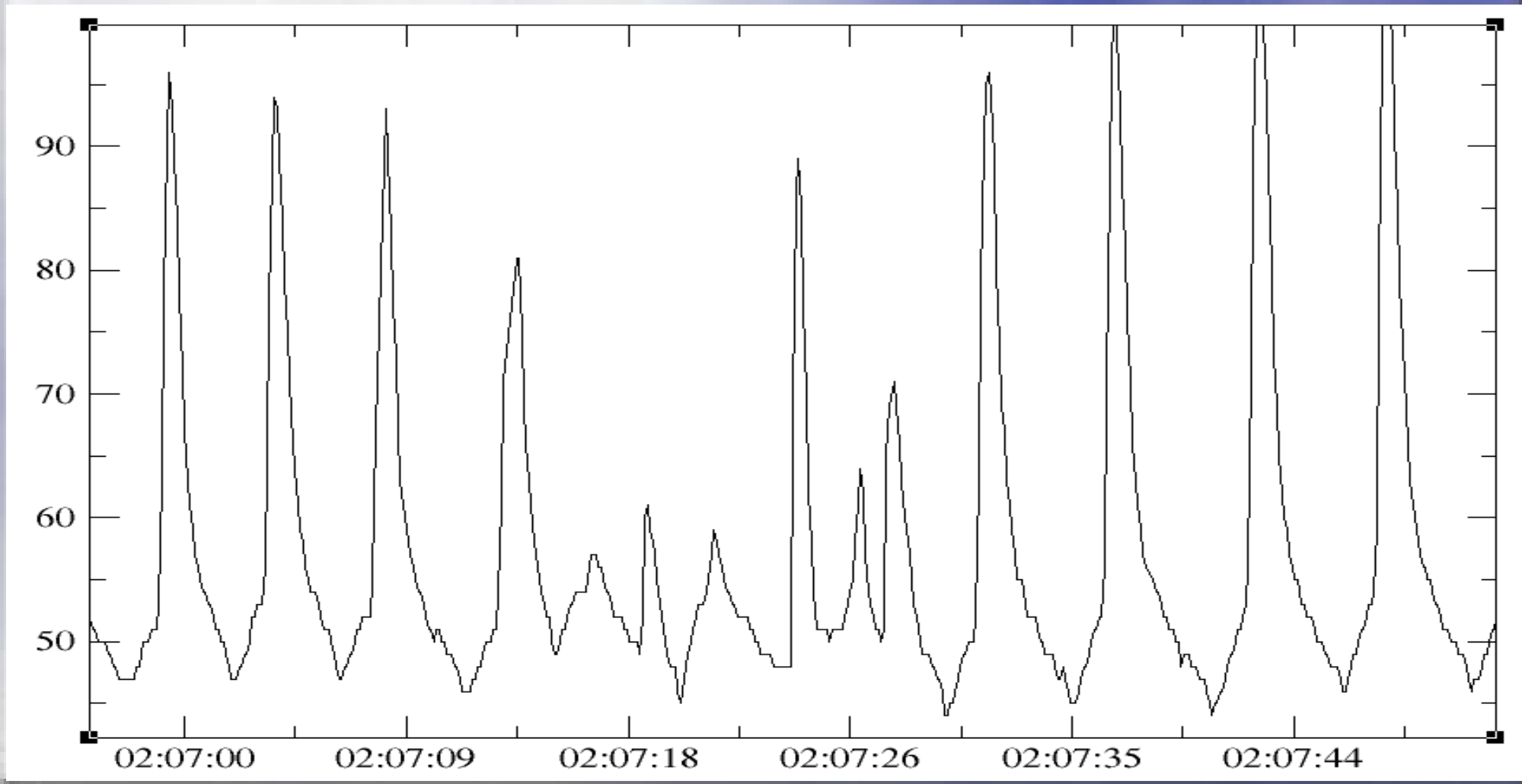
Nose cannula graphs

- On the surface, graph looks interesting
- Graph going down is due to temperature in the room going down.



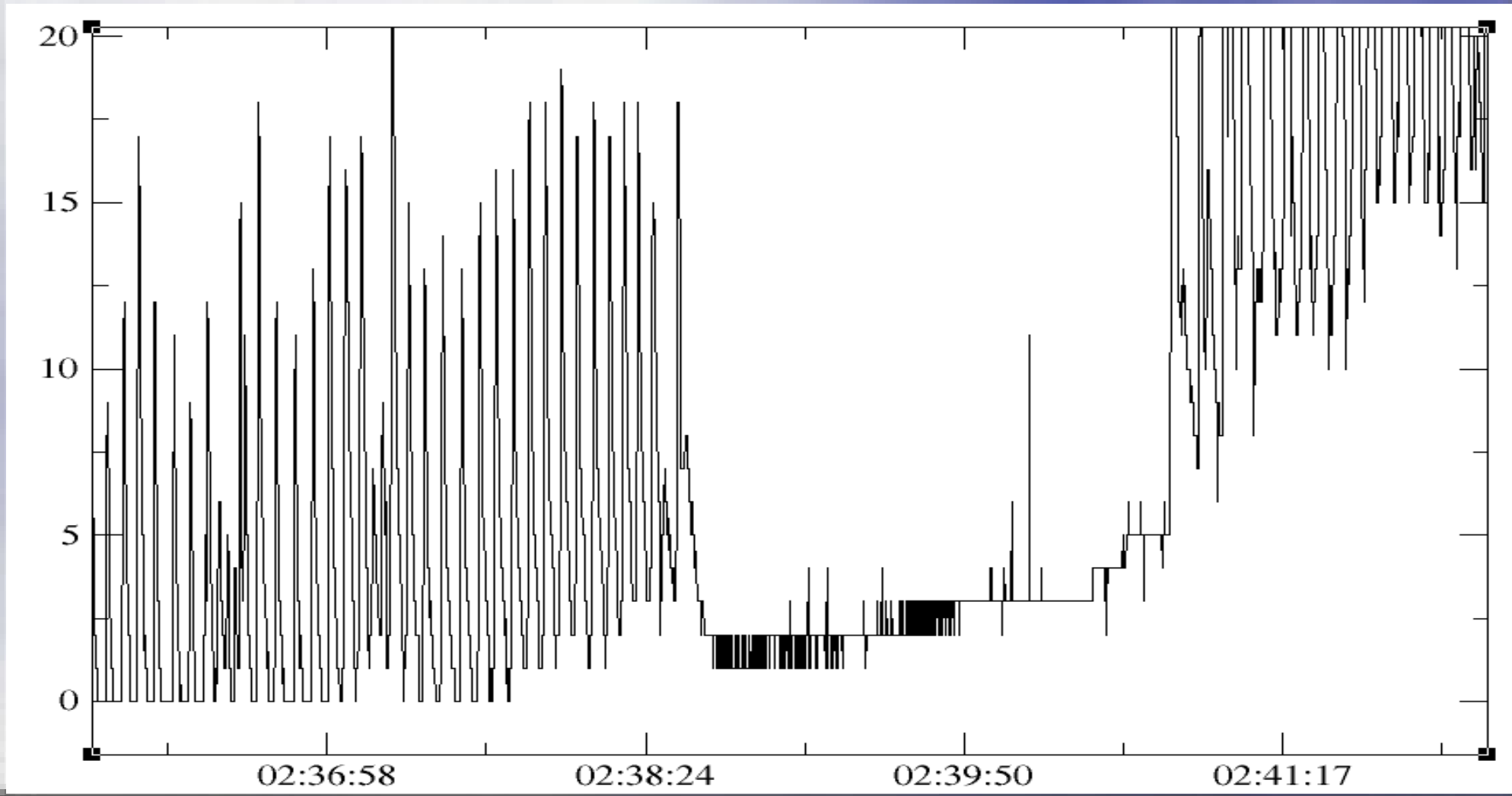
Nose Canula graphs (2)

- Zooming in shows that things aren't as simple
- Peak detection is going to pick up some false breaths
- Both inhale and exhale can go in the tube and create a peak



Nose Canula graphs (3)

- While the cannula was reasonably reliable, I move a lot and I could block the tubes, showing no breathing when in fact I didn't stop breathing for 2.5mn.



Breathing detection issues

- Ok, so I look like I dork with all that stuff on, but that was merely the beginning :)
- Because it uses the batteries to warm a heating element, it drains my 4 AAs in a single night.
- I had to tape the tubes so that I they didn't get ripped off my face with my head on the pillow.
- I'm pretty sure the cannula makes my sleeping worse.
- It's possible to twist or block the tubes and block airflow.
- It needs to be calibrated for room temperature that can change.
- Have to find a way to clean them (nose water vapour and germs)
- All it all, not perfect, but it was workable.

Trying again, without cannula

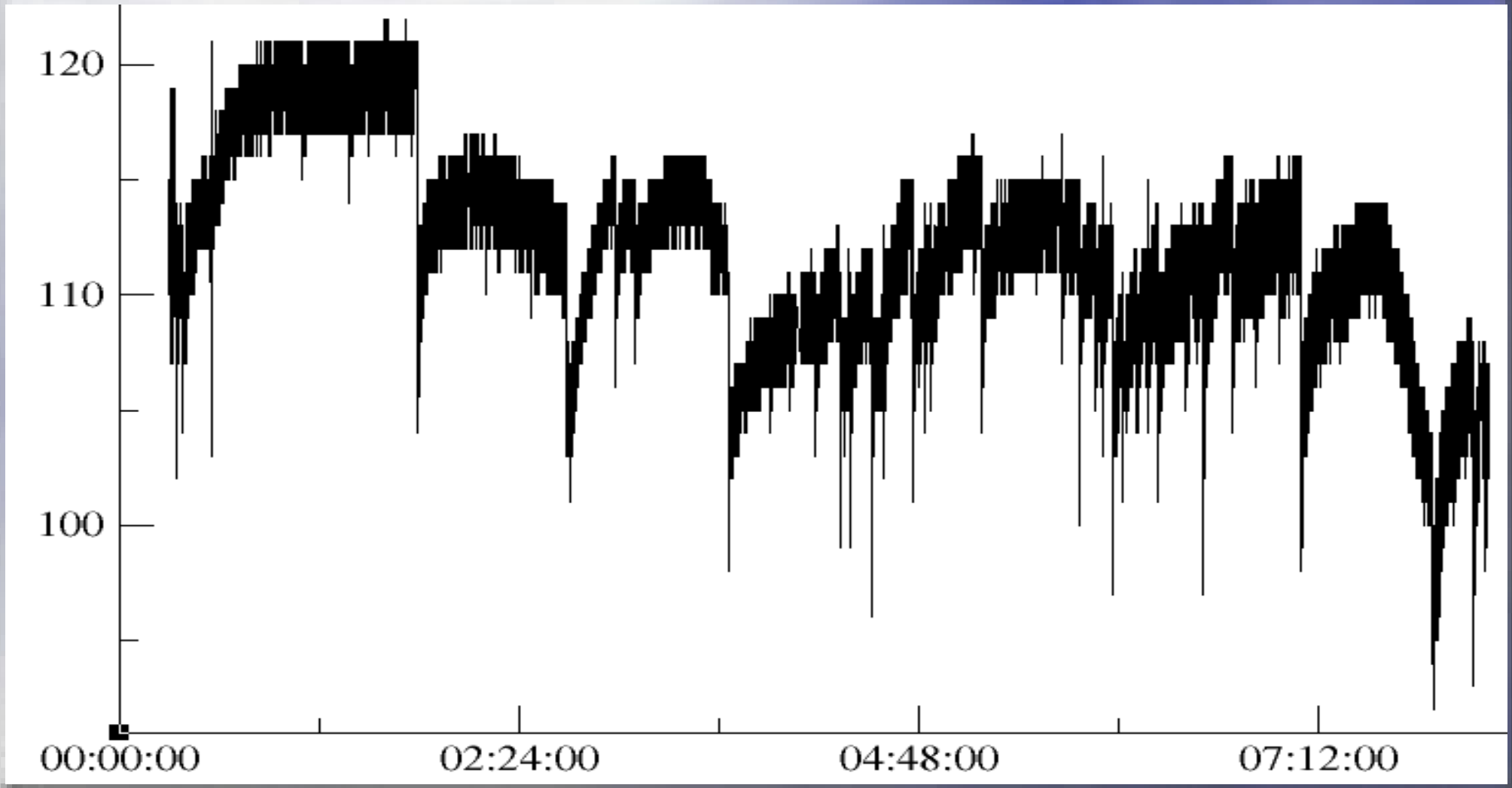
- At the time, I figured there were 2 ways to measure breathing, and the other was to measure expansion of the chest/belly with some kind of belt
- Stretch sensor first returned this rubber band:
  http://www.adafruit.com/products/519
  http://www.adafruit.com/blog/2011/11/02/new-product-conductive-rubber-cord-stretch-sensor-extras/
- It was a bit awkward to make a band I could wear around my waist at night to measure breathing.
- As expected, results showed when I was changing positions in the middle of the night, and that could be corrected for.
- But the results didn't really work out, it was hard to get enough stretch on it that could be measured easily.
- In other words, one could not tell breathing from those readings.
- Also, the band had a tendency to break if stretched too much.

Stretch rubber band

- I reused a hard rate monitor strap to attach the band that gets stretched and created a plug for my board.

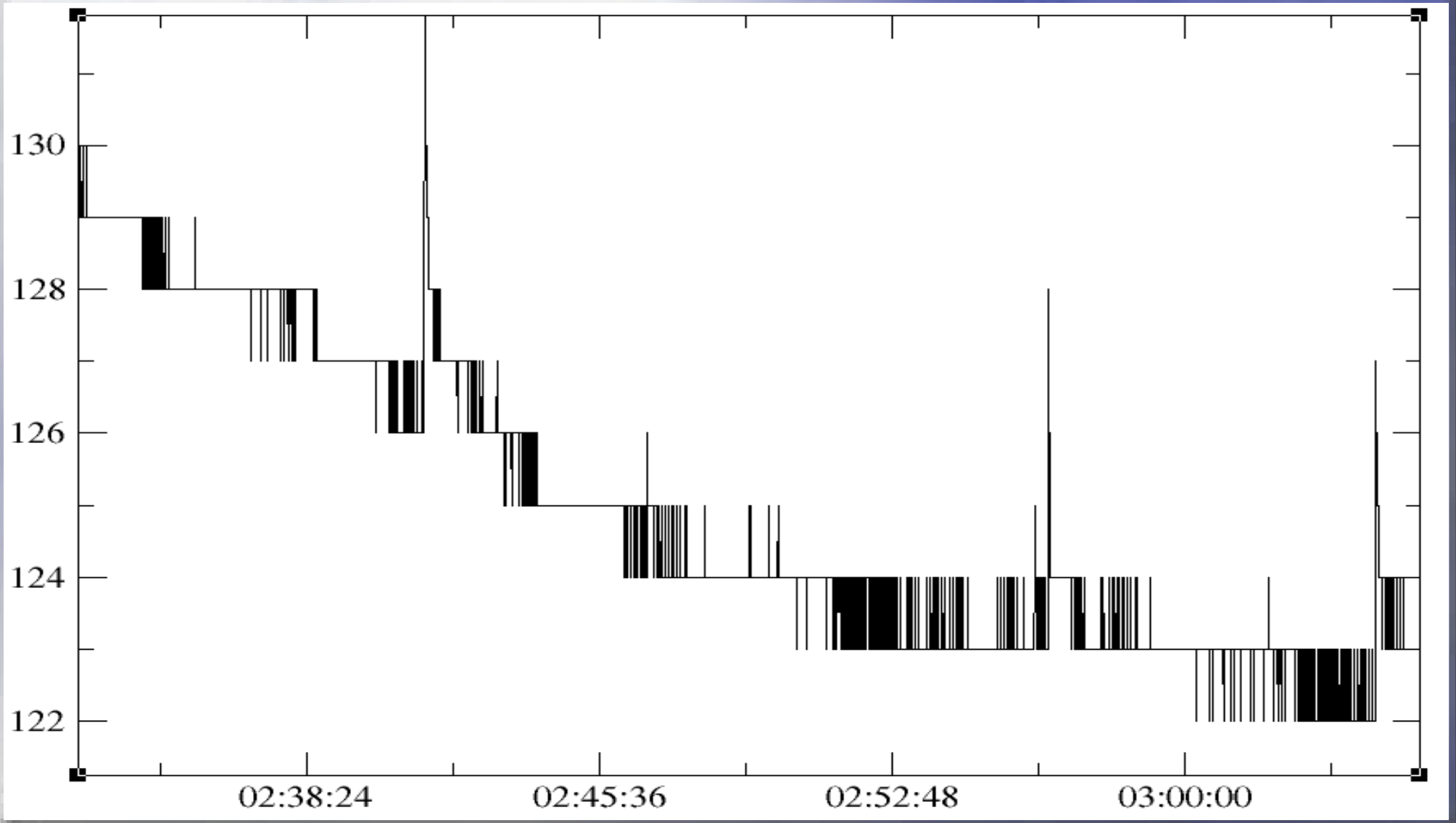
Breathing measured with stretch sensor band

- The data didn't look promising, only an amplitude of 3 or 4 analog steps.
- Mmmh, there is also a noise problem, we'll get back to that.



Breathing measured with stretch sensor (2)

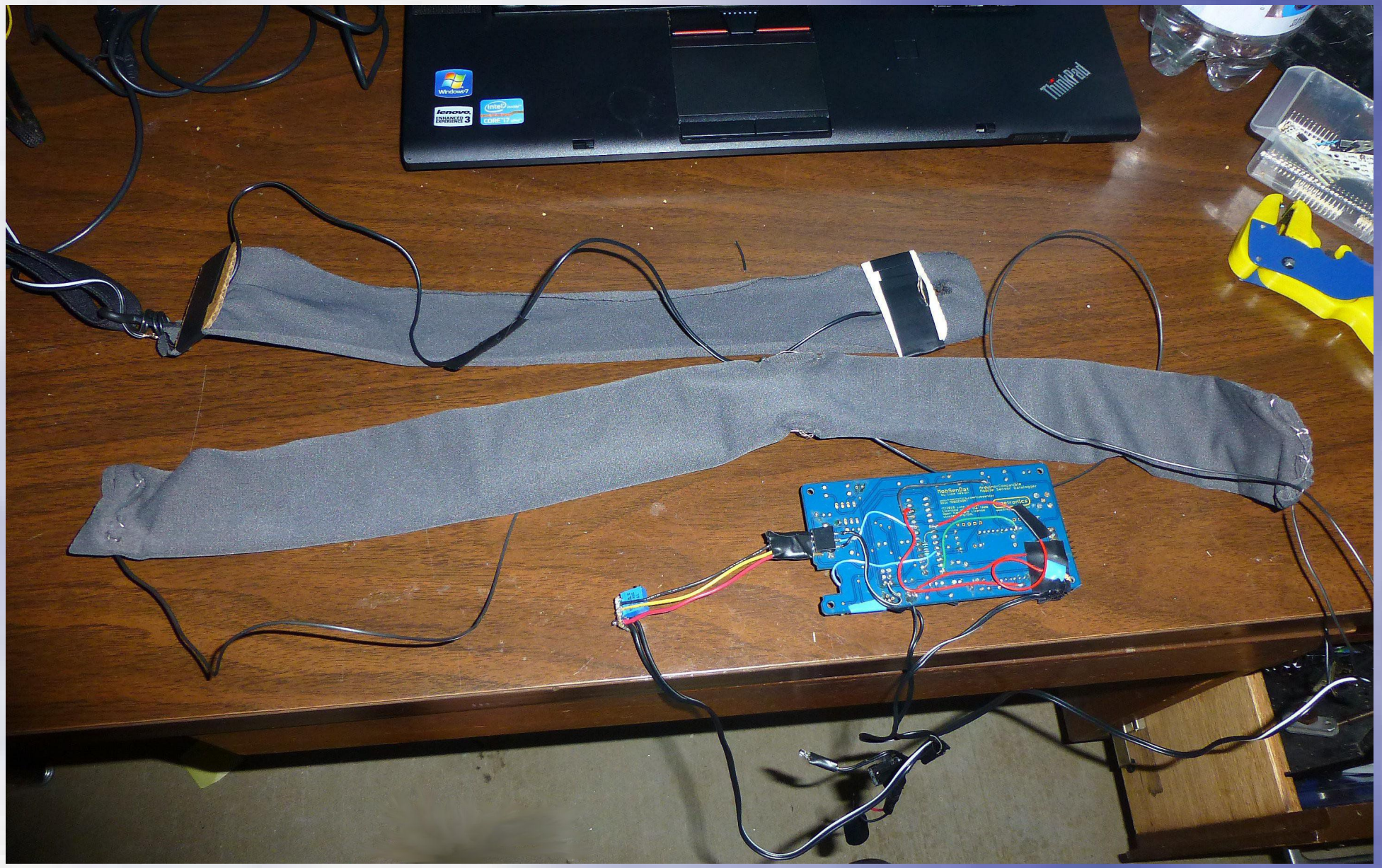
- Zooming in shows that the data is not usable.



Trying stretchable fabric

- Searching on the net gave me some hits of textile with variable resistance: http://www.kobakant.at/DIY/?p=1762 and http://www.kobakant.at/DIY/?p=210
- The only option I found for sale in the US was STRETCH CONDUCTIVE FABRIC from http://www.lessemf.com/fabric.html
- It worked, but resistance was too low (just a few ohms)
- Then, I found conductive textile/yarn at http://www.eeonyx.com/eeontex.php and http://www.eeonyx.com/eeonyarn.php who nicely gave me a sample.
- LG-SLPA-16K-VR fabric ended up being the winner: 25 to 50kOhm for a piece that goes across my chest.

Trying again with stretch fabric

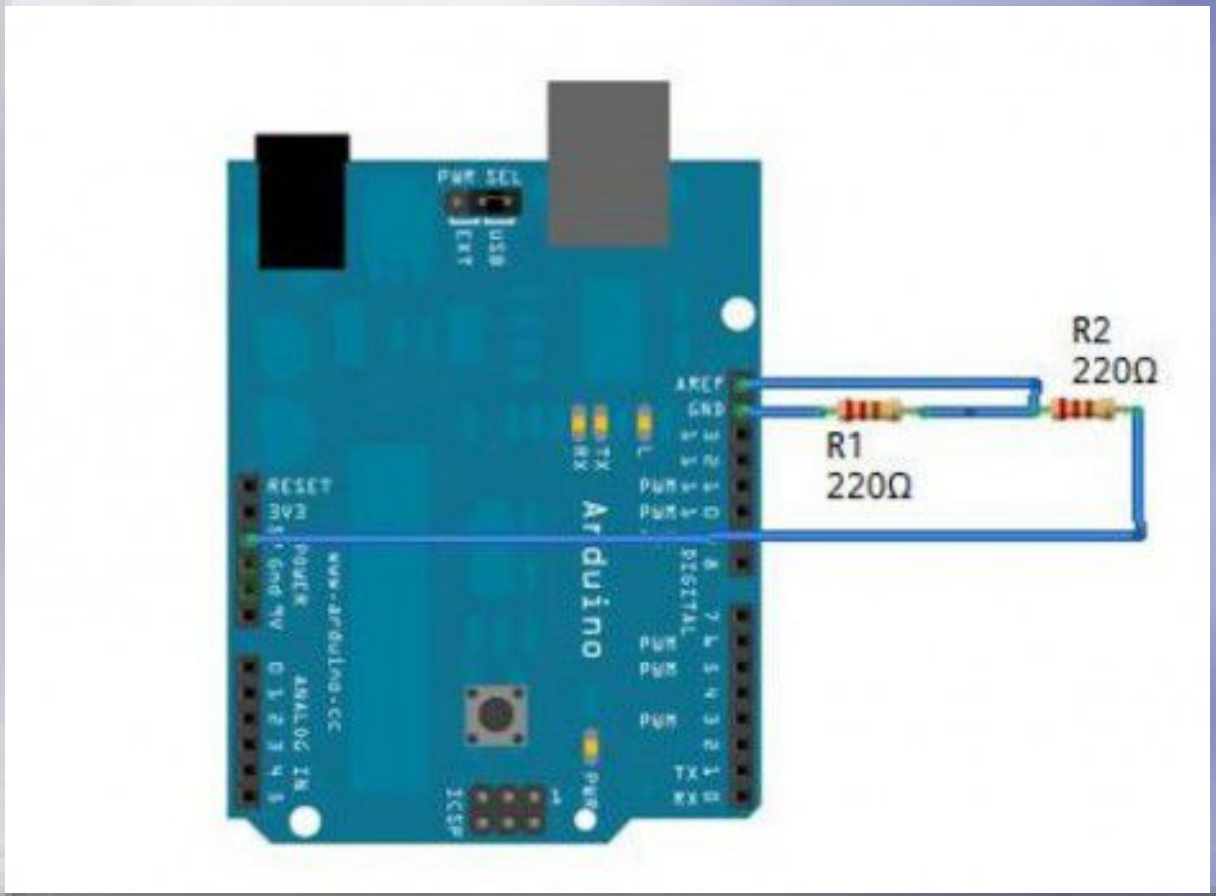


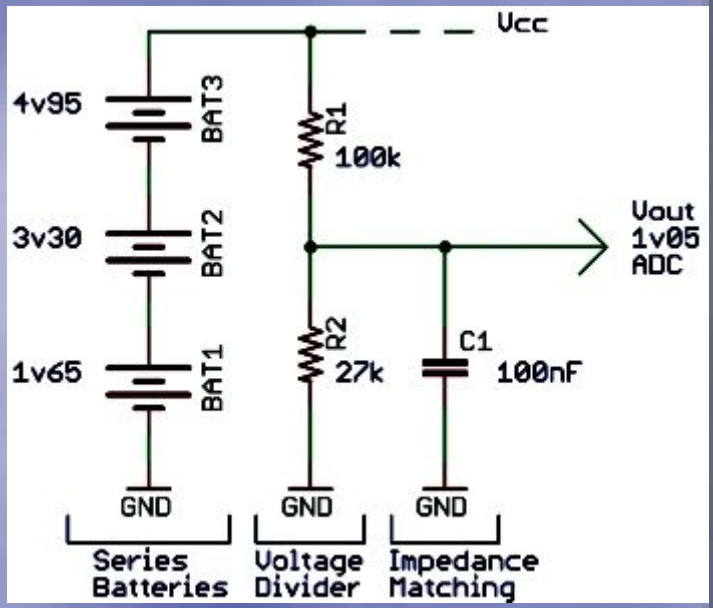
Short eeonyx fabric belt

- First, I figured a small amount of fabric would work great.
- Total resistance was 50 to 100kOhms, which was great to limit battery consumption.
- Then, I found out that my voltage divider was measuring proper voltage, but the arduino was giving ADC readouts all over the place.
- Turns out the impedance of my voltage divider was too high compared to the expected impedance for an arduino ADC (100k vs 10k)
- But adding a capacitor, or two, fixes the problem since the capacitor loads up with the expected voltage and can hold it long enough for the arduino to sample it.

Arduino analog reads with voltage dividers

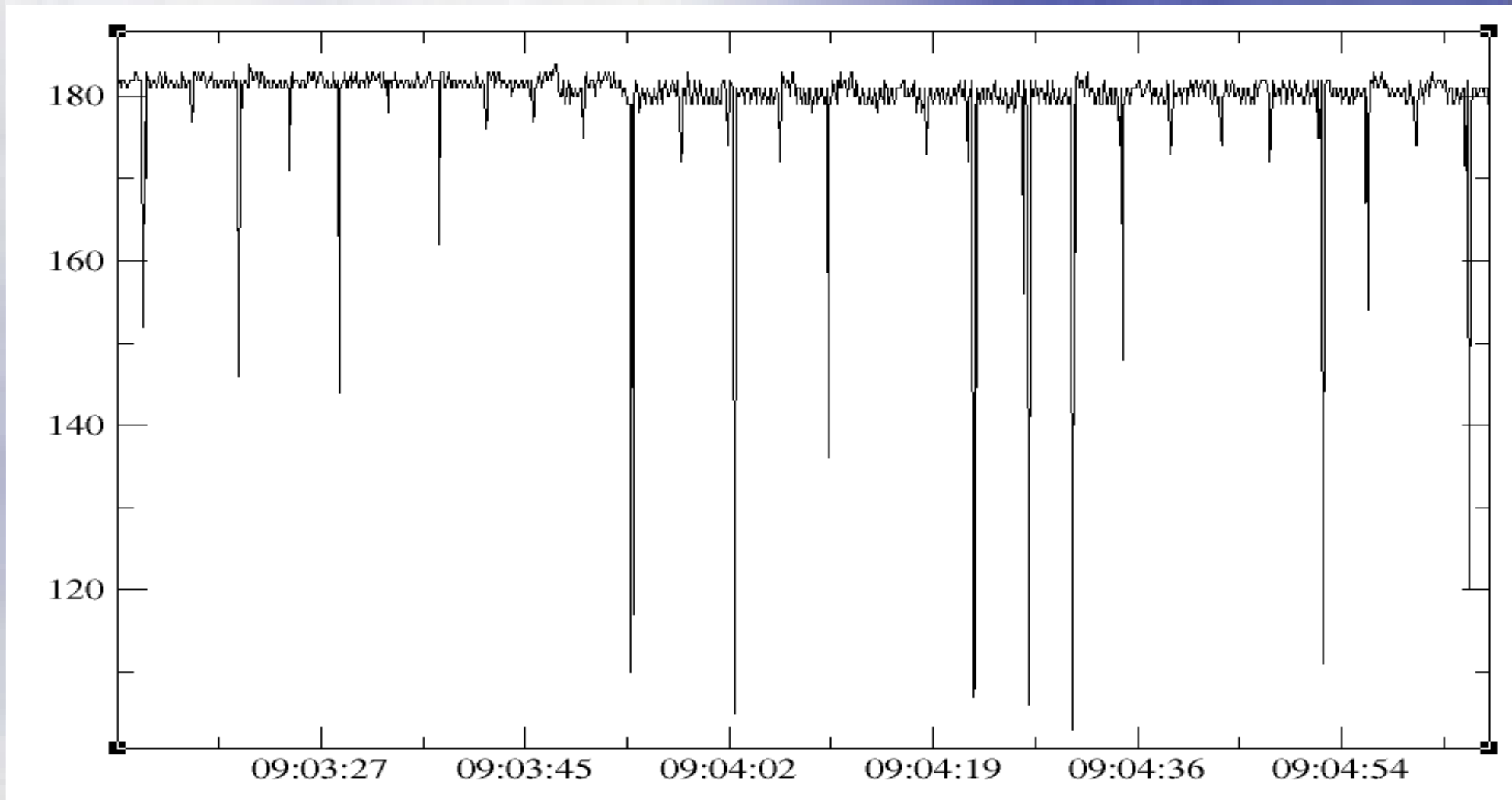
- Using R2 as a variable resistor to measure breathing, measuring voltage between GND and R2 with an arduino gives a variable analog reading.
- In my case, R1 is a variable resistor I use for tuning.





Electronics:why things never fully work

- Things did get better, but then I got this:



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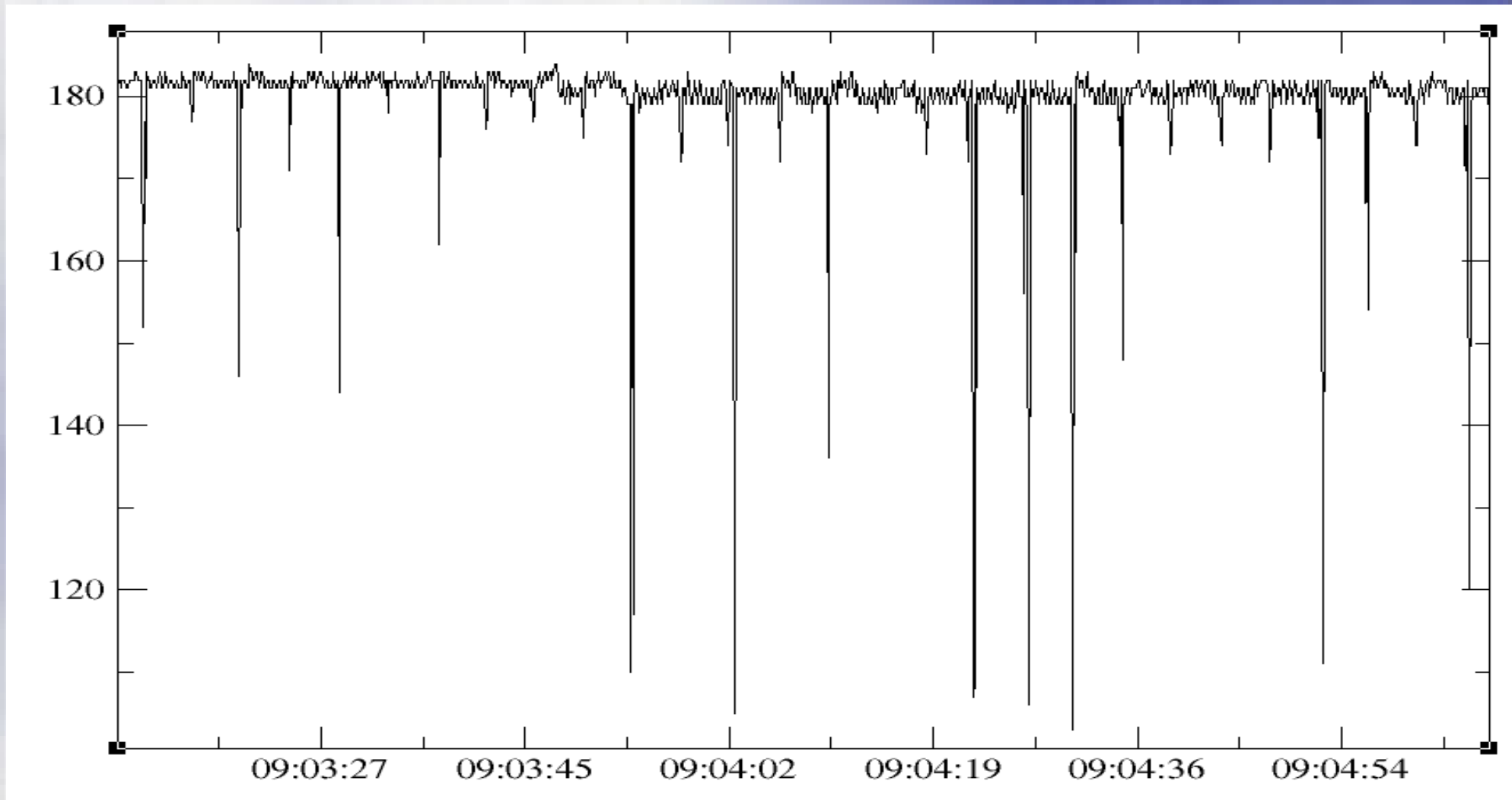
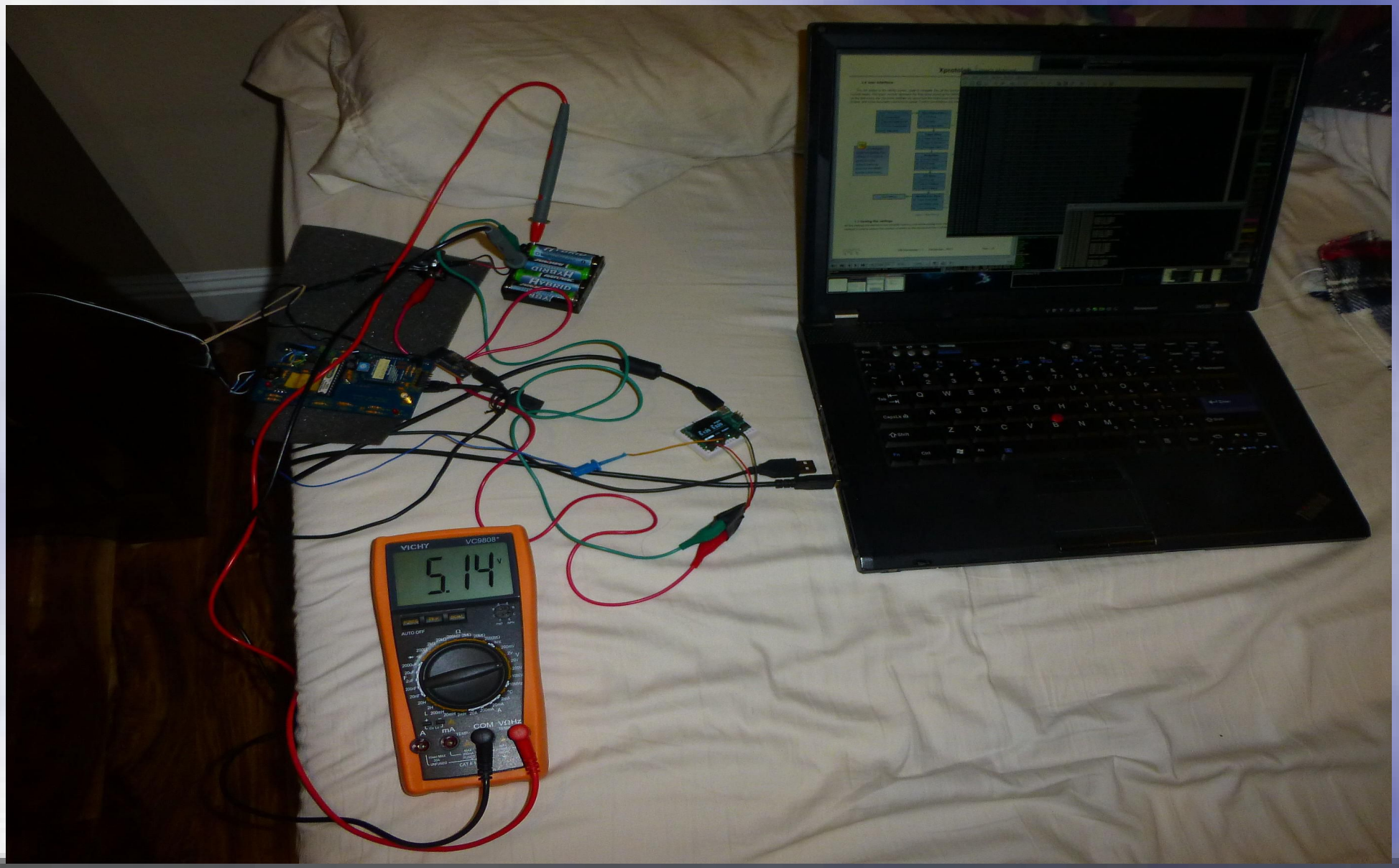
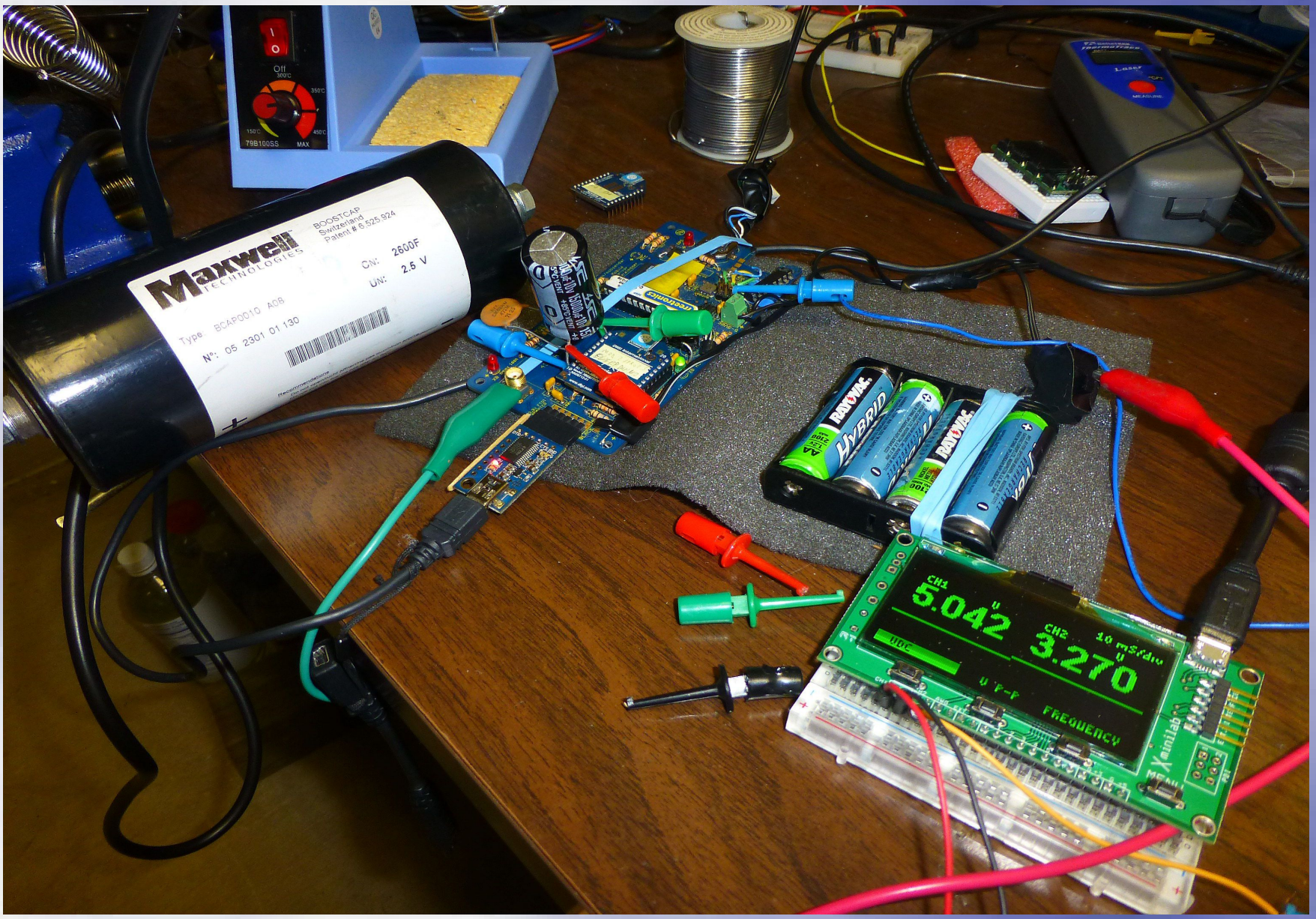


You need an understanding S.O.

- Sometimes bedtime became debugging time :)



Killing the noise: you just need a bigger cap :)

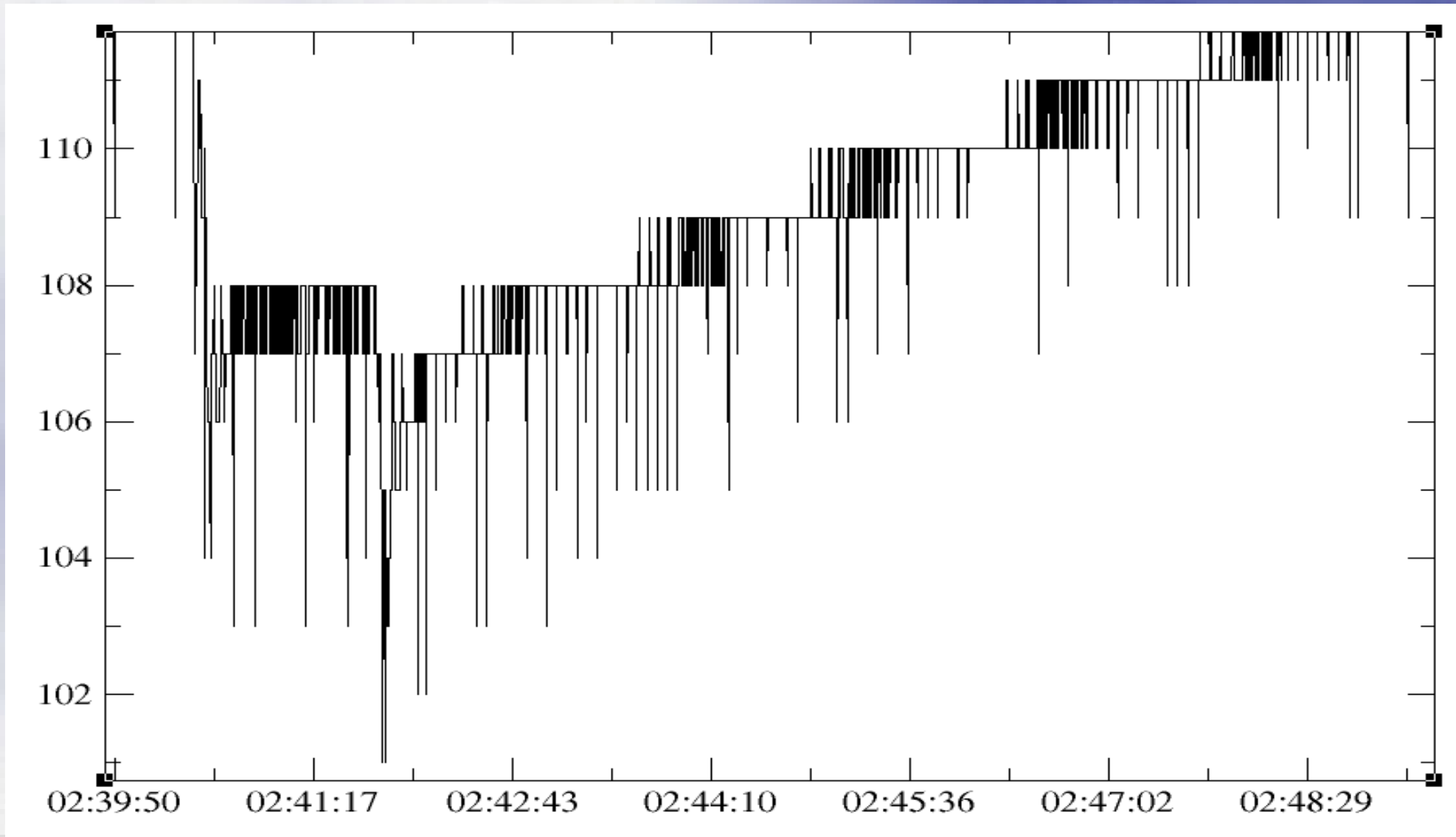


Detecting more breaths and killing noise

- I had two problems: too much noise, likely due to a high impedance, and not enough amplitude in some sleep positions.
- When sleeping on my tummy, not enough of the belt moves, and it may be stuck under my body.
- A longer belt seemed like a way to detect movement all around my chest.
- But to compensate for increased resistance (mine was already too high), I put a triple layer of fabric. This brought resistance down to 10kOhm, this sounded perfect!
- Results were disappointing, the noise didn't go away, and the amplitude measured went down since the amount of stretch per fabric length was lower.
- So, back to a smaller single piece of fabric.

Longer triple fabric was a failure

- Oh my, noise, and no more breaths :(

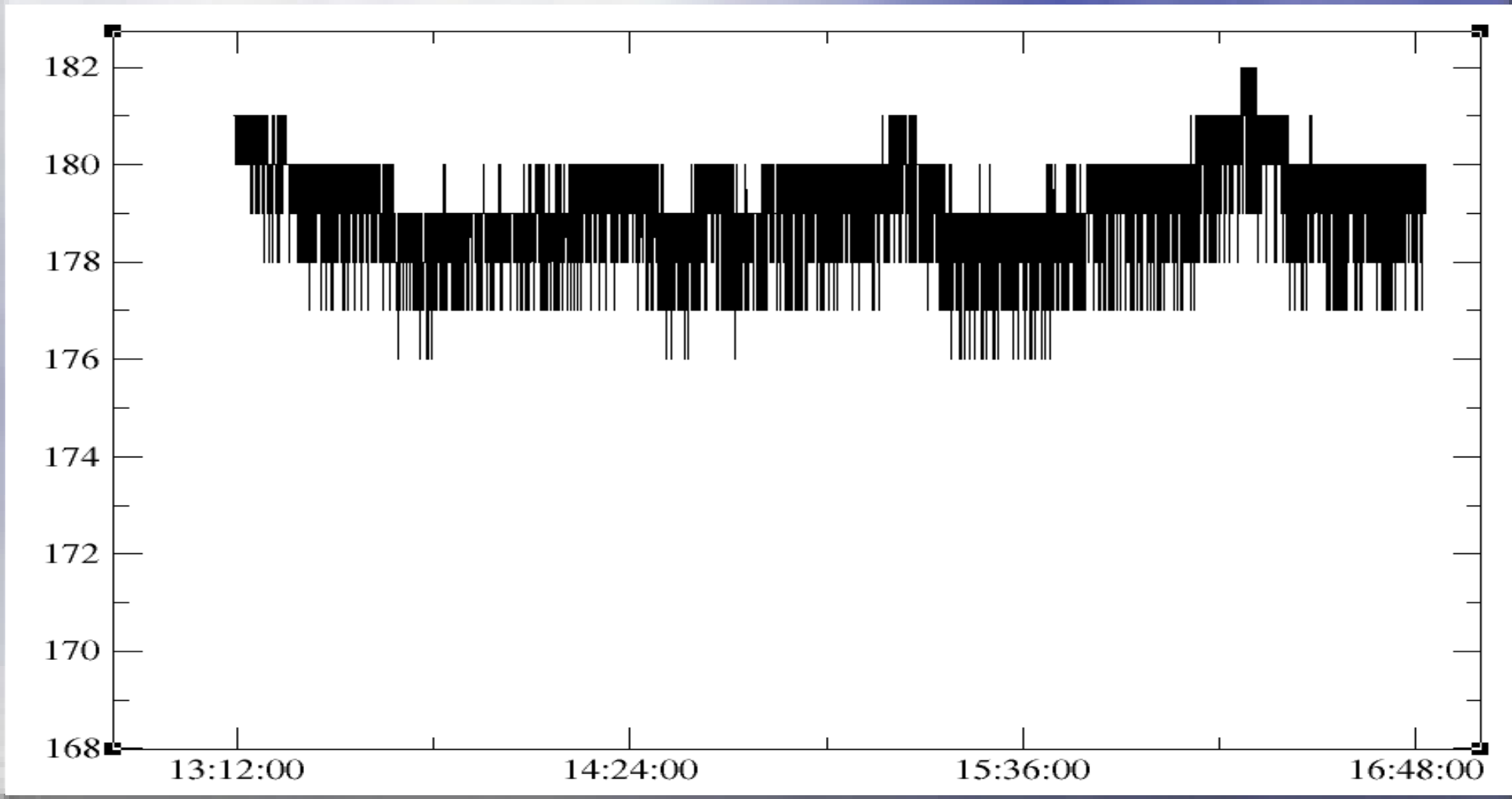


Killing noise, continued

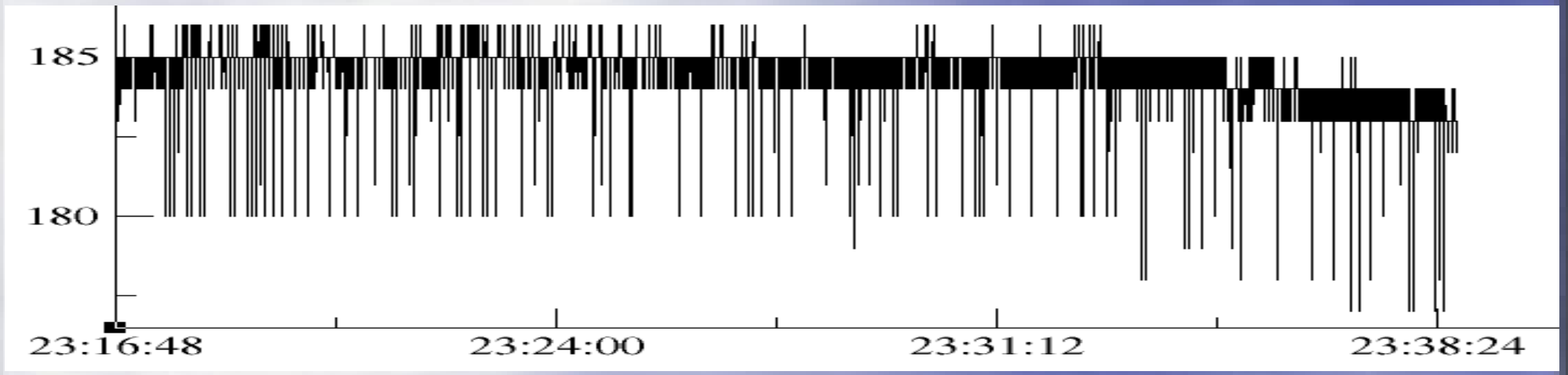
- I started looking into this sampling noise and found out it was worse with an xbee pro than a regular xbee.
- I tried to protect my Vcc from fluctuations by adding more capacitors, but that didn't help.
- Eventually, I found it happened more when the batteries weren't full, and that the voltage out of the regulator was dipping below 3.1V instead of 3.3V.
- Then I realized that the diode that protects the input of my voltage regulator dropped about 0.7V and was enough to turn the 5V out of my batteries into 4.3V, which was too marginal for the voltage regulator under load.
- Solution was simple, short circuit the diode.

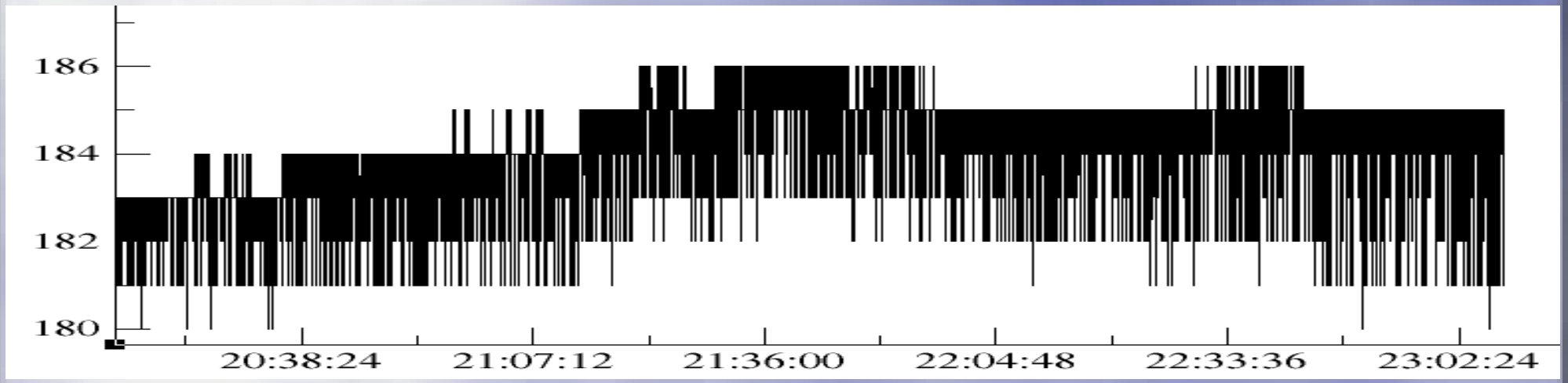
Testing noise

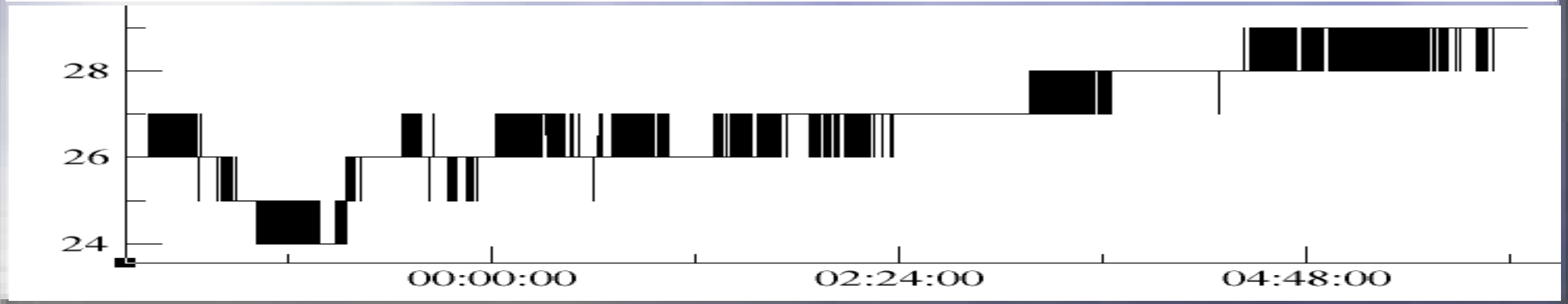
- I'm still getting random noise that is hard to track down
- This is a test of the band not moving, showing a potential of 50% noise amplitude compared the amplitude of a low breath.



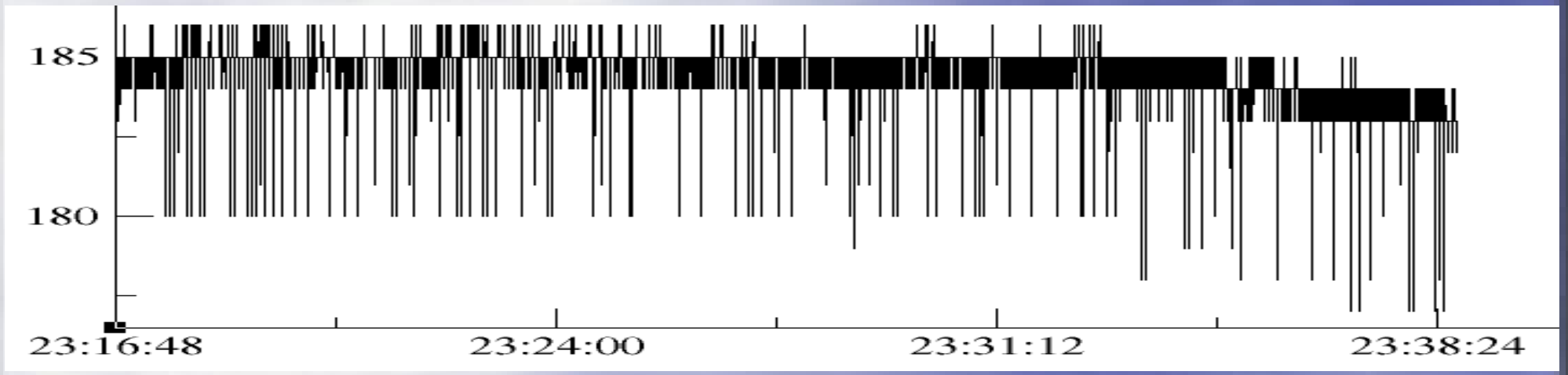
Random Noise: Xbee pro vs Xbee vs no Xbee

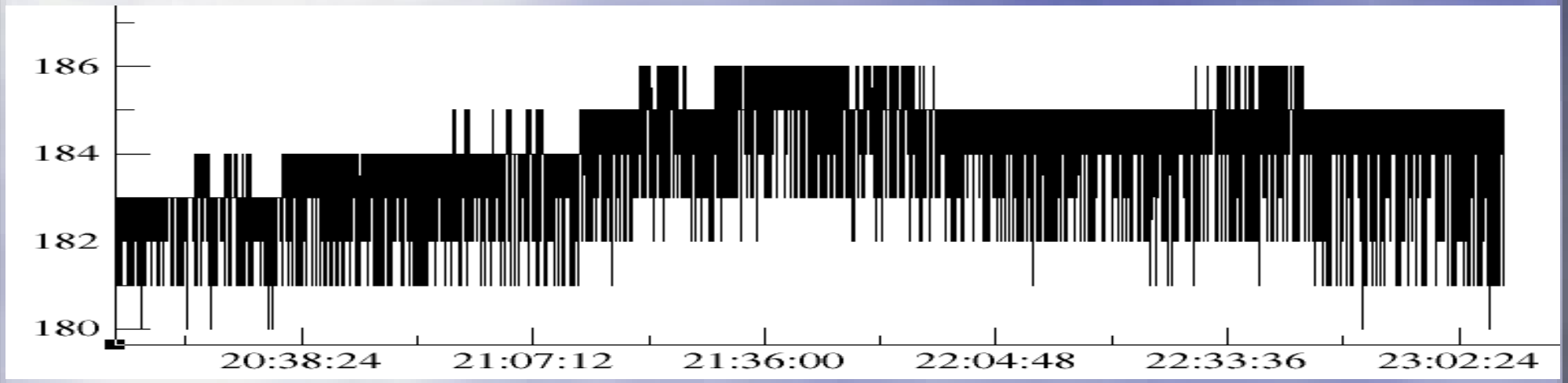


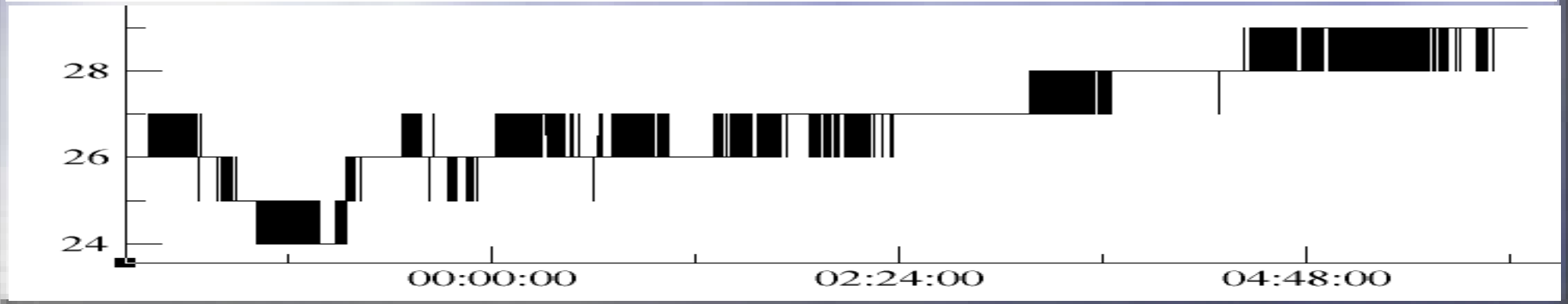




Random Noise: Xbee pro vs Xbee vs no Xbee





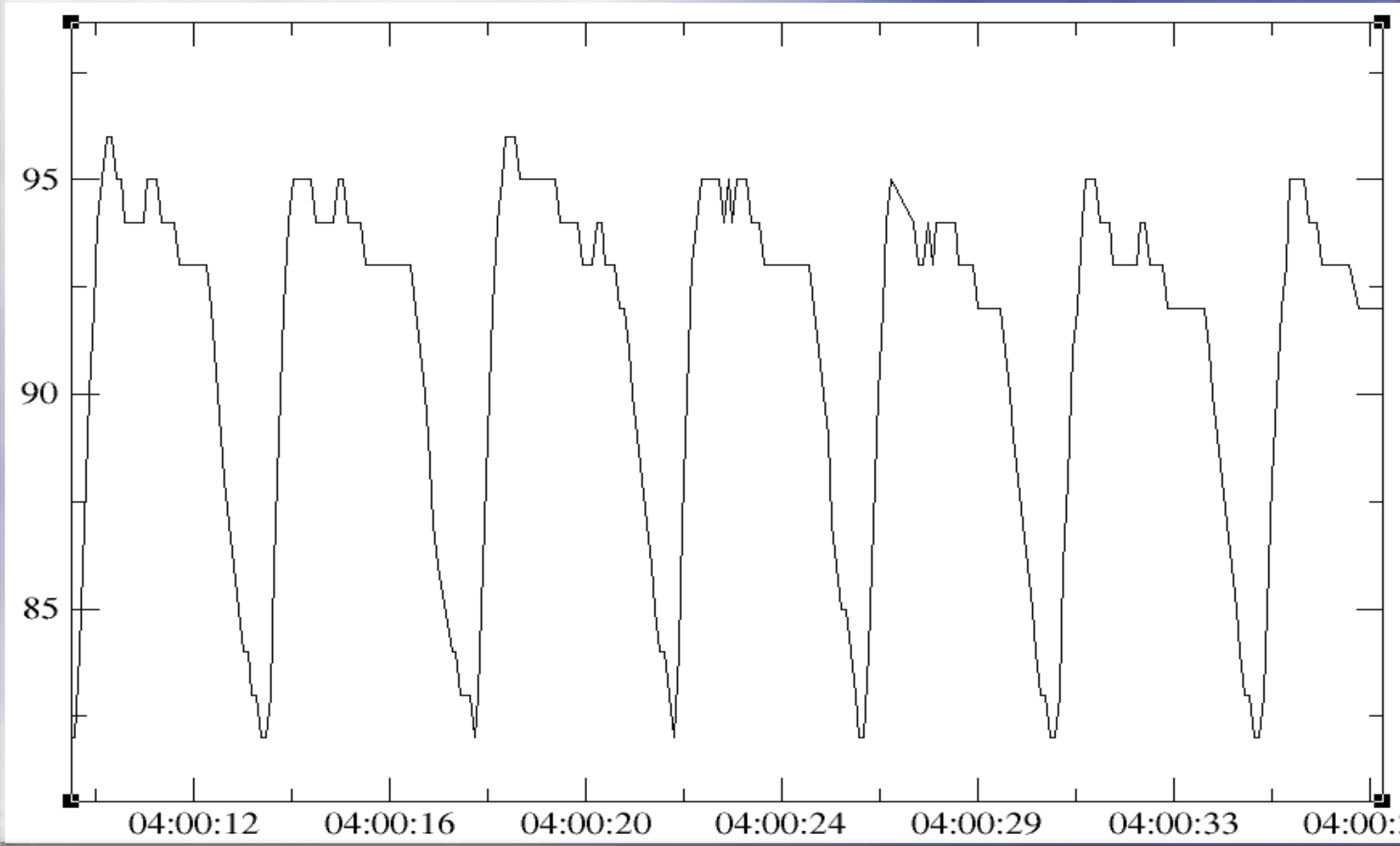


Current status

- Now that the noise problems have decreased, I get more useful data.
- Getting false breaths isn't as bad as missing breaths
- Need more data (many nights of sleep) to get trends and see if they make sense.
- I'm going to try to further shorten the fabric belt to create more change in length from a single breath.
- If the belt data doesn't become good enough, I may just go back to the cannula.

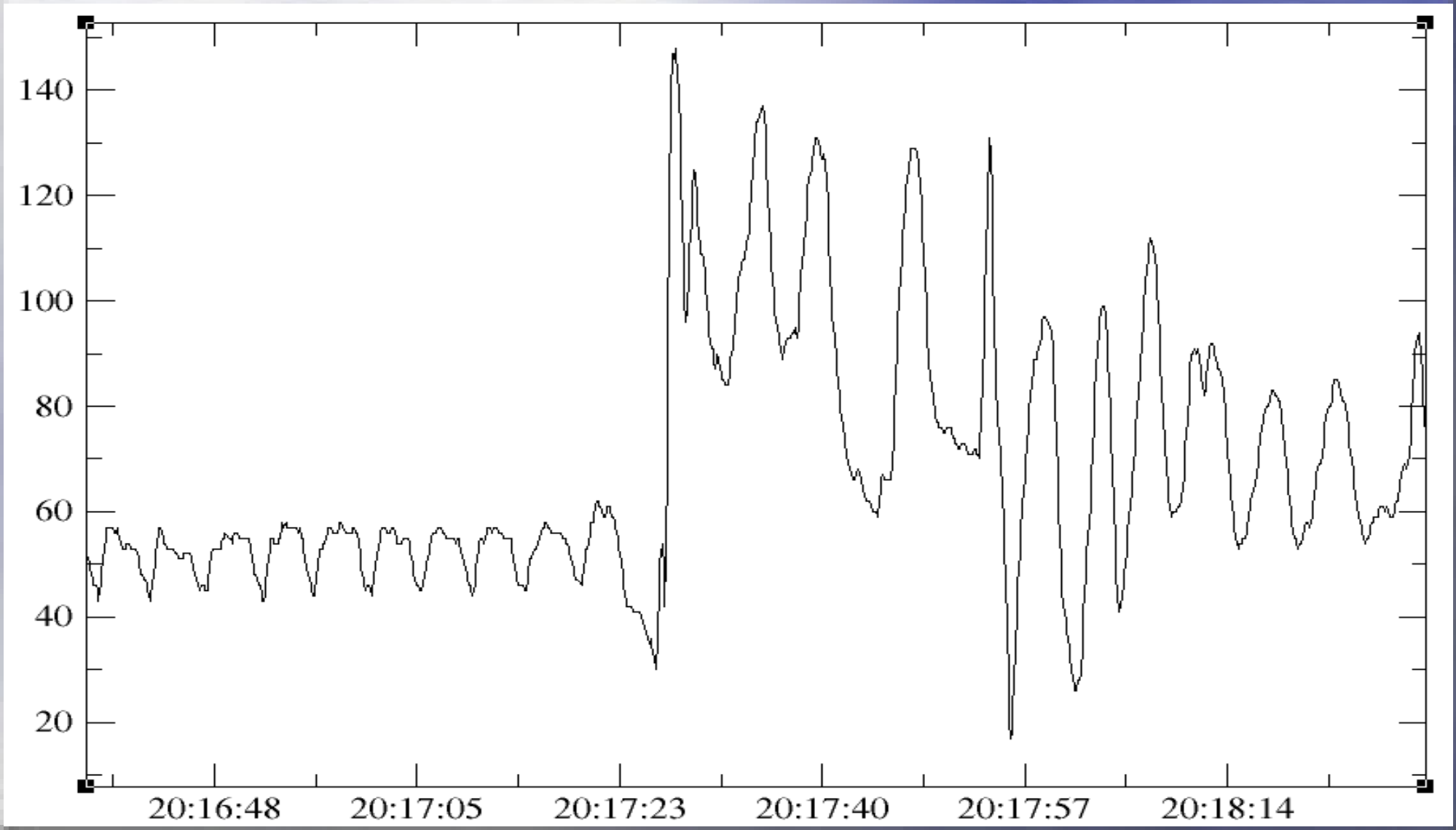
Peak Detection

- Double or triple peaks make things more interesting.



Peak Detection (2)

- Low amplitude when on my tummy and moving body also make things more interesting.



Current logs:

- More data can be computed, but here is what I have for now.

```
[1] At 2012/08/25 13:13:34 (127), new position is now down (from unknown)
[1] At 2012/08/25 14:42:55 (1199), new position is now left (from down)
[1] At 2012/08/25 15:34:00 (1812), new position is now down (from left)
[1] At 2012/08/25 15:53:25 (2045), new position is now left (from down)
[1] At 2012/08/25 16:01:45 (2145), new position is now down (from left)
[1] At 2012/08/25 16:10:25 (2249), new position is now left (from down)
[1] At 2012/08/25 17:00:40 (2852), new position is now down (from left)
[1] At 2012/08/25 17:15:25 (3029), new position is now up (from down)
[1] At 2012/08/25 17:21:25 (3101), new position is now left (from up)
[1] At 2012/08/25 17:38:50 (3310), new position is now down (from left)
[1] At 2012/08/25 19:05:45 (4353), new position is now left (from down)
[1] At 2012/08/25 19:20:00 (4524), new position is now down (from left)
[1] At 2012/08/25 20:18:15 (5223), new position is now left (from down)
[1] At 2012/08/25 20:19:40 (5240), new position is now unknown (from left)
up,    down,  left,  right, unkwn,  hours sleep,  pos changes
01.4%, 63.1%, 32.5%, 00.2%, 02.8%,  7.3 H sleep,   14 pos chg
Number of breaths: 6365
Breaths with the longest delay:
8.1 -> 2012/08/25 20:17:47
7.7 -> 2012/08/25 17:14:43
7.5 -> 2012/08/25 15:52:37
7.5 -> 2012/08/25 16:09:24
7.4 -> 2012/08/25 13:13:25
```

Thanks

- Adafruit for providing great online resources and products
- Jamshid from Eeonyx for giving me a sample of their magic LG-SLPA-16K-VR fabric (http://eeonyx.com/).
- Zeo for opening up the firmware to their bedside device to allow recording realtime data from it http://zeorawdata.sourceforge.net/intro.html
- Luke Weston, and the other Melbourne Hackers who helped design the mobsendat board I used for my sleep monitor (sorry that mine never went to space, guys!)
- Jon Oxer (http://www.freetronics.com/) for starting the arduino miniconfs at linux.conf.au, and conning me into the evil world of analog electronics. Jon, you are an evil man :)

References for using Xbees

- http://forums.trossenrobotics.com/tutorials/how-to-diy-128/xbee-basics-3259/
- http://code.google.com/p/xbee-api/wiki/ChoosingAnXBee
- http://sensor-networks.org/index.php?page=0831631643
- http://www.jsjf.demon.co.uk/xbee/faq.pdf
- http://ftp1.digi.com/support/documentation/90000866_C.pdf
- http://code.google.com/p/xbee-api/wiki/WhyApiMode
- http://www.parallax.com/portals/0/downloads/docs/prod/book/122-32450-XBeeTutorial-v1.0.pdf
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Questions?

- This talk and documents:
  http://marc.merlins.org/linux/talks/ArduinoSleepMonitoring/