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Microbial Fuel Cell

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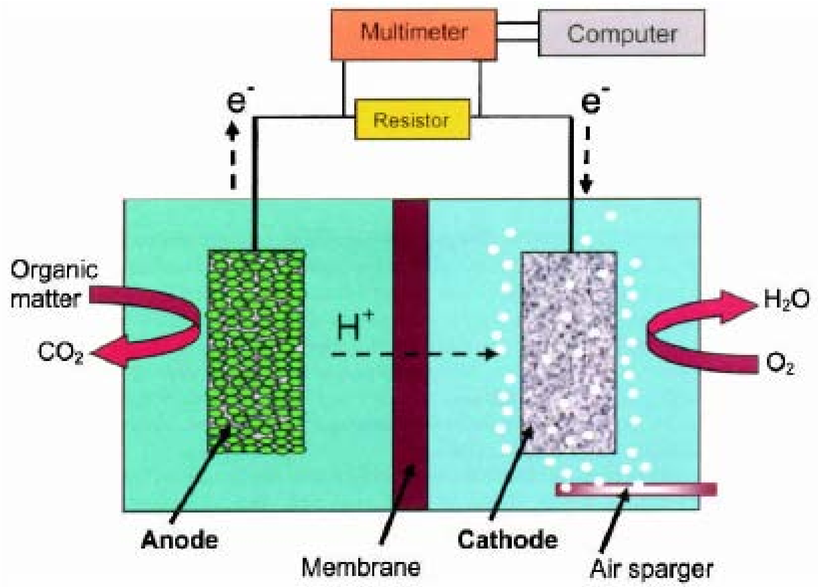
DECEMBER 21, 2009

NEW YORK UNIVERSITY

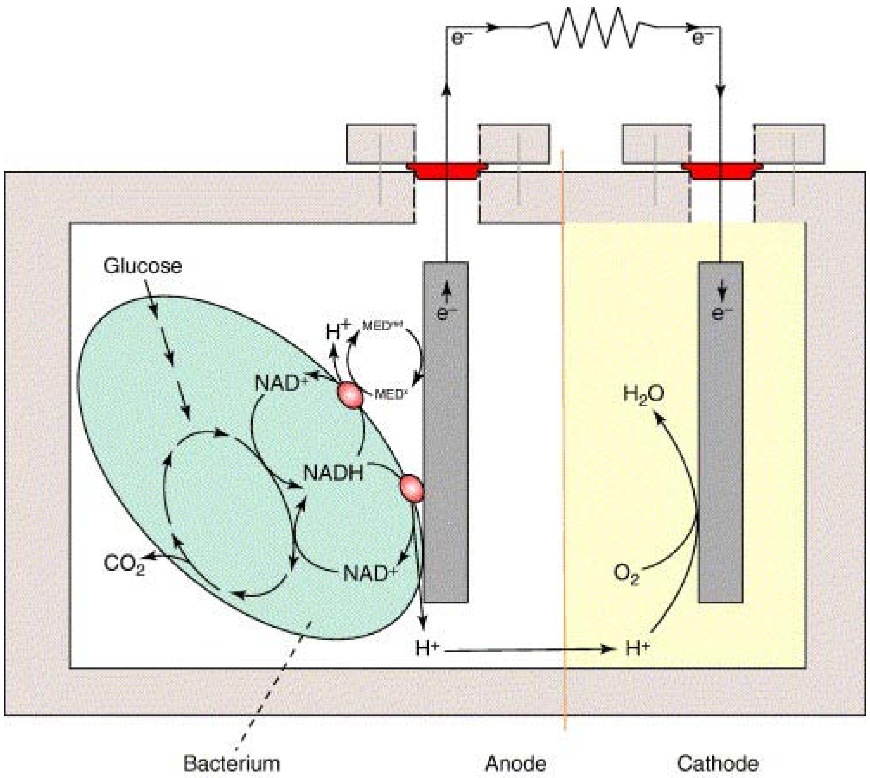
Microbial fuel cell (MFC)

- MFC's are devices that produce energy from bacteria (and other microbes) metabolism
- The devices involve an anode and a cathode
- In the anode bacteria's energy pathways are tapped into producing electrons and protons (H+)
- H+ crosses a PEM – H+ only barrier
- H+ in the cathode are oxidized to produce water`



Chemistry of electron production

- When microbes (in or case E. coli) metabolize glucose, intermediates are produced
- These intermediates along the energy pathway can give up an electron to an external molecule called a mediator
- The mediator undergoes a redox reaction, where the “trapped” electron is transferred to an electrode surface
- The mediator has the property traveling across the cell membrane



TRENDS in Biotechnology

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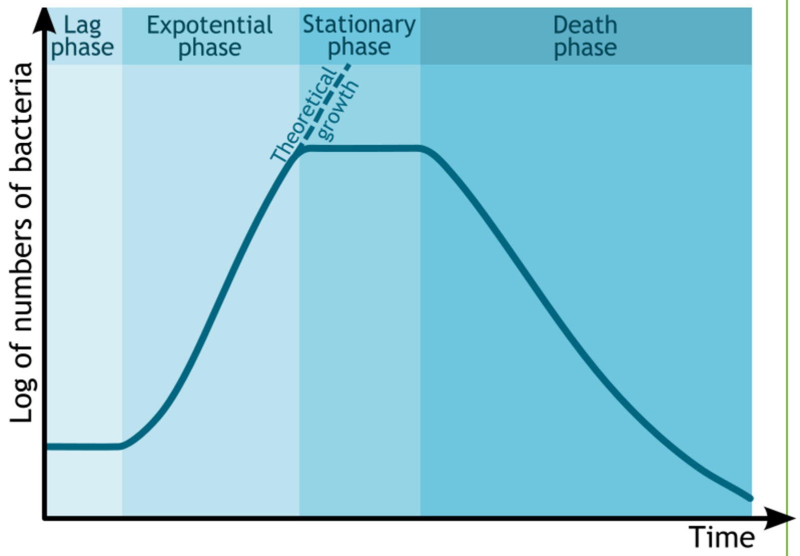
Bacteria growth kinetics

- Bacteria growth is dependent, most rudimentary, on the presence of substrate/food and on temperature (pH and other nutrients are also crucial, but assumed present)

- There are 4 phase characterizing bacteria growth

- **Lag –** bacteria become accustom to the environment
- **Exponential –** rapid growth
- **Stationary –** nutrient consumption leads Slowed growth
- **Death –** lack of nutrients



- The presence of bacteria then can be controlled through nutrient distribution and thermal energy (there is an optimal temperature for proper enzyme functioning)

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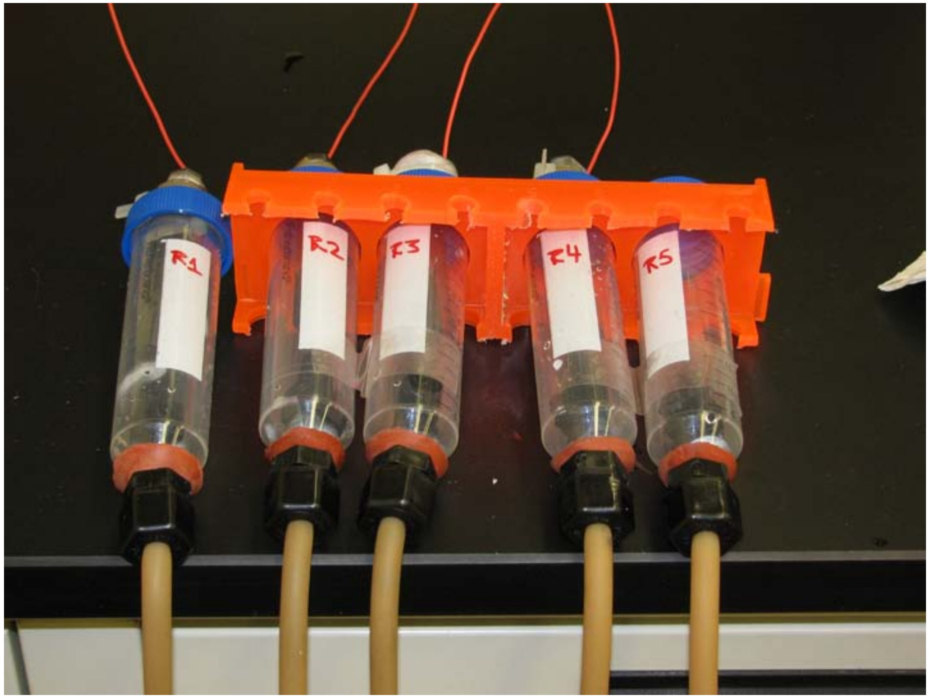
Project objective

- In this project it is the goal to maintain an optimum bacteria population, and consequent current production through control of **thermal energy**
- The bacteria population is proportional to the current produced
- A PID algorithm, is used
- BS2 communicates with MATLAB’s SIMULINK
- SIMULINK communicates with an automatic Heat exchanger via RS232 port

Construction

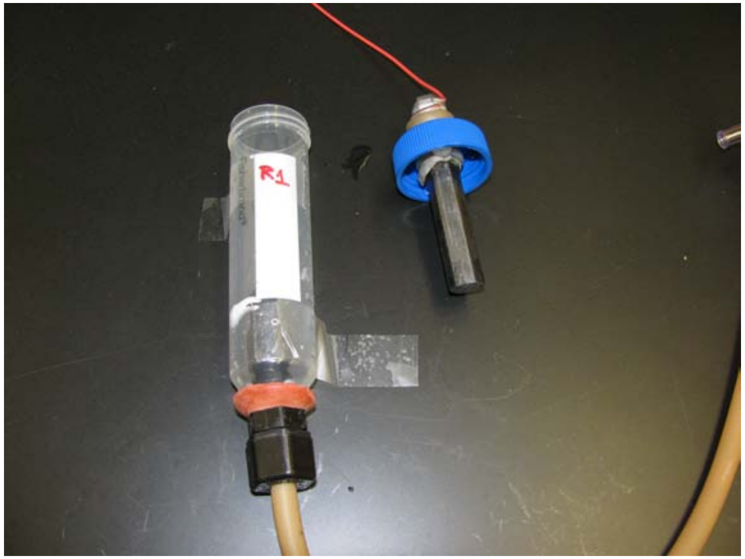
Design: Anode

- Five reactors are run simultaneously to increase current production in series
- Current of 0.025mA per ~ $4m^2$ and 5.1mV early in the lag phase
- Reaction volume of 35mL each*
- On anode side, LB broth is used at pH 6.8
- Humic acid mediator was used at 5% volume
- Fe(III) used as sacrificial reducing agent



Design: Bio-compatible electrode

- A bio-compatible electrode is needed
- 100% Graphite was used in high surface to volume
- The Conductance of 12mm thick by 18cm length graphite electrode is comparable to metals



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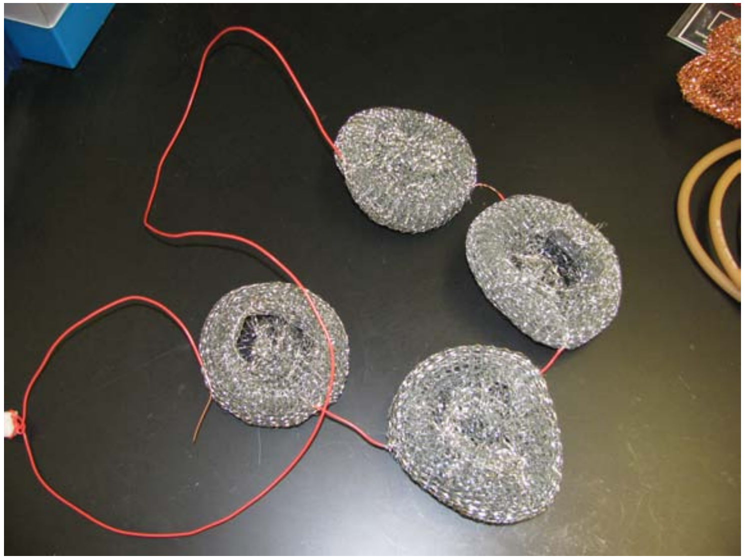
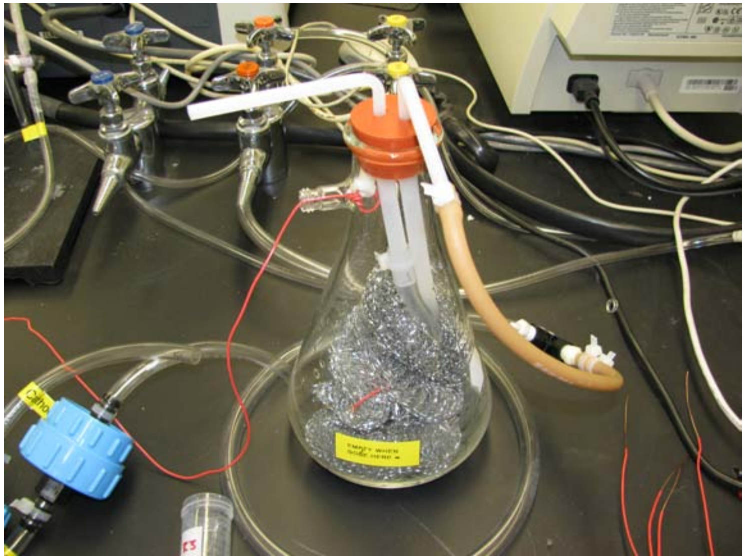
Design: Cathode

- Steel wool/low grade carbon steel is used as cathode catalyst
- This is used with a solution of Fe(III) (same concentration as in anode) to promote oxidation of H+ at pH 2.1





Proton exchange membrane

- We need a membrane that allows only H+/protons across
- Gortex is a common material with this property
- Gortex is held in place by a filter holder
- The Gortex interface is the bottle neck to current production
- Has the job of seperating two phases of differing pH

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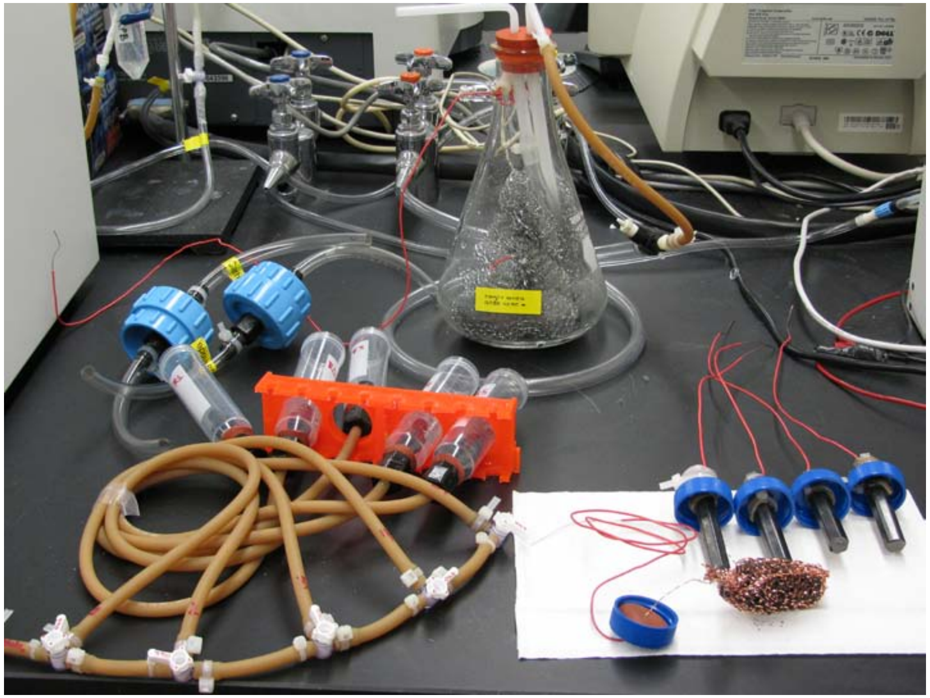
- Design: Construction



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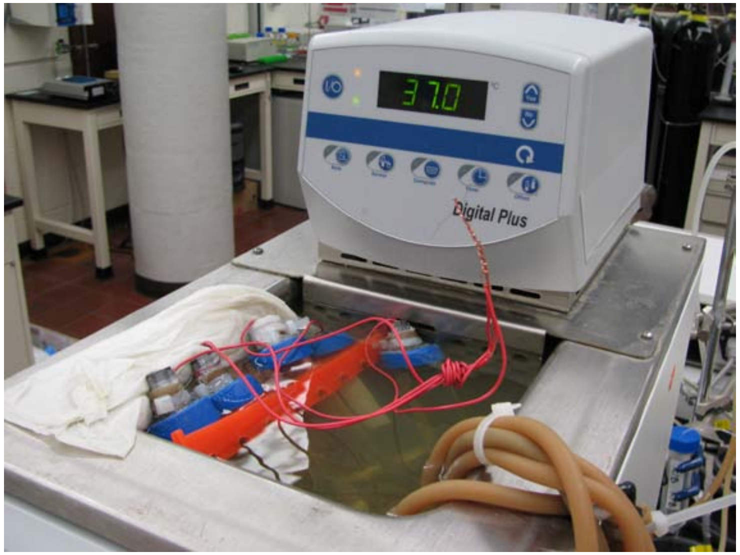
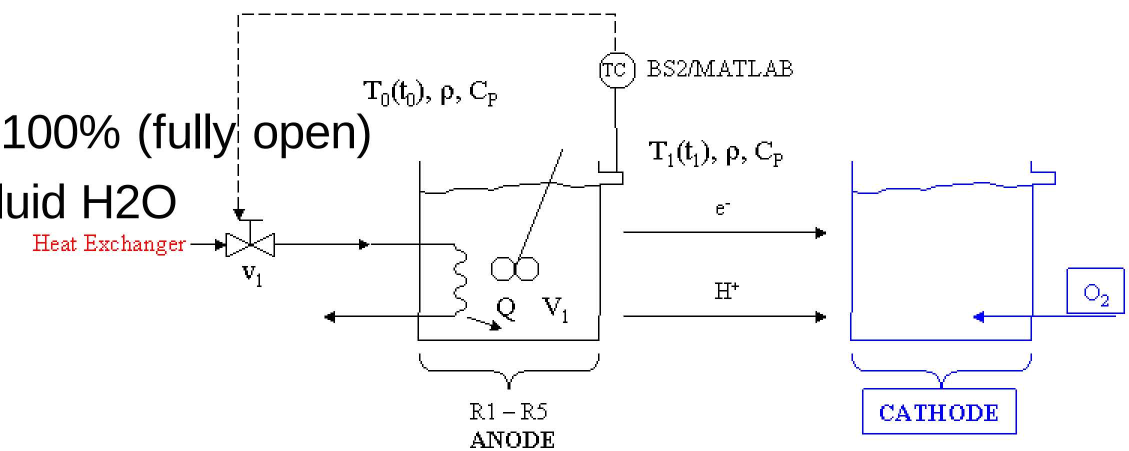
- Final setup



Mechatronics Implementation

Process Model – Temperature Control

- The process is modeled as a 1st order system with deadtime.
- V = 200mL
- F = 0.5L/sec
- To,init = 20oC
- To range: 0oC to 100oC
- Step = +60oC
- Step time = 100sec
- Valve Position: 0% to 100% (fully open)
- Constant properties, fluid H2O



Simulink Open loop temperature disturbance

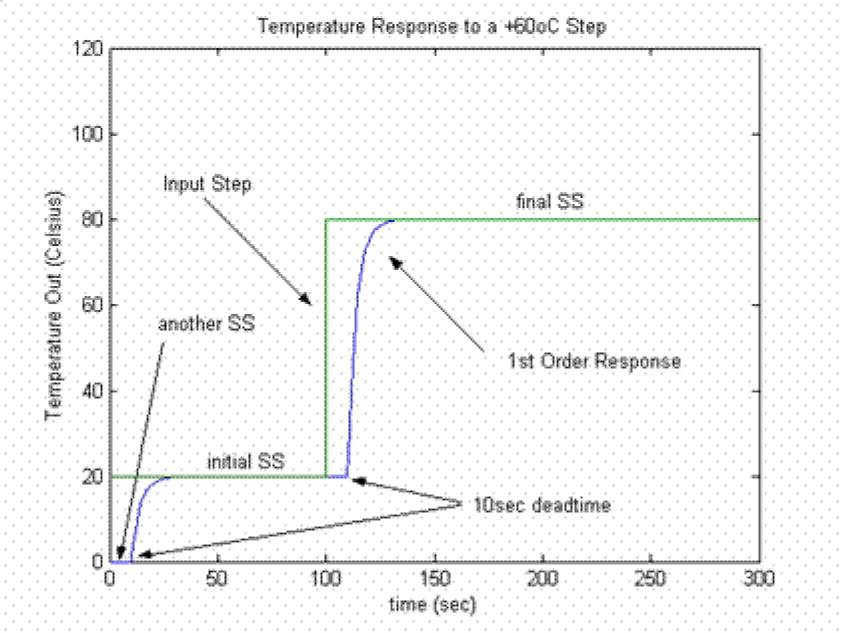
$$\frac{d}{dt}[mC_V T] = \frac{d}{dt}[\rho V C_V T] = \rho F C_P T_O - \rho F C_P T$$

$$\rho, V \text{ are constant; } C_V \approx C_P$$

$$\tau \frac{dT}{dt} + T = KT_O$$

$$\tau = \frac{V}{F} \qquad K = \frac{F\tau}{V}$$

$$G_P(s)\frac{T(s)}{T_O(s)} = \frac{K}{(\tau s + 1)}$$



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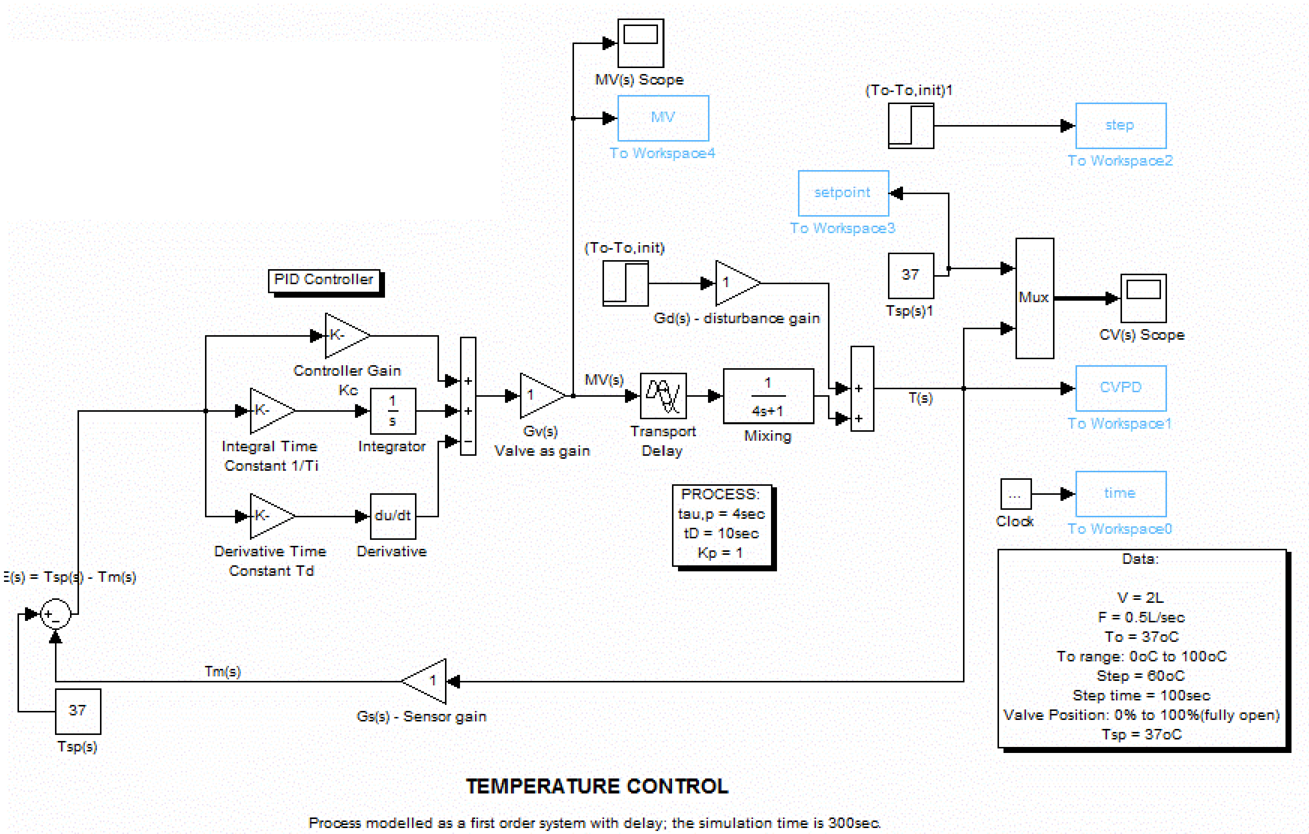
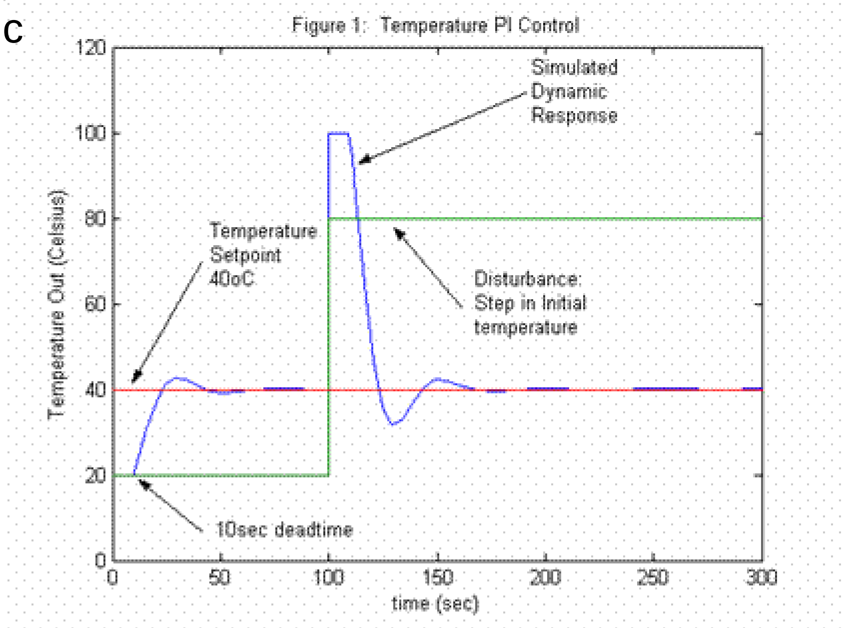
Simulink Closed loop PID temperature control



Simulink Closed loop temperature control

Controller Parameters:
(Cohen & Coon)

PID - Kc = 0.783; Ti = 14.42sec; Td = 0.25sec
PI - Kc = 0.443; Ti = 6.37sec; Td = 0
PD - Kc = 0.667; (1/Ti) = 0; Td = 0.339sec
P - Kc = 0.733; (1/Ti) = 0; Td = 0



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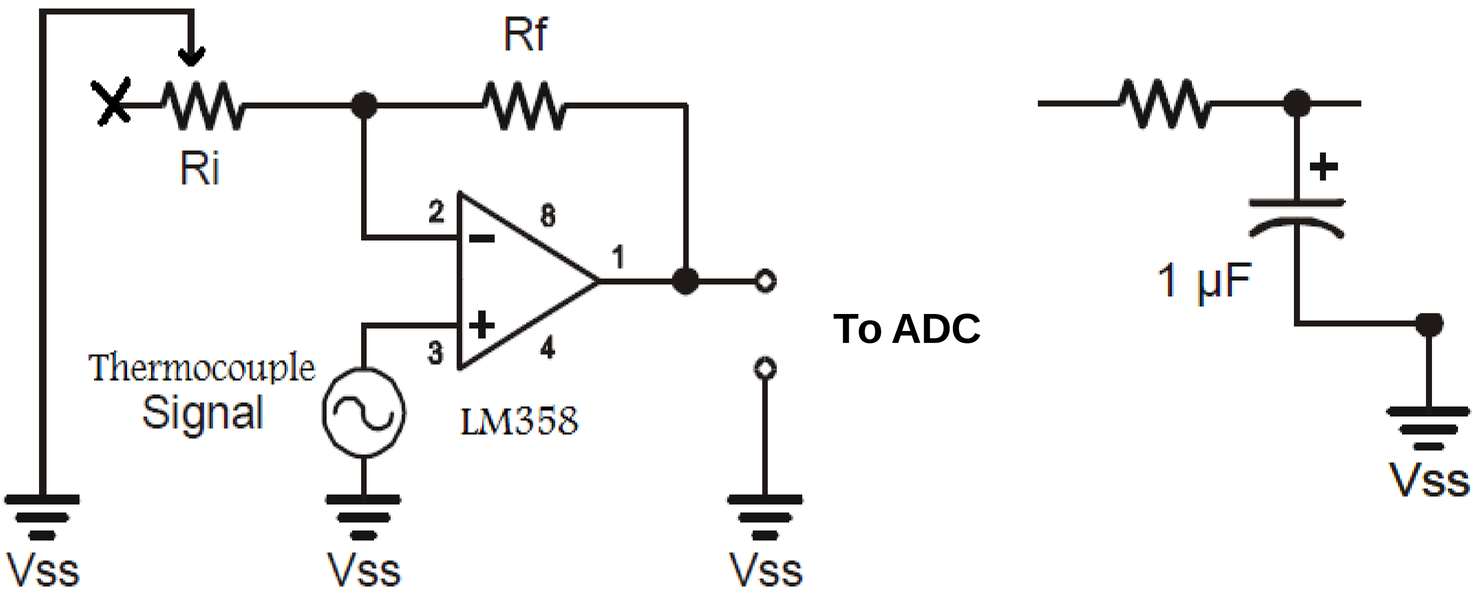
Sensor: Thermocouple

- Amplify thermocouple signal
- Filter out signal noise
- Calibrate the linear voltage to temperature scale



- Operational amplifier in non-inverting configuration
- Low pass filter used to reduce noise fluctuation

Sensor: Current sensor

- Vernier sensor can be interfaced with BS2 directly, through the 5 pins
- The current meter is used to measure current in parallel to the load
- In this experiment the load is a 10MOhm resistor
- 10uF capacitor used to eliminate noise in current produced
- According to manufacturer specifications, the heat exchanger is controlled

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Programming

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Now What?