

# The Hot Water Balloon

Wookey

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Debian / Embedded Debian / Balloonboard.org / iEndian / Toby Churchill Ltd

FOSDEM 2009 - Embedded Devroom  
Bruxelles

# What is this talk about?

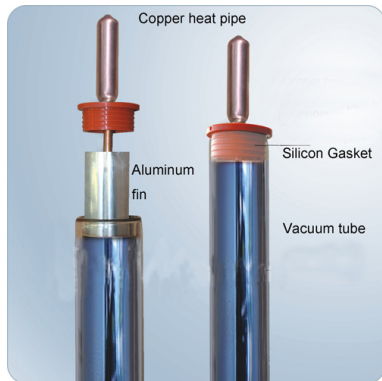
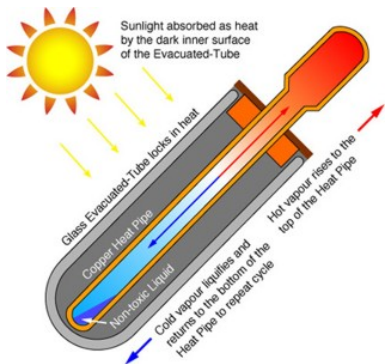
- Solar Thermal crash course
- Controllers
- 1-wire hackery how-to
- Results so far
- A look at what else needs doing

# Solar Thermal System

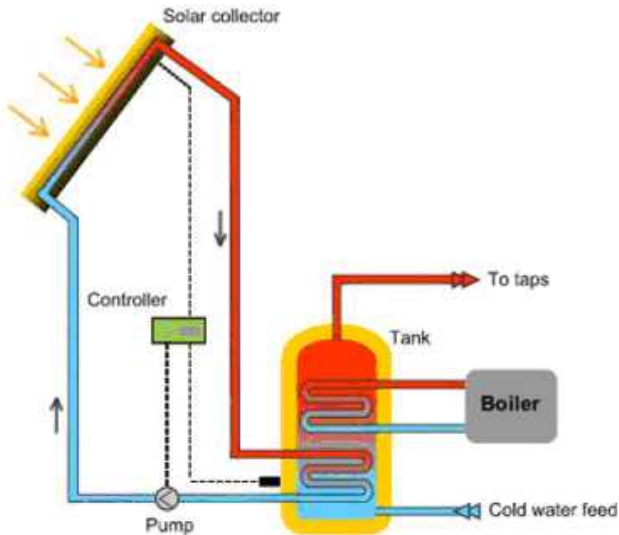


# Evacuated Tube

- Vacuum tube with heat-pipe

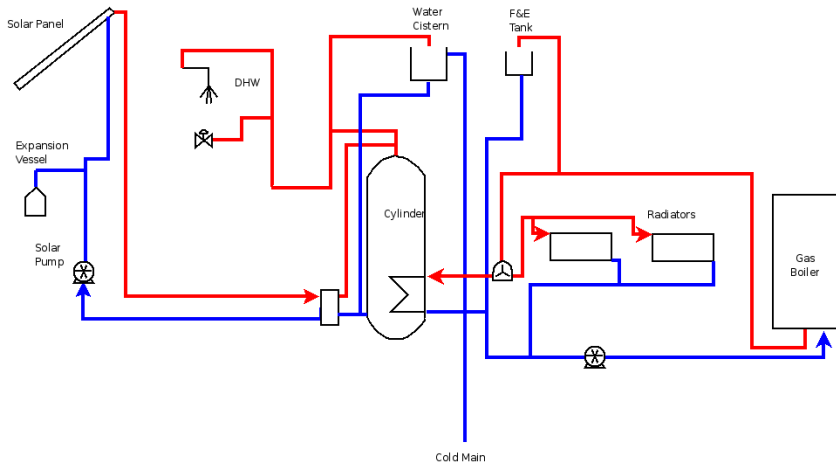


# Solar Thermal System



# Wook's System

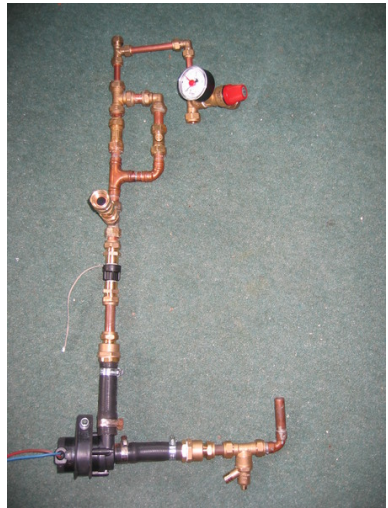
- plate heat exchanger (PHE) layout



# Panel Fitting



# Plumbing



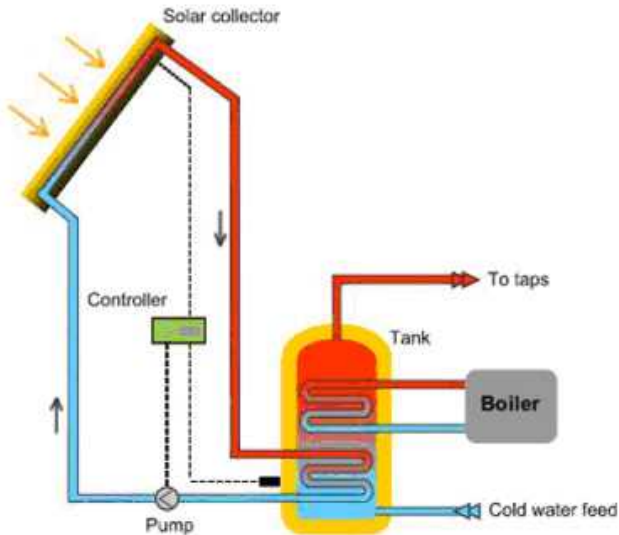


# Thermosiphon



- Existing Tank
- Thermosiphon
- Anti-siphon dip

# Solar Thermal System



# Commercial Controllers



- Standard: 164€
- with Vbus: 230€
- Datalogger: 260€
- Remote Display: 68€
- 10 sensors, 7 outputs: 388€



- 3 sensors, 2 outputs: 162€
- Ethernet connection: 454€

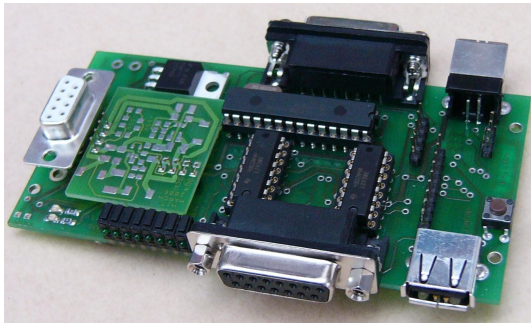
[www.navitron.org.uk](http://www.navitron.org.uk)

# Balloonboard



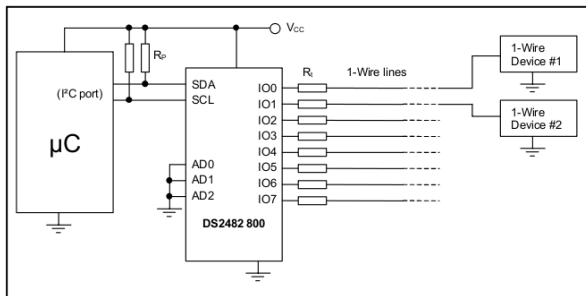
- PXA270, 1GB flash
- 384MB RAM, FPGA
- USB host, VGA display
- Open Hardware
- Distro choice, package management

# CUED IO Expansion board



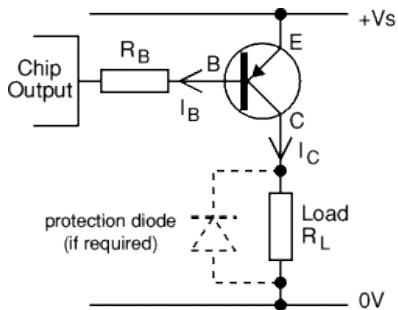
- I2C, 8 digital IO
- 6x 10bit ADC
- 15V/5V crowbarred supply
- USB host/slave
- PWM motor driver

# Hardware 1-wire



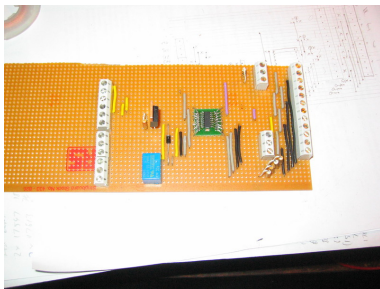
- DS2482-800: 8 multiplexed 1-wire buses
- Data: 14Kbit/s max
- Scan: 13 devices/second
- Measurement: 94-750ms
- I2C 400Kbit/s

# Hardware - Switching



- PCF8574a
- 8 channel IO
- I2C interface
- 'On' pulls pin low - PNP
- Relay needed for 12V
- puts out 45mA max

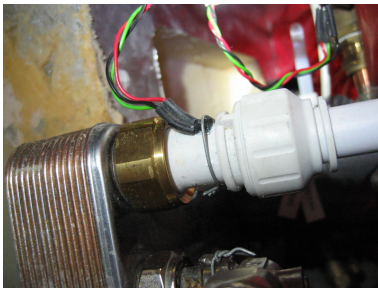
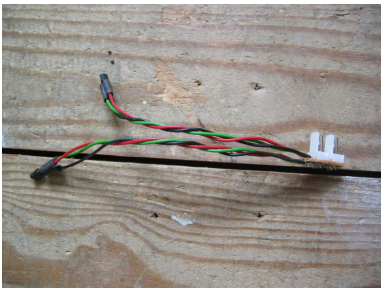
# Hardware - Building



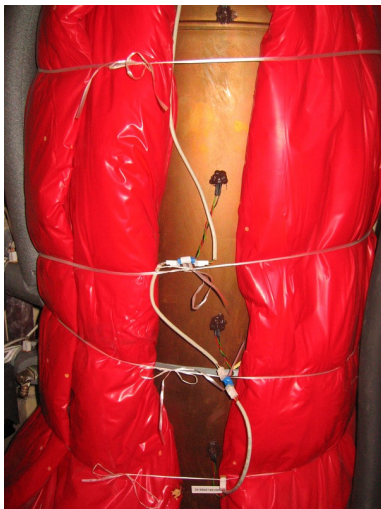
- 5 wires - I2CData, I2CClk, GND, +5V, IO0



# 1-wire Sensors

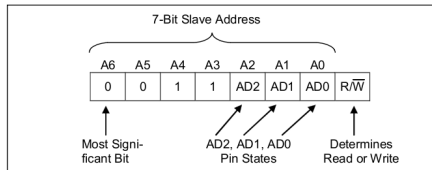


# Fitting Sensors



# Software - I2C modules and addressing

- `modprobe i2c-pxa`
- `modprobe i2c-dev`
- `/dev/i2c-0 /dev/i2c-1`
- bus 0 is general, bus 1 is power
- I2C addresses fixed.
- 7bit - bottom bit is r/w
- on DS2482 Address is 0011nnn
- 0x18-0x1F
- pull all three pins low to get 0x18



# Software - I2C access, 1-wire

- i2cdump from lm-sensors or i2c-tools
- i2cdump 0 0x18

```

      0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f          0123456789abcdef
00: XX XX XX XX XX XX XX XX XX XX XX XX XX XX b5    XXXXXXXXXXXXXXXXXXXX?
10: XX XX XX XX XX XX XX XX XX XX XX XX XX XX b5    XXXXXXXXXXXXXXXXXXXX?X
20: XX XX XX XX XX XX XX XX XX XX XX XX XX b5 XX XX XXXXXXXXXXXXXXXXXXXX?XX
30: XX XX XX XX XX XX XX XX XX XX XX XX XX b5 XX XX XXXXXXXXXXXXXXXXXXXX?XXX
...
b0: XX XX XX XX f3 XX XX XX XX XX XX XX XX XX XX XX XXXXX?XXXXXXXXXXXXX
c0: XX XX XX 87 XX XX XX XX XX XX XX XX XX XX XX XX XXX?XXXXXXXXXXXXX
d0: XX XX 00 XX XX XX XX XX XX XX XX XX XX XX XX XX XX.XXXXXXXXXXXXXX
e0: XX 00 XX XX XX XX XX XX XX XX XX XX XX XX XX XX X.XXXXXXXXXXXXXX
f0: 18 XX XX XX XX XX XX XX XX XX XX XX XX XX XX XX ?XXXXXXXXXXXXX

```

# Software - I2C access, pump switching

- pcf8574a on 0x38
- modprobe pcf8574
- On: echo "0" > /sys/bus/i2c/devices/0-0038/write
- Off: echo "255" > /sys/bus/i2c/devices/0-0038/write
- Yes, OK, that switches all 8 IO channels - my code sucks

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# Software - OWFS

- FUSE filesystem
- configure in `/etc/default/owfs`
  - `SERVER_OPTS="-d /dev/i2c-0"`
  - `CLIENT_OPTS="-s localhost:4304"`
- run with `/etc/init.d/owfs start`
- not yet in debian (on etch needs older python, swig, libfuse)
- deb <http://alt.smurf.noris.de/debian> testing smurf
- `apt-get install owfs libowfs26 libfuse`

# Software - OWFS

- Discover: `owdir -s 4304 /28.D23974010000`
- Read: `owread -s 4304 /28.D23974010000/temperature`  
34.25



# Manual rrdtool - create database

- Create Round Robin Database
- Filled in with rrdupdate

```
sudo rrdtool create /var/log/solar.rrd -s 10\  
  DS:panel:GAUGE:40:-20:125\  
  DS:tanktop:GAUGE:40:-20:125\  
  DS:tankbott:GAUGE:40:-20:125 \  
  DS:pump:GAUGE:40:0:1 RRA:AVERAGE:0.5:1:20160\  
  RRA:LAST:0.5:1:20160 RRA:MAX:0.5:60:1120
```

- Should be 9 days, actually 2.5

# Manual rrdtool - generate graph

```
sudo rrdtool graph --end 18:00d --start 06:00d /tmp
  /solardetail.png -M -i \
  -t "'Wook's solar system'" -v "'Temp (C)'" -h 200
  -w 800\
  DEF:pump=/var/log/solar.rrd:pump:LAST TICK:pump#
    000000:0.05: "'Solar Pump on'" \
  DEF:panel=/var/log/solar.rrd:panel:LAST LINE2:
    panel#FF0000: "'Panel Temp'" \
  DEF:tanktop=/var/log/solar.rrd:tanktop:LAST LINE2
    :tanktop#00FF00: "'Top of Tank'" \
  DEF:tankbott=/var/log/solar.rrd:tankbott:LAST
    LINE2:tankbott#00ffff "'Bottom of Tank'"
```

# Munin

- local and remote munin setups
- hides rrdtool details
- Easy plugin scripts
- Munin-graph uses 85% of cpu
- Munin broken on arm

# Munin plugins

- Any language
- Called with config: prints variables
- Called normally: prints values

## **sudo munin-run panels**

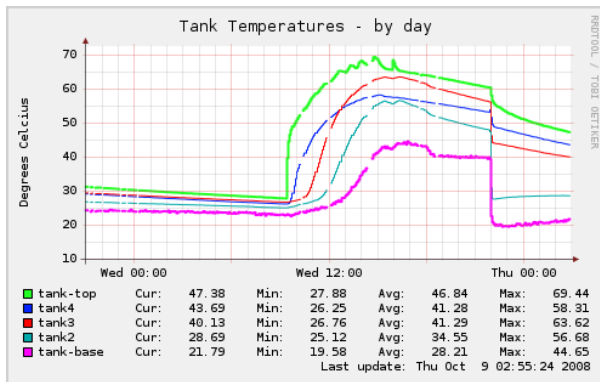
```
panelin.value      10.875
panel1.value       9.5625
panel2.value       10.4
pump.value         0
```

# Munin plugin for panel

## **sudo munin-run panels config**

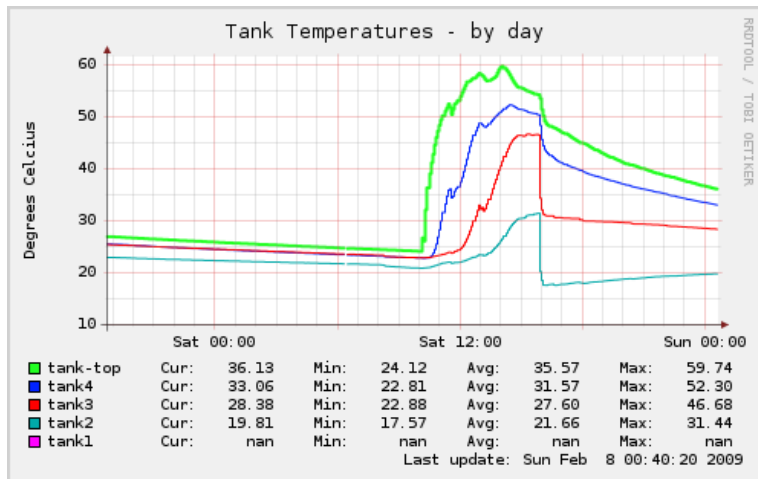
```
graph_title Solar Panel Temperatures
graph_order panelin panel1 panel2 pump
graph_vlabel Degrees Celcius
graph_info This graph shows solar panel temperature
graph_period minute
panelin.label panels-in
panelin.draw LINE1
panelin.max 126
panelin.min -20
panelin.type GAUGE
panelin.info Temp flow into solar panels
```

# What did I discover



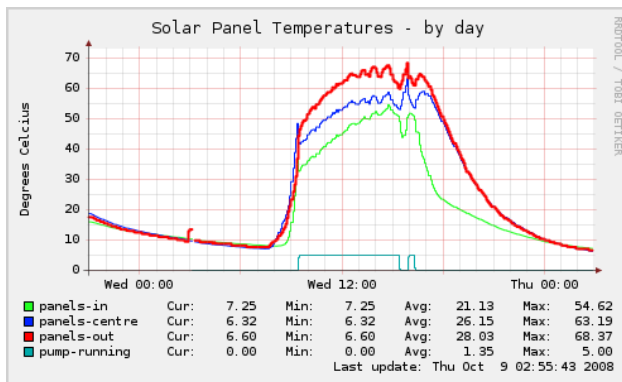
- It works!
- Thermosiphon reacts very quickly (<30 seconds)
- Control is interesting question

# Stratification



- Stratified Loading (Feb 7th 2009)

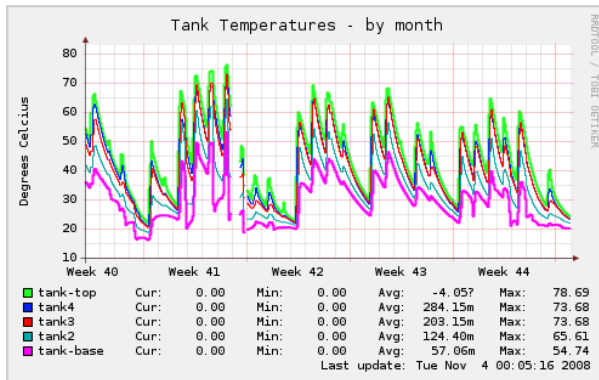
# Panels



- 15°C rise across panels
- 68°C in October



# Monthly summary

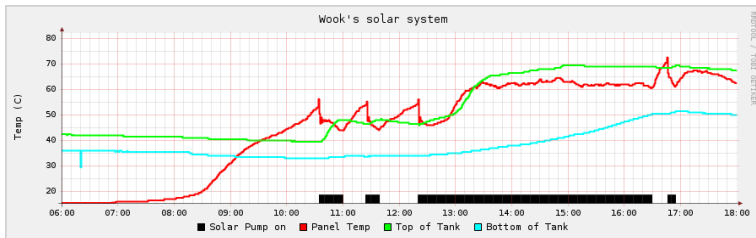


- Provided hot water about 23 days of 31 in October

# Control

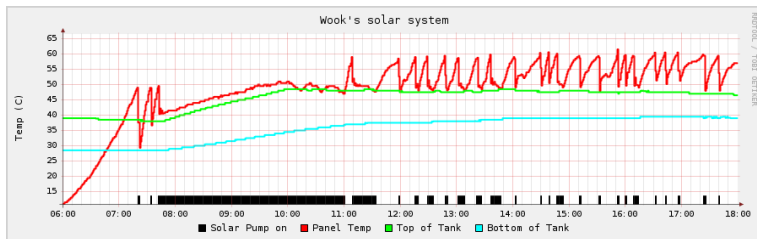
- if panel >tank\_bot + 20 or panel >tank\_top + 4 : pump on
- if panel <tank\_bot + 10 : pump off
- if tank\_top >80 : pump off
- Horrible shell script
- Decimal temp readings - bc
- DIYzoning... PID control

# Control Example



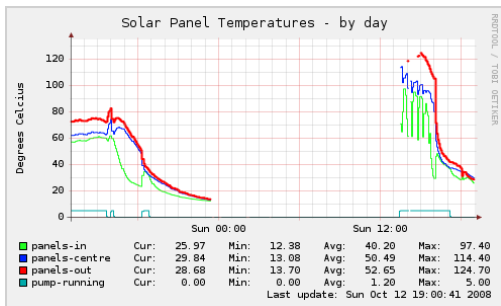
- Tank hotter than panel?

# Medium day



- Hysteresis between  $+10^{\circ}\text{C}$  and  $+20^{\circ}\text{C}$

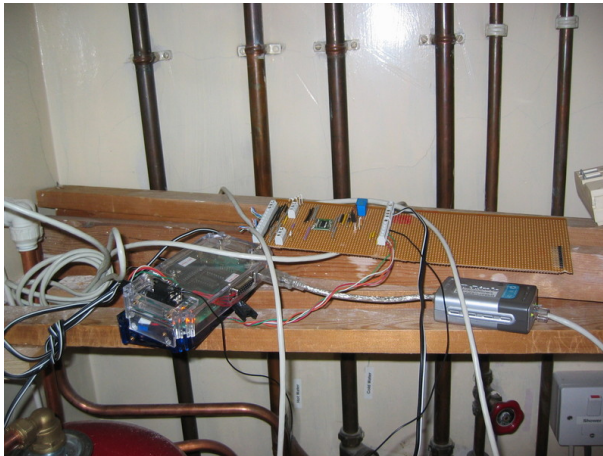
# Reliability



- Uptime: 87 days
- owserver crashed once in 5 months
- survived disk full
- Some 1-wire problems

# Wook's tidy airing cupboard

- Balloon, extra IO board, USB ethernet adaptor



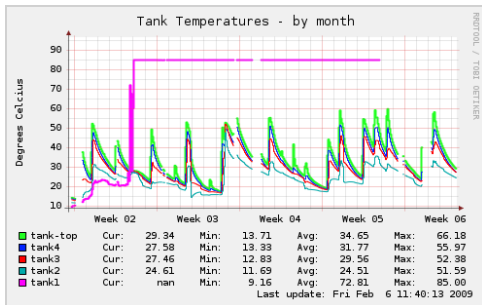
# Reliability



- Installed properly



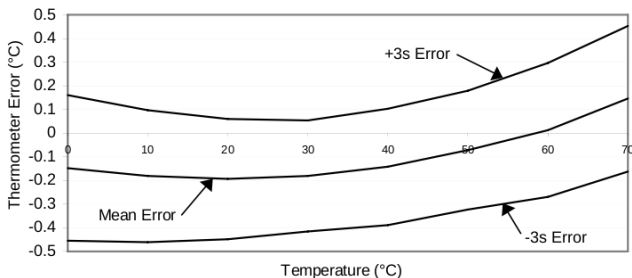
# 1-wire reliability



- 85 °C is suspicious reading
- owserver gets stuck often - restart nightly
- one sensor died
- smart logging is a good idea

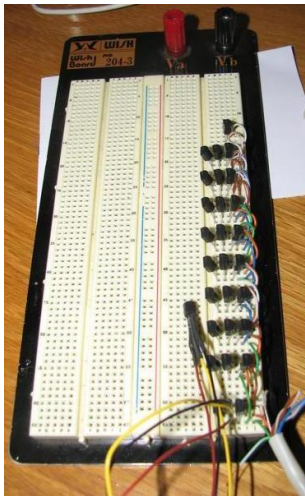


# Temp accuracy



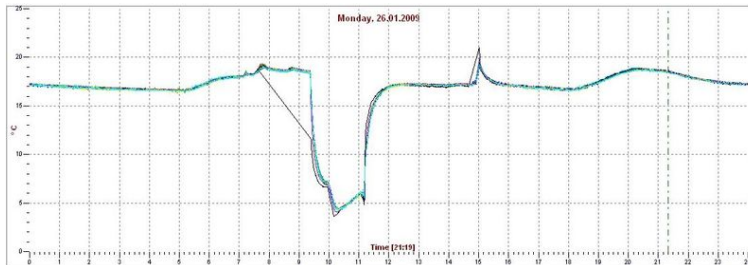
- Nominal 0.5°C accuracy (0-55°C)
- 2°C accuracy (below 0°C, above 55°C)
- 3.8°C difference
- Stuck at 85°C, and 10% low

# Temp accuracy



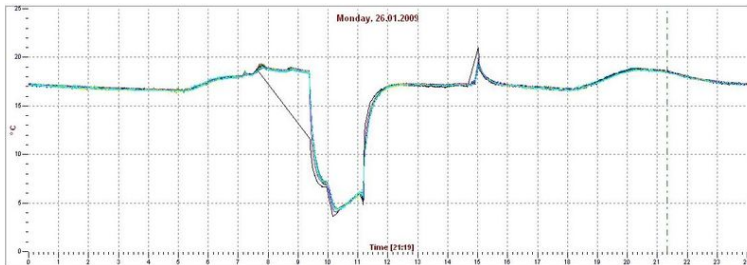
- Tested 28 at once

# Temp accuracy



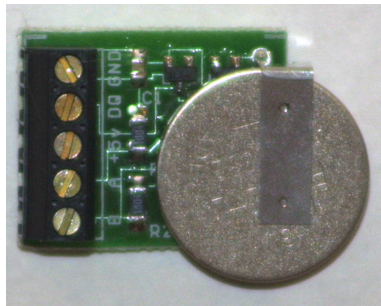
- Put in fridge
- All consistent within 0.5C

# Temp accuracy



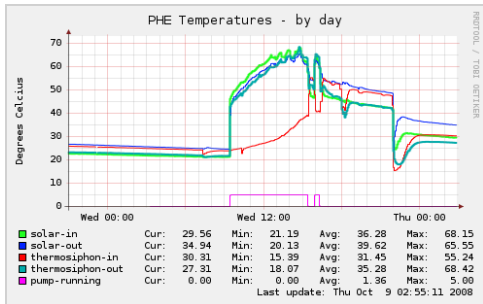
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# Flowmeter



- Swissflow SF800 - optical sensor
- Battery-backed Counter board

# Flowmeter



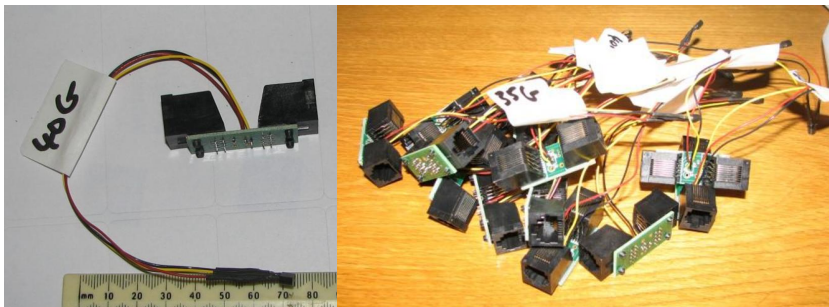
- 1.3 million pulses
- 6100 pulse/litre => 1.6 l/min
- 4°C temp drop
- $Specific\_heat(kWh/KgC * Mass(Kg) * Temp\_diff(C) = Energy(Kwh)$
- $0.00116 * 1327532 / 6100 * 4 = 1kWh$

# Bigger project



- 60kWh log batch boiler, 2 \* 2500L tanks
- heating, hot water, swimming pool

# RJ45 sensors



- Digitemp board design - Open Hardware
- Response testing - < 5s



# What's missing/Future?

- power-fail proofing
- Local User Interface
- Solar: Display tank temp, Bath status, Energy gain
- House: Room temps, Active zones
- Inputs: 'Make a bath' button, Leaving house, +1hr
- Configuration: Sensor allocation, Rule adding/adjusting
- How?: Browser, GTK, Misterhouse, Wt
- MythTV plugin, SMS
- Interfaces: xAP, wireless sensors, moon on stick
- Upload data for comparison: pachube, AMEE





# Software

- temploggerd
- DIYzoning?
- Misterhouse?
- Wt app?
- ...

# Conclusions



- Solar Thermal is great
- 1-wire is great
- UI is harder - needs work
- I have a very tolerant wife

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