

Free as in Free Beer

Or, the foundations of civilization

Greg “groggy” Lehey
grog@FreeBSD.org
grog@NetBSD.org
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Have a beer!

- Beer has been around for ever.
- Earliest records in Sumeria at the dawn of civilization.
- Made from the same ingredients as bread.
- How was it discovered?



Ancient diets

- Ancient man was nomadic.
- He hunted, ate grass, roots and leaves.
- The best part of the grass is the seed.
- Seeds are hard.
- Primitive man had difficulties to soften them for eating.
- Milling won.
- Boiling was another option (gruel).



How beer was discovered

- Warm, moist grain sprouts.
- Warmer moist sprouted grain converts starch into sugar.
- Watery sugar solutions tend to ferment.
- Fermented watery sugar solutions make you feel good.
- Still much harder to make than wine.



Making wine (simplified)

- Pick grapes (by hand).
- Place in a watertight vessel.
- Wait. Natural yeasts crack the skin and ferment the juice.



Making beer (simplified)

- Harvest grass using tools such as knives.
- Thrash grass to separate the grain.
- Moisten grain and allow germination to start.
- Dry grain again.
- Crush grain.
- Warm grain in water for some time.
- Wait.



Making beer: implications

- Making beer is complicated.
- It takes time.
- Difficult to do while moving from place to place.
- Made people settle down, notably in Sumeria.
- The foundation of civilization.



Making beer: expert opinion

- In March 2006, I met Dr. Robert Launay, professor of anthropology at Northwestern University (Illinois, USA).
- His opinion was gentle.
- “Bullshit!”
- It seems that nomadic people made beer too.
- I’m sure it made them stay in one place longer.



Making beer (modern version)

- Most beer is made from barley.
- A lot of wheat, maize and rice is also used.
- Some beers use other grains, such as oats, millet and rye.
- All grains consist mainly of starch.
- *Hops* are used in small quantities to add aroma and bitterness.



Malting and mashing

- Allow grain to germinate, releasing enzymes, notably α -amylase and β -amylase.
- Dry grain at temperatures between 40° and 100°. The resultant grain is called *malt*.
- Crush malt to allow access to the starch.
- *Mash* at temperatures between 40° and 78°, converting the starch to sugar (*maltose*). The resulting liquid is called *wort*.
- Boil the wort with *hops*, to make more resistant to bacterial infection and to add flavour.



Uncrushed malt



Crushed malt



Crystal malt



Hops



How to make beer: mashing

- Add crushed malt to hot water. Mix.
- Keep mash at specific temperatures for a certain period of time (“rest”).
- “Single infusion mash” for about 60 minutes at 67° is good for most brews.
- For better control of beer character, use step infusion or decoction.
- Rest times vary between 10 and 60 minutes.



Mash rests (1)

Rests between 35° and 55° can perform four different changes. None of these rests are very common.

- *Acid rest*, between 35° and 53°, lowers pH (makes more acid).
- *Debranching*, between 35° and 45°, may help dissolve starches.
- Between 35° and 45°, *glucanase* can break down gums.
- The *ferulic acid* rest at 43° produces ferulic acid, which with appropriate yeast can produce wheat-beer specific flavours.



Mash rests (2)

- Between 45° and 55° *peptidase* produces Free Amino Nitrogen and *protease* breaks up proteins that cause haze but also promote head retention.
- The β -amylase rest between 55° and 66° converts straight parts of starch into maltose.
- Between 68° and 72°, α -amylase breaks down the branches in the starch into simpler sugars.

There is considerable interaction between the α -amylase and β -amylase rests: the β -amylase converts some of the starch converted by the α -amylase into sugar.



How to make beer: fermentation

- After boiling, cool down to room temperature.
- Saturate wort with oxygen to promote yeast growth.
- *Pitch* with yeast to start fermentation.
- Ferment at temperatures between 8° and 24°, depending on the yeast.
- Ferment for between 5 and 14 days, depending on the yeast.
- Store at temperatures between 1° and 15° for between 2 weeks and 3 months before drinking.



Kinds of yeast

Three main kinds of yeast in modern beers:

- *Top-fermenting yeasts (sacchoromyces)* are used for ales and other British-style beers.
- Usually ferment between 16° and 22°.
- Form scum on top of wort.
- Complete primary fermentation in 3 to 4 days.



Top-fermenting yeast



Top-fermenting yeast (2)



Bottom-fermenting yeast

- *Bottom-fermenting* yeasts (*saccharomyces*) are used for German and Bohemian “lager” style beers.
- They do not form a scum on the wort.
- Generally ferment at lower temperatures, between 8° and 13°.
- Differ from top-fermenting yeast mainly by strain.
- Many yeasts have intermediate characteristics.



Belgian yeasts

- Many Belgian beers use other organisms for fermentation, such as *brettanomyces*.
- Can ferment at temperatures up to 28°.
- Considered an infection in other styles.



Free beer?

- TANSTAAFB.
- Yeast can really be free.
- Count 1 kg malt for 5 litres of beer (\$3).
- 5 to 10 g hops for 5 litres of beer (\$0.50).
- It's practicable to grow your own hops.
- Prices in the order of \$0.70 per litre, \$0.30 per stubby.
- Kits are usually *more expensive*.



Computers and brewing

- Calculate beer composition.
- Control mash.
- Control fermentation.



Composition parameters: ethanol

- Ethanol content, measured as percentage (*abv, alcohol by volume*).
- 100 ml of 5% abv beer contains about 3.95g ethanol.
- Range between 2.5% (USA) and 12% (Belgium).
- Most beers have between 4.5% and 6%.



Composition parameters: bitterness

- Bitterness, in *International Bitterness Units (IBU)*.
- Contributed by hops.
- IBUs are the parts of hop alpha acid per million.
- Range between 20 IBU (barely perceptible) to 80 IBU (India Pale Ale).
- Typical range between 25 and 40 IBU.



Composition parameters: colour

- Contributed by malt and other grains.
- Warmer malting creates darker malts.
- Slightly influenced by mash procedure.
- Various units of measurement.
- In Australia, measured in *EBC* (*European Brewery Commission*) units.
- Light-coloured beers range between 5 and 10 EBC.
- British-style ales range from 20 to 30 EBC.
- Dark beers can have over 100 EBC.



Composition calculations

- *ProMash*
- *Qbrew*
- *Brewnix*
- *Brewsta* (made in Australia, so probably uses metric units).



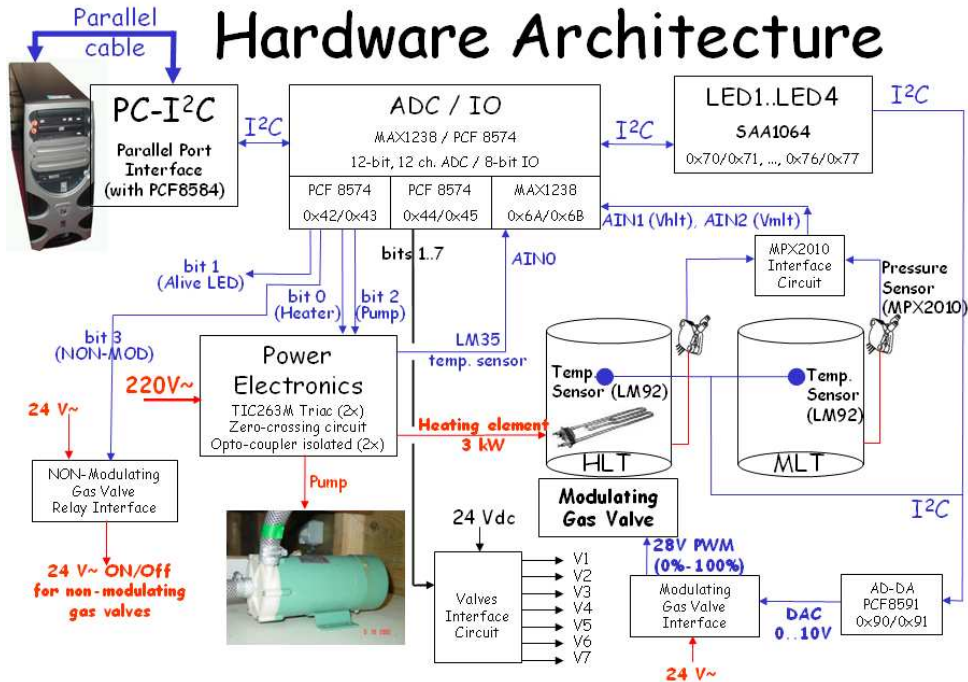
Mash temperature control

- Very rewarding application.
- Requires relatively complicated mash equipment.
- Emile van de Logt has done one implementation.



Mash temperature control (2)

Hardware Architecture



Fermentation temperature control

- Helps ensure correct beer flavour.
- Not as interesting as mash control.
- Easy to implement.
- Has been done in many forms.



Fermentation temperature control

- Simplistic approach: put in a fridge.
- Fridge thermostats are in the wrong range.
- External thermostats work.
- First attempt used a digital thermostat.



Digital thermostat



Problems

- Mains voltage inside fridge.
- External thermostats work, but regulate the wrong temperature.
- Beer temperature can deviate by up to 5°.
- No “dead” range in the middle.
- Thermostat always turns on either heater or cooler.
- Not suited to moist environment.



Where to measure?

- Wort temperature is not uniform.
- Fermentation causes temperature rise.
- Measuring in the middle gives too high a reading.
- Measuring on the outside gives too low a reading.
- Measuring in the wort is an infection risk.
- Measuring in the wort reacts very slowly, giving rise to overshoots.
- Chose surface measurement.



Computer-based solution

- Use digital temperature sensors to measure temperature.
- Use parallel port relay board to control cooler and heater.
- Use old computer (Intel 80486) as the basis.
- More details in the paper.



The challenges

- Mechanical problems.
- How to mount the probe assembly?
- How to mount the sensors?
- What cables to use?
- Groggy is not a practical engineer.
- Still not solved.



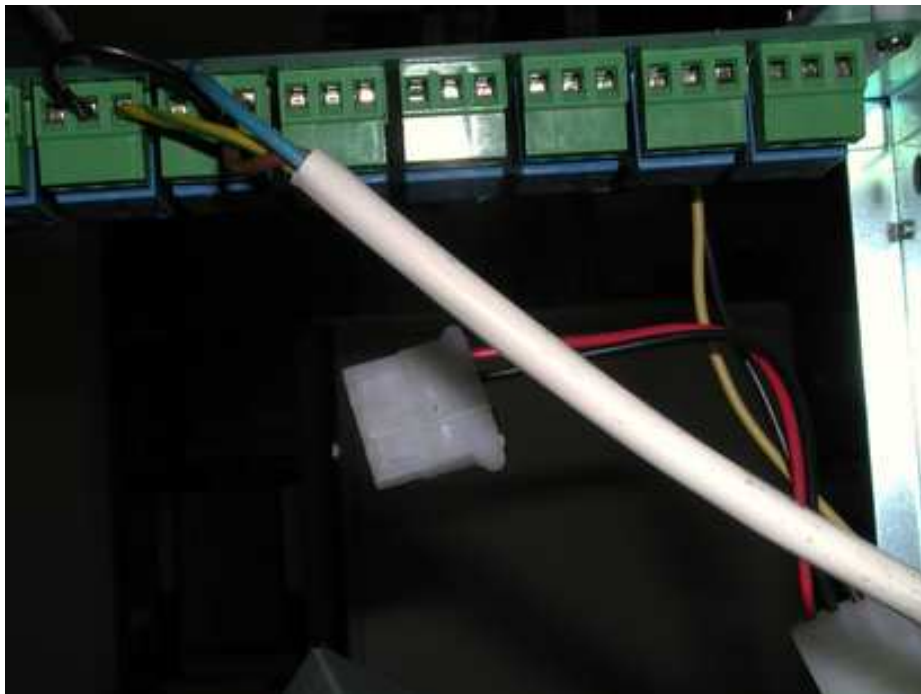
Logger board



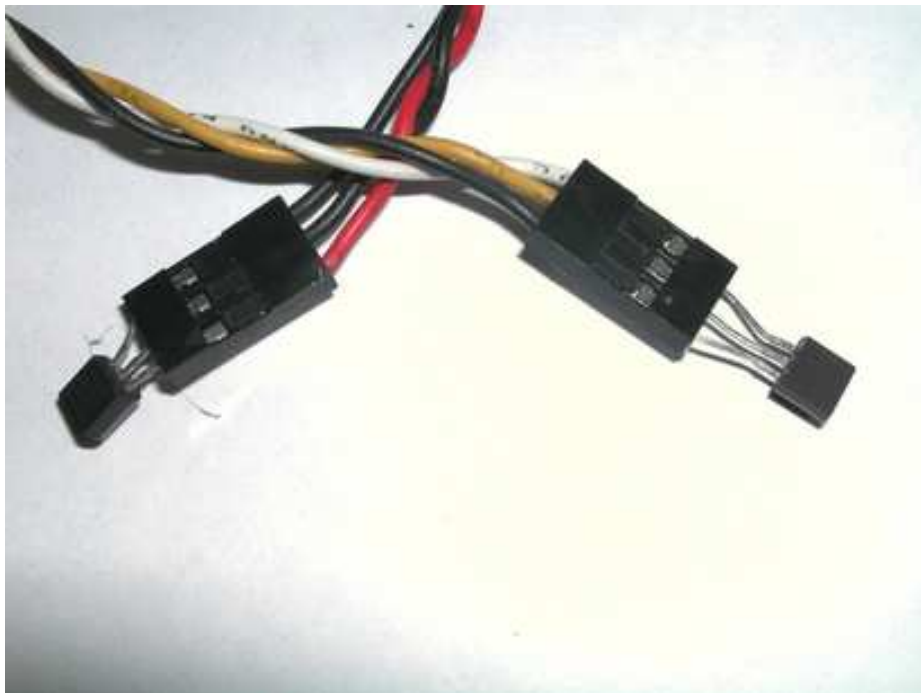
Relay board (1)



Relay board (2)



Temperature sensors



Temperature sensors (2)



Temperature sensors (3)



Complete assembly



The software

- Measures surface temperature of fermenter.
- Turns on heater (lamp) or cooler (fridge compressor) as required.
- Can ramp temperatures at a constant rate.



Installation

- The hard part is the hardware—see above.
- Install from the Ports Collection (*/usr/ports/misc/tempcontrol*).
- Alternatively, get tarball at <http://www.lemis.com/grog/brewing/tempcontrol-1.1.tar.gz>, unpack the tarball, and `Make install`



The config file

- Actions controlled by a configuration file.
- Program can run without a config file.
- Defaults are seldom what you need.
- Specify at least temperature and name of brew (for plots).
- Program notes updates to config file and reads automatically.
- Program outputs log files.
- Second log file is usable for plotting graphs.



Status display

- Program displays current status on screen.
- Status display also available via network (*telnet* to port 4135).

```
Time      Brew      Brew      Base      Ambient      Goal      Offset      Room
          63-a      63-b
12:24:46  19.25    18.81    19.03    20.37    19.00    0.03    16.75
Status: Idle
```



Main log file

```
14:37:49 18.62 15.50 18.62 15.50 19.00 -0.38 15.25
Status: Heating
14:45:04 19.06 17.43 19.06 14.81 19.00 0.06 15.43
Status: Idle
14:55:27 19.12 16.43 17.78 20.37 19.00 -1.22 15.75
Status: Heating
14:57:09 19.31 18.50 18.90 20.37 19.00 -0.10 15.93
Status: Idle cancelled cooler on wait
14:58:09 19.25 18.62 18.94 20.37 19.00 -0.06 16.00
Status: Heating
14:58:39 19.31 19.18 19.24 20.37 19.00 0.24 15.75
Status: Idle Heated for 00:01:42
15:15:42 19.62 18.12 18.87 20.37 19.00 -0.13 15.18
Status: Heating
15:16:13 19.56 18.31 18.93 20.37 19.00 -0.07 15.18
Status: Idle cancelled cooler on wait
17:09:56 19.75 18.50 19.12 20.37 19.00 0.12 16.06
Status: Cooling
17:10:34 19.62 18.50 19.06 20.37 19.00 0.06 15.87
Status: Idle
17:12:34 19.68 18.43 19.06 20.37 19.00 0.06 15.75
Status: Cooling
17:13:04 19.68 18.43 19.06 20.37 19.00 0.06 16.06
Status: Idle
18:43:52 19.50 18.25 18.88 20.37 19.00 -0.12 15.25
Status: Heating
```



Graph log file

| | | | | | | | | |
|------------|-------|-------|-------|-------|-------|------|-------|---|
| 1128750471 | 19.56 | 18.93 | 19.24 | 20.37 | 19.00 | 0.56 | 15.00 | 1 |
| 1128750531 | 19.62 | 18.93 | 19.28 | 20.37 | 19.00 | 0.62 | 14.93 | 1 |
| 1128750591 | 19.62 | 19.00 | 19.31 | 20.37 | 19.00 | 0.62 | 15.00 | 1 |
| 1128750651 | 19.68 | 19.00 | 19.34 | 20.37 | 19.00 | 0.68 | 15.06 | 1 |
| 1128750711 | 19.62 | 18.93 | 19.28 | 20.37 | 19.00 | 0.62 | 14.81 | 1 |
| 1128750771 | 19.68 | 18.87 | 19.28 | 20.37 | 19.00 | 0.68 | 15.25 | 1 |
| 1128750831 | 19.68 | 18.87 | 19.28 | 20.37 | 19.00 | 0.68 | 15.06 | 1 |
| 1128750891 | 19.68 | 18.81 | 19.24 | 20.37 | 19.00 | 0.68 | 15.12 | 1 |
| 1128750951 | 19.68 | 18.68 | 19.18 | 20.37 | 19.00 | 0.68 | 15.18 | 1 |
| 1128751011 | 19.68 | 18.68 | 19.18 | 20.37 | 19.00 | 0.68 | 15.00 | 1 |
| 1128751071 | 19.75 | 18.68 | 19.22 | 20.37 | 19.00 | 0.75 | 15.00 | 1 |
| 1128751131 | 19.75 | 18.62 | 19.19 | 20.37 | 19.00 | 0.75 | 15.43 | 1 |
| 1128751191 | 19.75 | 18.62 | 19.19 | 20.37 | 19.00 | 0.75 | 15.18 | 1 |
| 1128751251 | 19.75 | 18.62 | 19.19 | 20.37 | 19.00 | 0.75 | 15.12 | 1 |



Temperature ramp control

- Temperature can be changed at a constant speed.
- Specify end temperature and time for ramping.
- Issues remain with restarting during ramping.

```
starttemp 19  
endtemp 12.5 20 October 2005 12:00
```



Real config file

```
# Fermentation
starttemp 19
endtemp 12.5 20 October 2005 12:00
fermenter1label Brew-63-a
fermenter1label1 Brew
fermenter1label2 63-a
fermenter2label Brew-63-b
fermenter2label1 Brew
fermenter2label2 63-b
graphlogfile /var/log/brewing/brew-63.graphlog
graphloginterval 60
dosyslog on
loginterval 86400
logfile /var/log/brewing/brew-63.log
# XXX End of stuff that normally needs changing
```

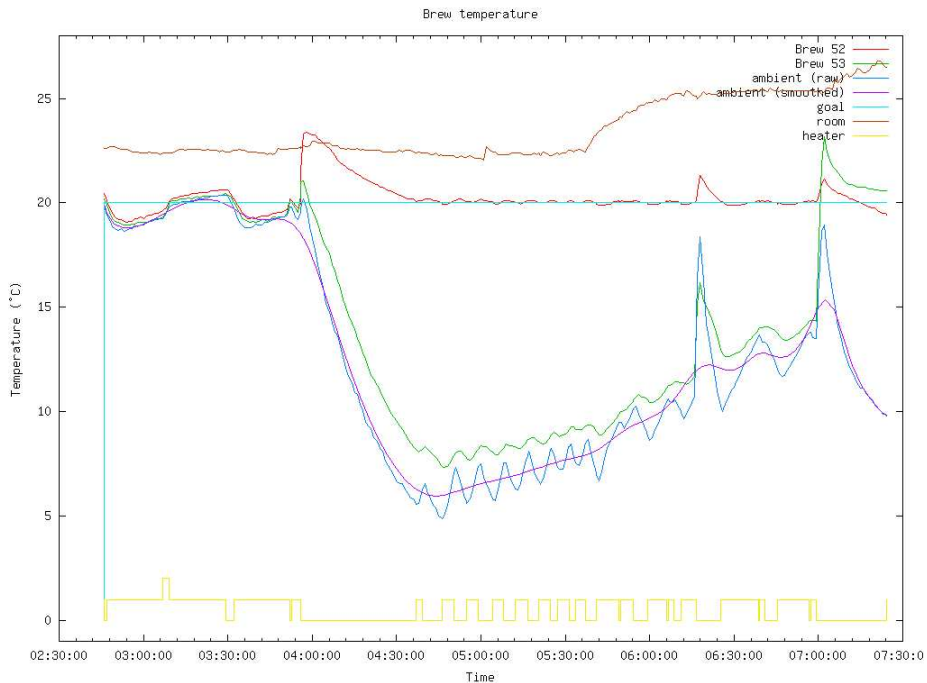


Real config file (2)

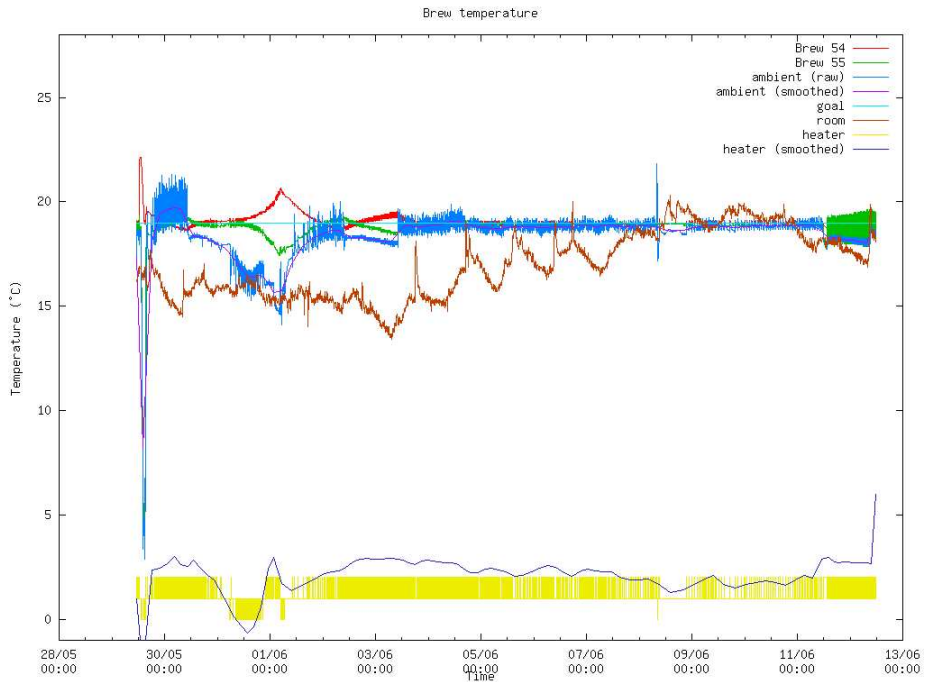
```
relayline /dev/ppi0
fermenterprobe 3
fermenter2probe 2
ambientprobe 4
roomtempprobe 1
minambienttemp -1
heaterholdoff 0.1
coolerholdoff 0.1
coolerovershoot -0.05
heaterovershoot 0
coolertoheaterdelay 3600
heatertocoolerdelay 3600
heateroffmin 60
logpagesize 22
maxcooltempdiff 20
cooleroffmin 120
probe2factor 0.5
displayfile /dev/tty
monitor
```



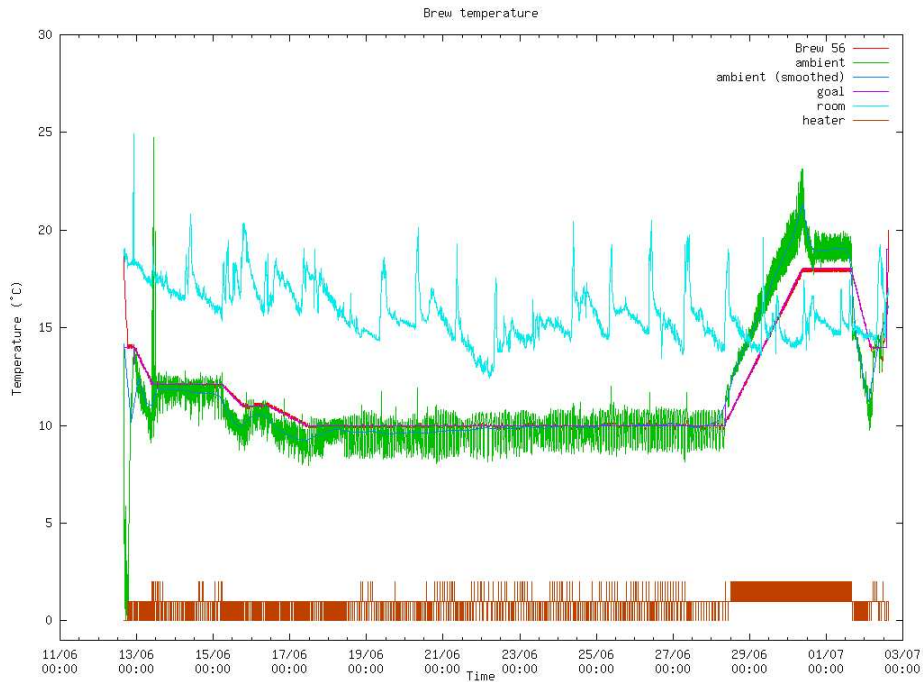
Initial temperature adjustments



Two fermentations



Lager fermentation



Experience with the system

- Now in active service for nearly four years.
- Reacts well to power failures.
- Contact problems with the temperature sensors.
- Temperature logger then often produces junk.
- Difficult to get good contact with fermenter.
- Don't do this over NFS!



Other implementations

- This is not the only temperature control system.
- Daniel O'Connor has a PIC solution.



Future directions

- Write documentation.
- Handle power failure during ramp operation.
- Add UDP network interface.
- Adapt to multiple fridges.
- Adapt to mashing operation.
- Adapt to other functionality, such as house cooling and heating.



The End

- Thanks for watching.
- The latest version of the paper is at
<http://www.lemis.com/grog/Papers/freebeer/paper.pdf>.
- The latest version of these slides are at
<http://www.lemis.com/grog/Papers/freebeer/slides.pdf>.
- Daniel O'Connor's solution described at
<http://www.dons.net.au/~darius/hgwebdir.cgi/beermon/>
- Emile van de Logt's mash temperature control is described at
http://home.bccnet.nl/e.vd.logt/htm/hardware_uk.htm