Brewing with Electricity

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January 2011

Outline

- What
- Why
- How

Goals:

-Brief Introduction

-Clear up misconceptions

-Not a detailed design guide

-Potential Follow-On Tech Meetings:

1. Detailed System Design
2. RIMS system

What

- Using Electricity to heat & boil water for the brewing process.

Fully Electric – Fancy Kettles

Gas Kettles & Electric RIMS

Fully Electric – Shitty Kettles

Heat Stick

Electric Coolers

Electric Stove

Electric HLT

Why

- Brew Indoors
- Lower Recurring Costs
- More Efficient
  - >95% vs <60% for gas
  - 200k BTU/hr is useless if most of it heats the air
- Insulated Kettles
- Safe to Leave Unattended
  - Set It & Forget It
- Kill Switches
- Easier to Automate/Control
- Fun to experiment
- Makes more intrinsic sense*

*This statement may only apply to Electrical Engineers.

How : Buy Pre-Fab'd

Midwest Supplies

HighGravityHomebrew.com

Homebrewing.com

BCS-460

Minibrew.com

How : DIY

- Safety
  - GFCI
- Kettles
  - Same options as gas, but also plastic
- Heating Elements
  - Water Heater
  - Variable Size
- Controllers
  - Analog
  - PID
  - Software
  - None

Safety

- Ground Fault Current Interrupter
- In-Line
  - Up to 30 A
- Circuit Breaker
  - Up to 50 A
- Check for Voltage & Current Rating
  - 120 V, 15 A
  - 240 V, 30 – 50 A
- Kill Switches

Heating Element

- Water Heaters
  - High Density
  - Low Density
  - Ultra-Low Density
- Materials
  - Ni-Chrome Wire
  - Ceramic Sheath
  - Outer Coating
  - Dry Firing = Fire
    - **Incoloy is safer**
    - **Float Switches**
- Power Ratings
  - 1500W : 120V
  - 3500W - 5500W : 240V

16.5 Ω : 3500 Watts
12.8 Ω : 4500 Watts
10.5 Ω : 5500 Watts

Quantities, Concepts, & Units

- Voltage – electric potential (Volts)
- Current – moving electrons (Amps)
- Resistance – Voltage/Current (Ohms)
- Energy – (Joules, kW-hr, or BTUs)
- Power – Energy/time (Watts or BTU/hr)
  - 1 Watt = 3.412 BTU/hr
- Mass – (kg)
- Specific Heat – energy per unit mass required to raise water temp (4.186 J-gm/°C)
- Vaporization Heat – energy required to vaporize a unit of water (2260 J/gm)

Quantities, Concepts, & Units

- Energy – What it takes to boil water (difficult to measure)
- Power – How long it takes (easy to measure)
- Current – Limited by house wiring & breakers
  - 120V circuits – 15 or 20A breakers = 1,800 – 2,400W
  - 240V circuits – 30 or 50 A breakers = 7,200 – 12,000W
  - Will most likely limit max power you can use
- AC: Changing with time (wall outlets)
  - "120V" = the RMS voltage (actual peaks are ±170V)
- DC: Fixed with time (batteries & phone chargers)

Quantities, Concepts, & Units

$$Q = P * t = c * m * \Delta T$$

$$t = \frac{Q}{P} = \frac{c * m * \Delta T}{P}$$

Sample Calculation

1. Volume = 10 Gal = 37,854 cm^3
2. Mass = 0.98804 gm/cm^3 * Vol = 37,401 gm
3. c = 4.186 J/g/°C
4. ΔT = 55.56C (Start = 75F, Final = 175F)
5. Q = 4.186 * 37,401 * 55.56 = 8.699×10^6 J
6. time = Q/P = 8.699×10^6 J / 4500 W = 1,933 sec
7. time = 1,933 sec / 60 = **32.2 min**

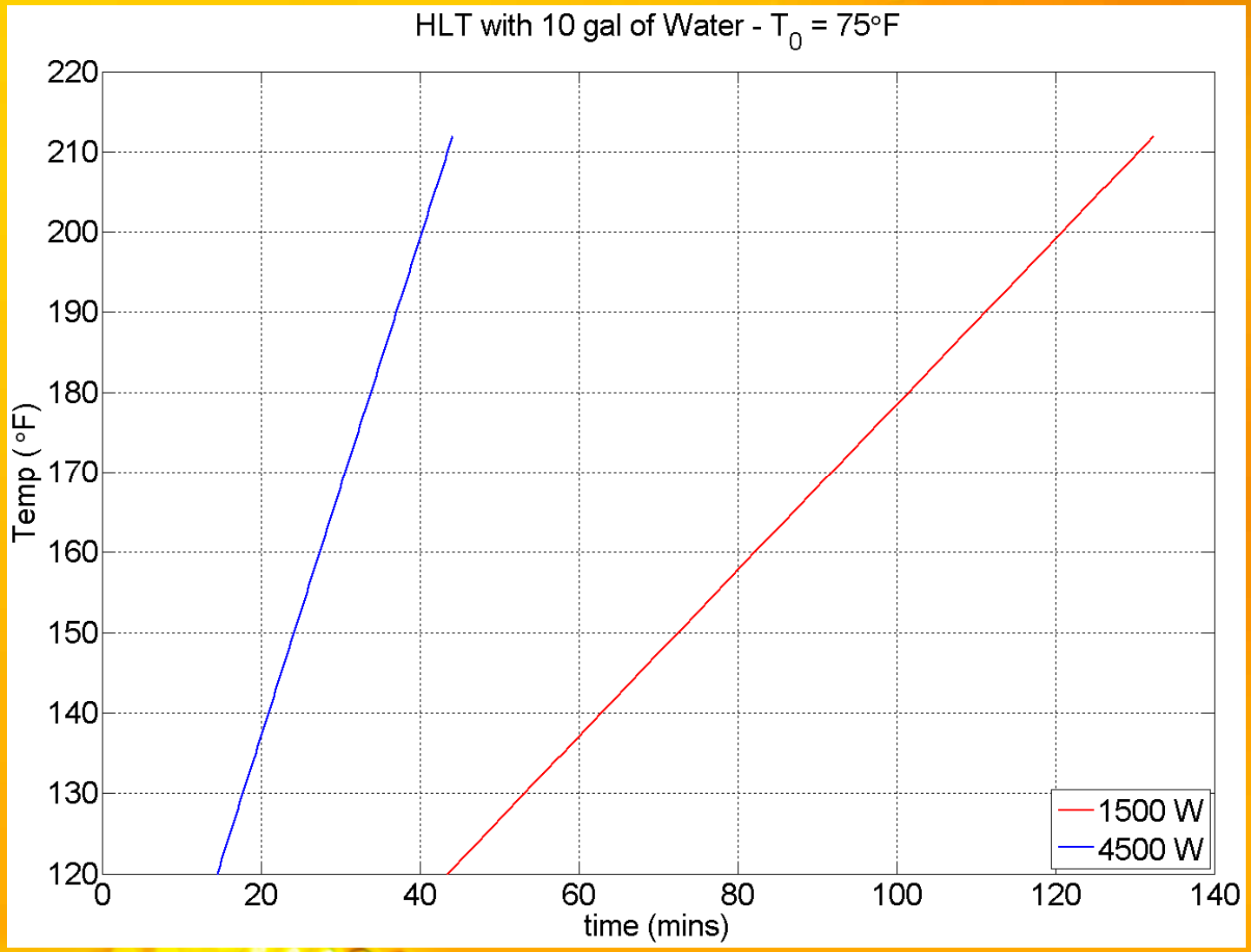
Kettle Losses will perturb calculations
Insulation is a good idea

$$P = V * I = I^2 * R = \frac{V^2}{R}$$

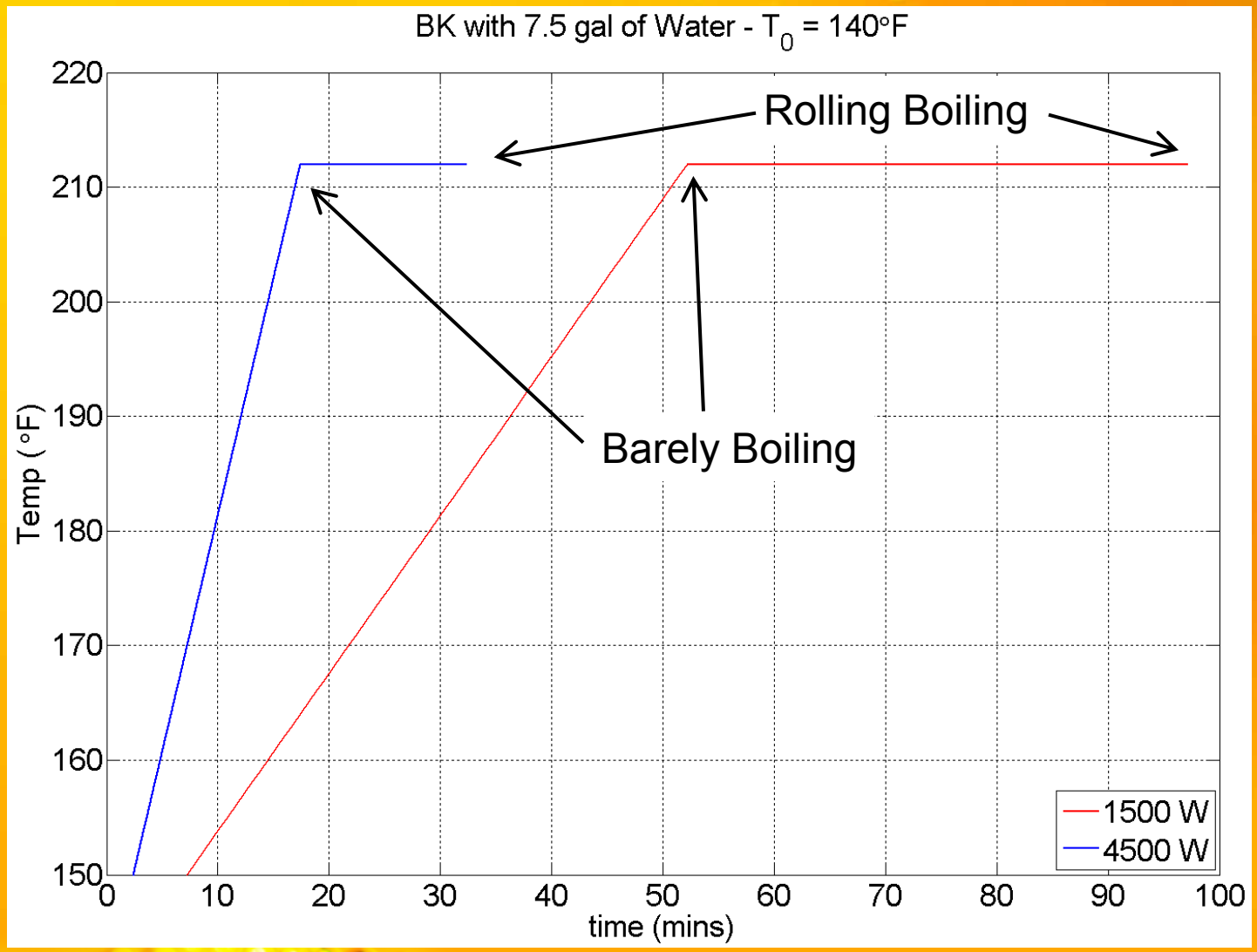
Note the V^2 relationship

- P1 at 240 V = P1/4 at 120V
- 6000W @ 240V = 1500W @ 120V

How Much Power Do I Need?

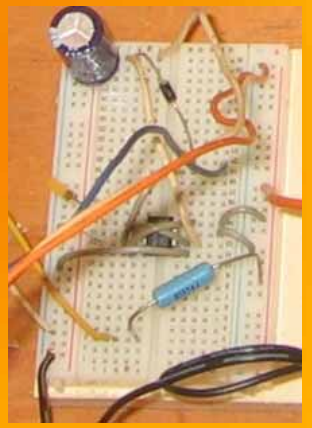


Boil Kettle Example



Analog Control

- Dimmer Switch
- PWM
- Thermostat/∞ Switch (electric stove)
- All electrical options require a relay
  - AC control
  - DC control

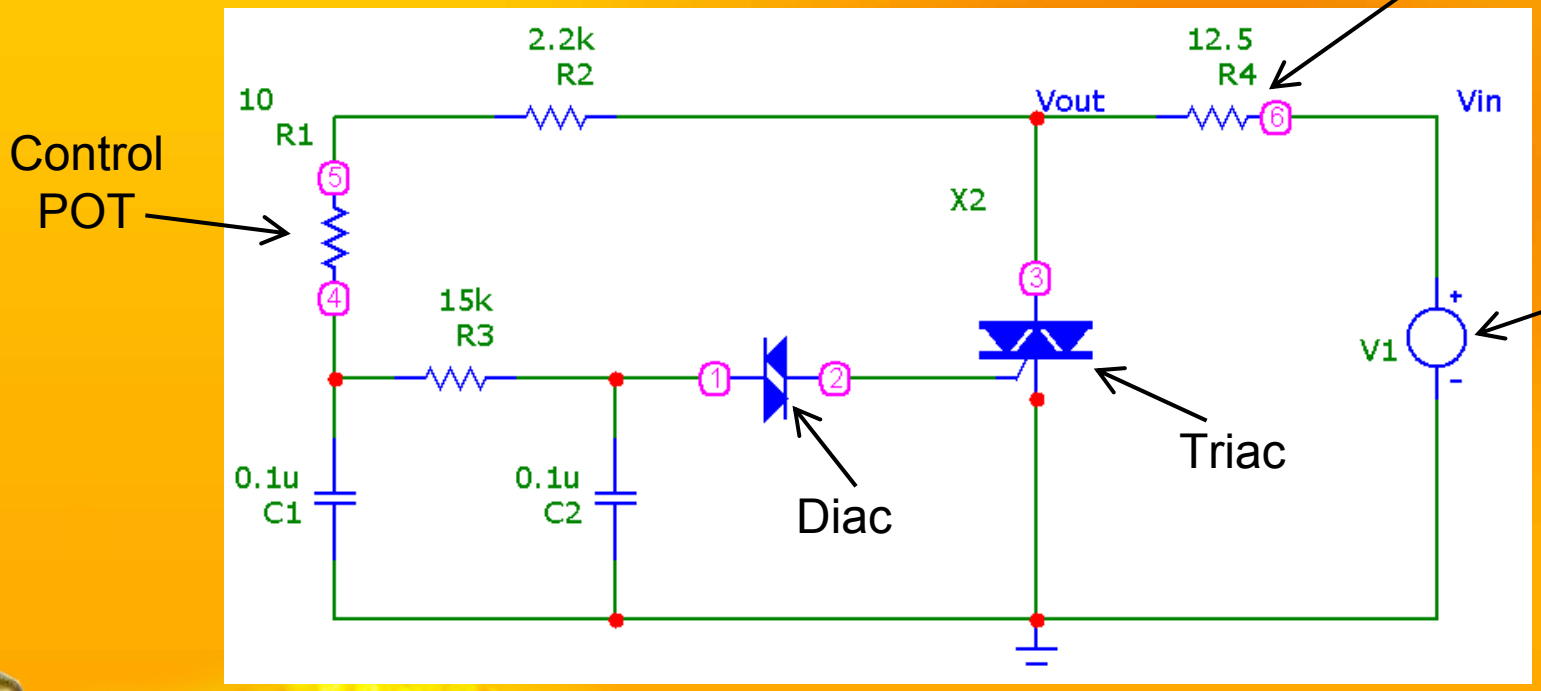


Relays

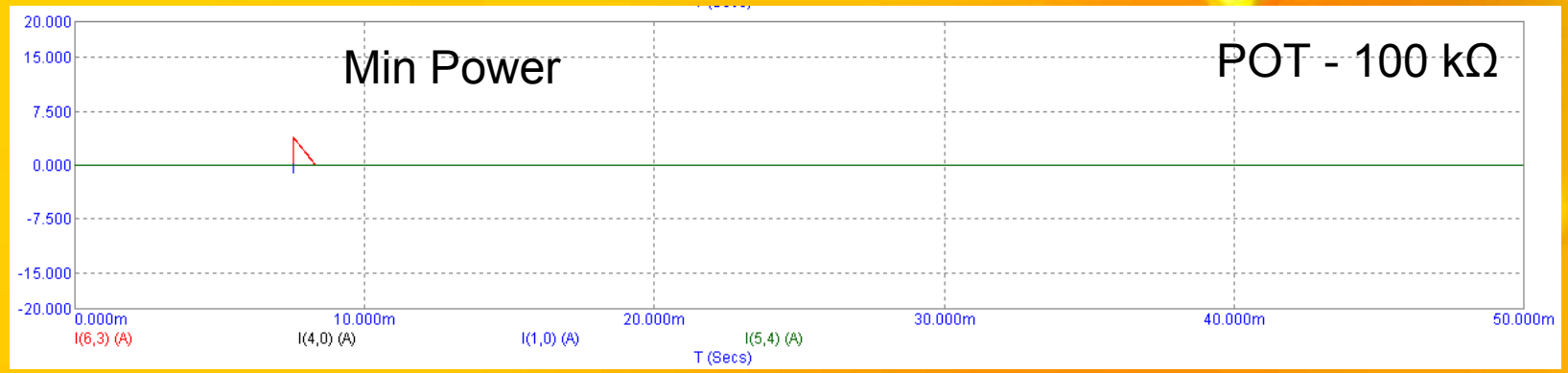
- Voltage or Current controlled Switch
- Solid State Relays (SSR)
  - Voltage Controlled
  - Faster response time & longer life
  - Max Current Handling Assumed Infinite Heat Sink
    - No heat sink = de-rate by a factor of 2-5
- Electro-Mechanical Relays
  - Current Controlled
  - No Heat Sink Required
- DC or AC

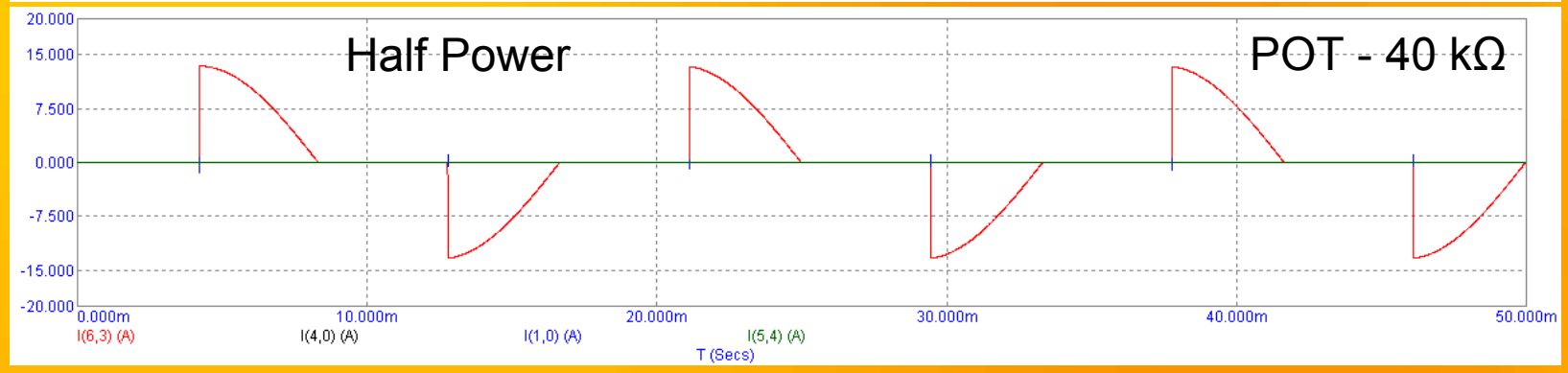
Dimmer Switch

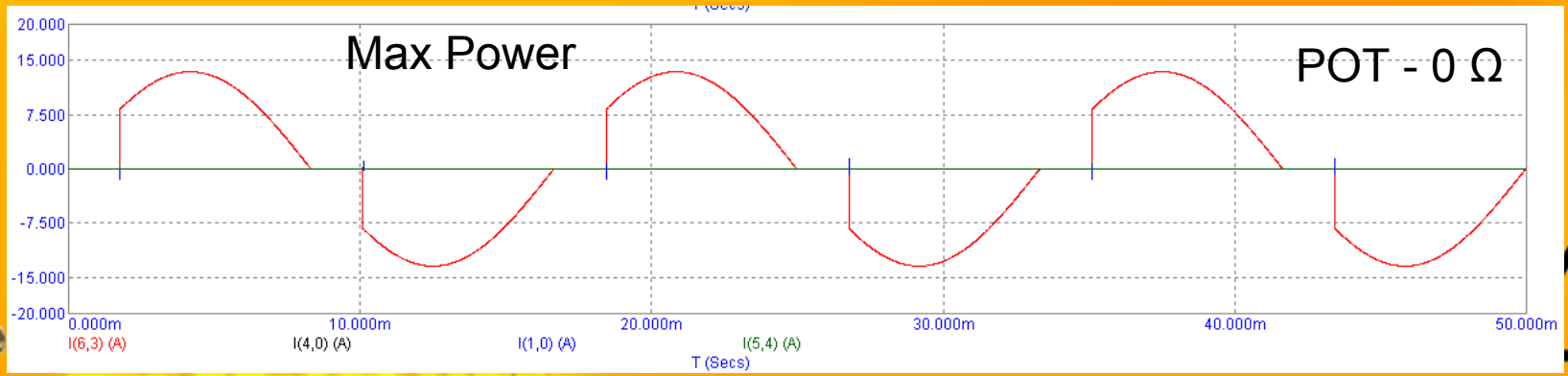
- Inexpensive & Simple
  - Less than $15
  - Self-Biasing
- No SSR required
- Non-Linear power control



Dimmer Switch – Heater Current

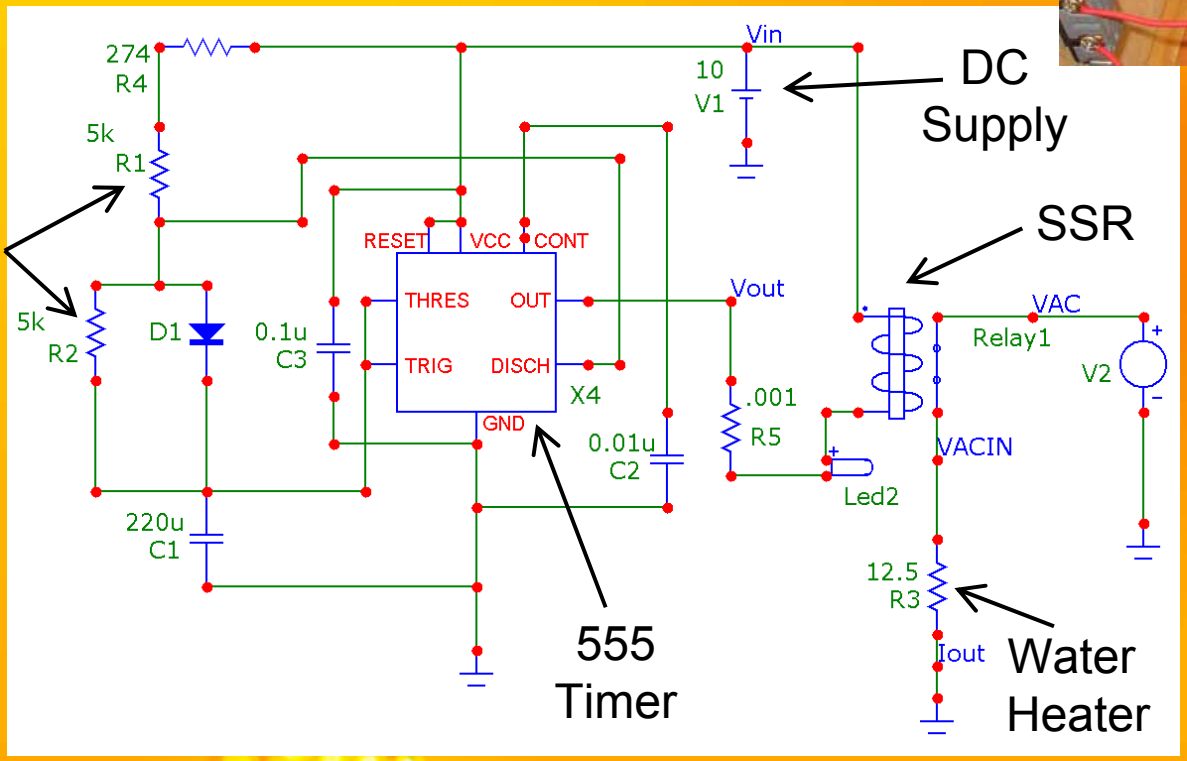


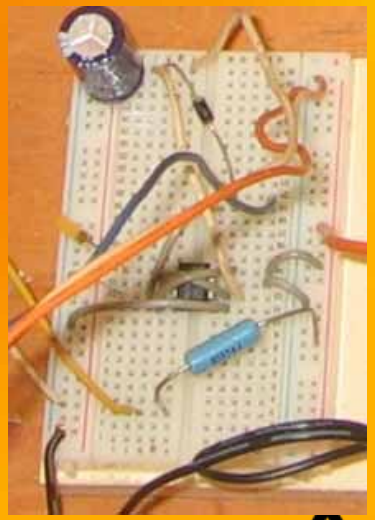




PWM – 555 Timer

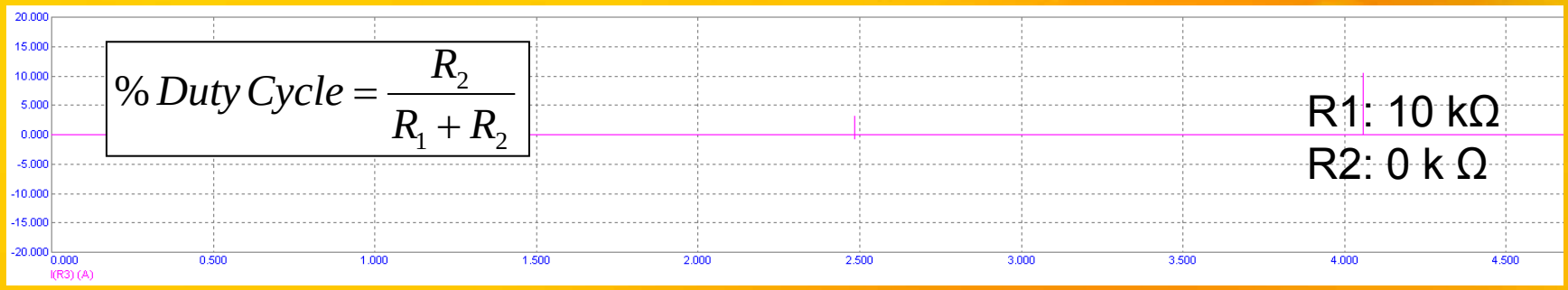
- Simple
- Linear power control
- Requires an SSR & DC Bias





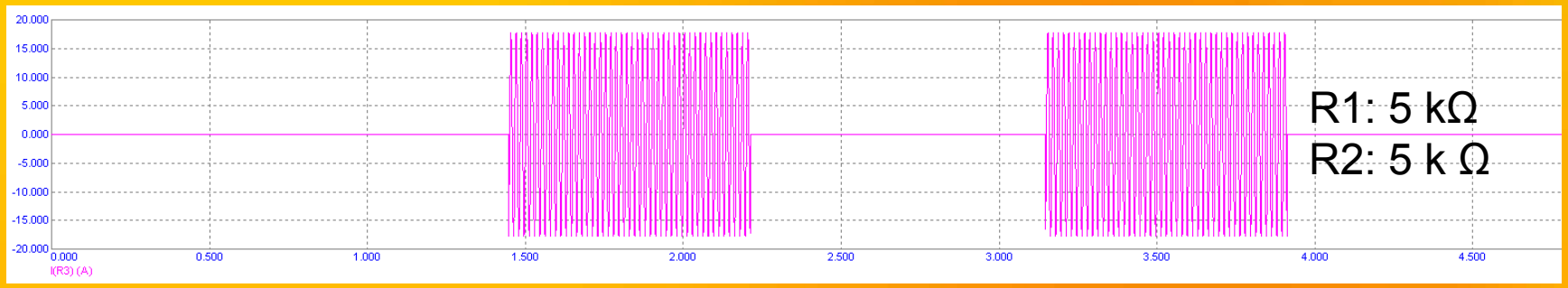
555 Timer – Heater Current

$$\%\,Duty\,Cycle = \frac{R_2}{R_1 + R_2}$$



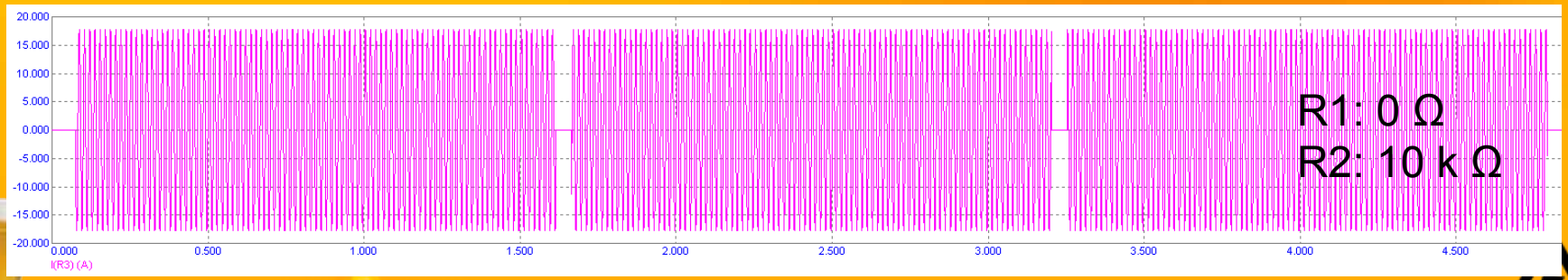
R1: 10 kΩ
R2: 0 k Ω

Min Power



R1: 5 kΩ
R2: 5 k Ω

Half Power

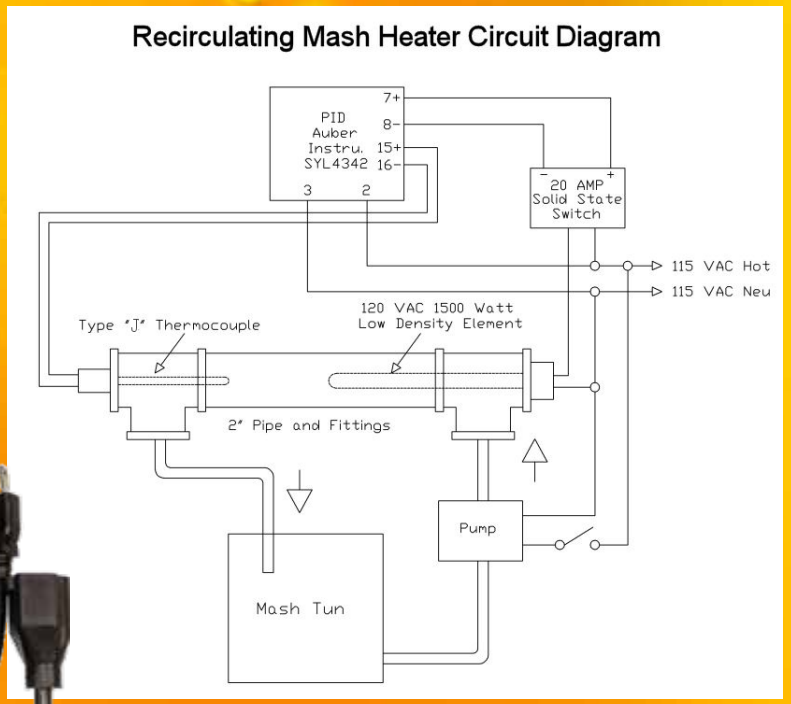


R1: 0 Ω
R2: 10 k Ω

Max Power

PID Control

- Requires Probe & Relay
  - Johnson A419 includes both
- Great for HLTs
  - Set it and forget it
- Can be controlled via RS232/485
  - On/Off PID
  - PWM %Power

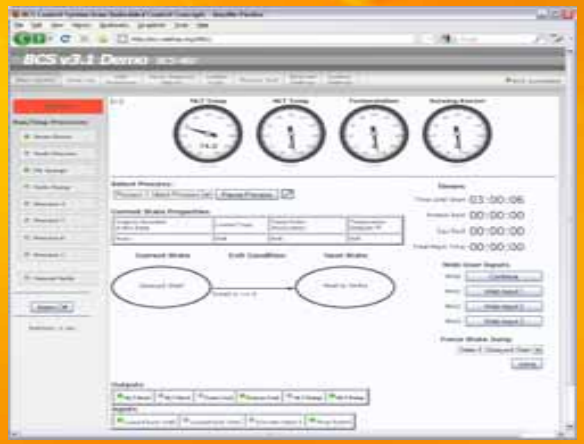


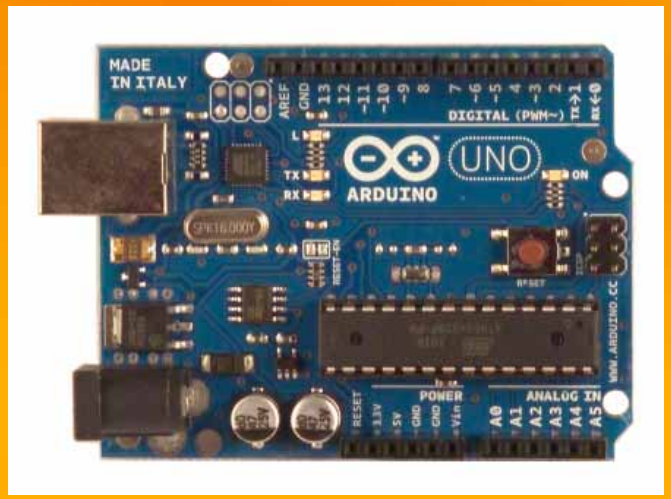
Temperature Probes

- RTD
  - 3 Wires
- Thermocouple
  - 2 Wires
- Most PIDs take either

Software Control

- Commercial
  - BCS 460
- Homebrewed
  - Arduino micro-controller
  - PID Software
  - USB Interface
- Needs Temp Probe & SSR





Take-Aways

- Electric brewing systems are varied & tailorable
  - Electric HLT
  - RIMS & Gas
  - Fully Electric
- Safety is critical, but not that hard
- Not many commercial options yet
  - More Beer & others are developing them
- DIY is pretty wide open – everyone's systems seem to look different so far
- Follow-On Tech Meetings are an option

References

- Google (1st result will get you there)
  - The Electric Brewery
  - Pol's electric HERMS
  - DrPaulsen's flickr photostream
  - High Gravity Homebrew electric
  - BCS-460
- Parts Suppliers
  - Menards, Lowes, Home Depot
  - McMaster-Carr
  - Auber Instruments
  - Amazon
  - The Electric Brewery -> /master-parts-list
- Wikipedia – Great for Basic Concepts