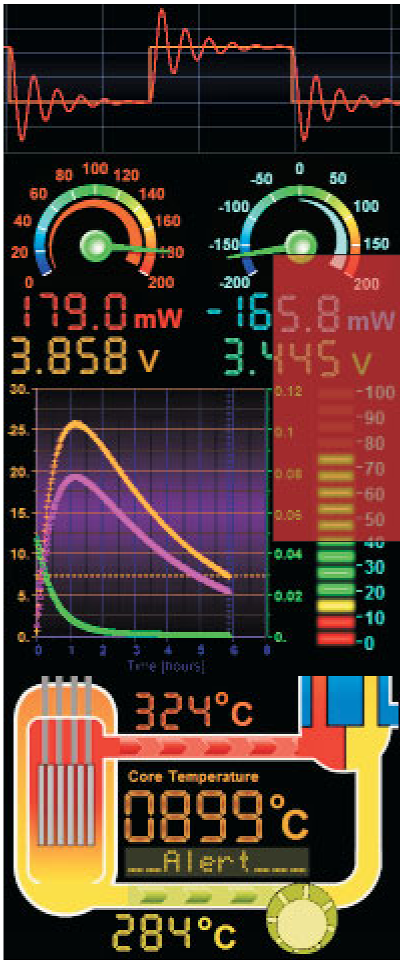
Reflow Oven PID Control



A reflow oven for surface mount soldering was builtusing LabRecon software and chip to implement PID feedback control of temperature following a specified temperature profile.

LabRecon

Software and Hardware for Measurement, Control and Simulation

The below panel was created in LabRecon as an interface to control the oven operation, adjust PID parameters, and view the temperature profile during a reflow operation.

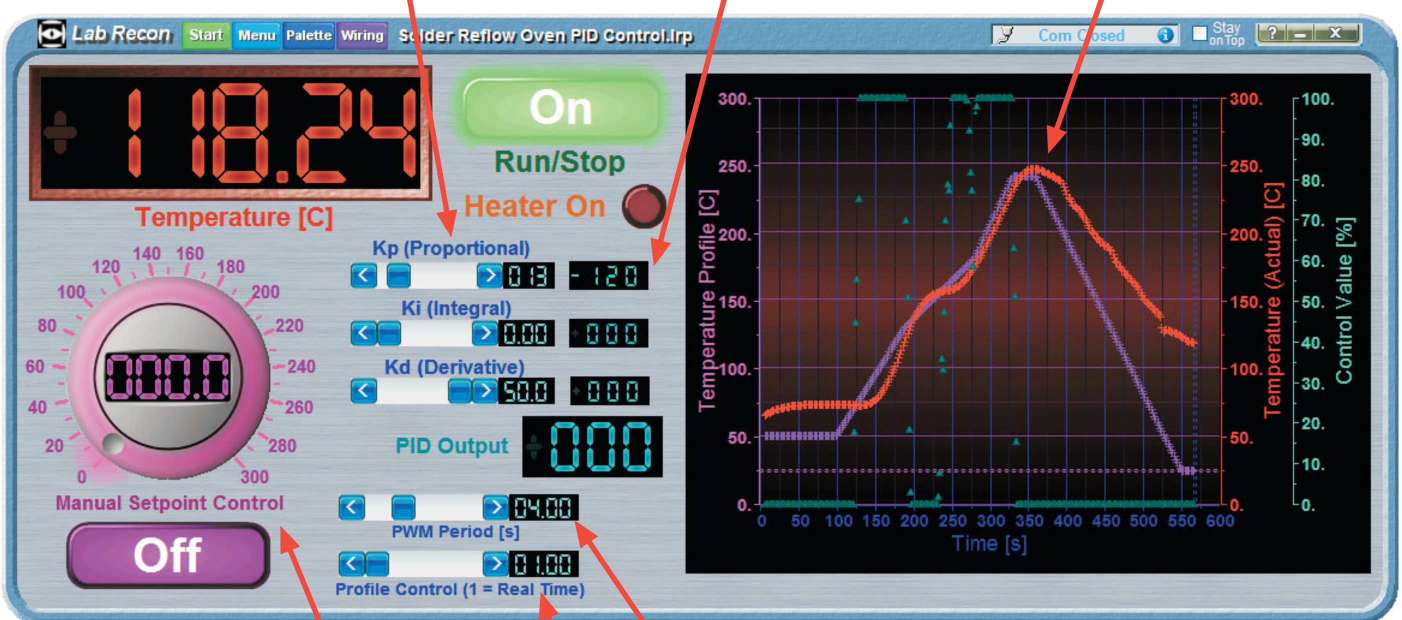
This project is included as an embedded sample project in LabRecon and can be modified to meet user needs.

Scroll bars allow the **PID (Proportional, Integral, and Derivative)** gains to be adjusted.

For the reflow oven, the **Integral** gain is set to 0 and the **Derivative** gain dominates to eliminate overshoot, which would occur due to the slow response of the oven.

Displays were added to show the contribution of each control term to the final PID output.

A X/Y Chart was added to display the desired temperature profile (violet), the actual (red), and the control output (light blue).



A knob and button were added to allow optional control of a constant temperature setpoint when the button is On. Under normal operation this knob is not used because the setpoint is controlled according to a temperature profile.

The PWM (Pulse Width Modulation) period can be set with this scroll bar. Since the oven has a slow response, a mechanical relay is used for heater control, and thus a long PWM period of 4 seconds is used.

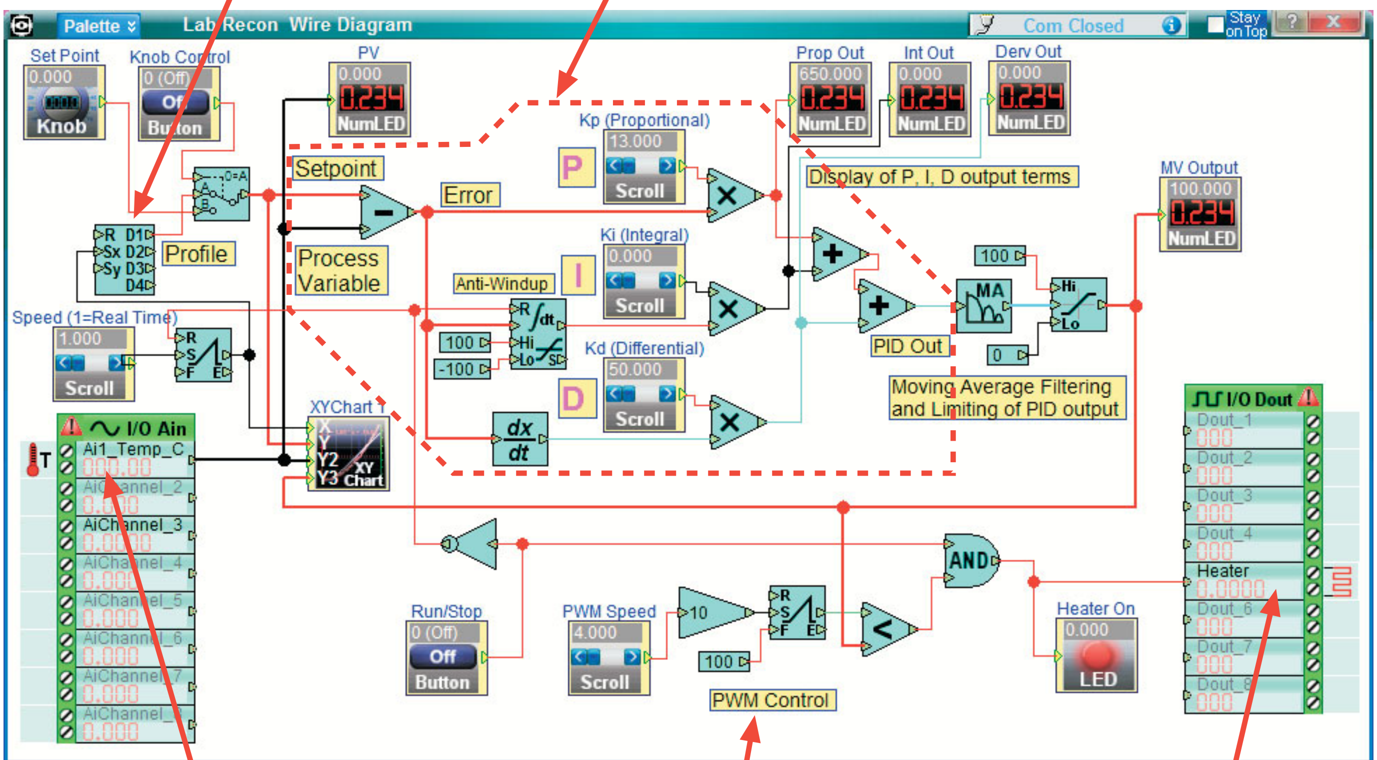
This scroll bar was added to allow speeding up the sweep time, to quickly visualize the temperature profile. The temperature profile data is loaded into a function on the Wiring Diagram.

The following page shows the Wiring Diagram which implements the control algorithm.

Each object on the panel has a corresponding object on the Wiring Diagram.

A Data Import object was added to hold 7 pairs of Time,Temperature values to define the temperature profile. The object's Properties screen can be opened to change or paste new values.

The outlined elements comprise the PID (Proportional, Integral, Derivative) control algorithm. It also implements Anti-windup to limit the integral output.



One of the 8 Analog Inputs was configured using the Measurement Wizard for a K-type thermocouple using an AD595 amplifier to provide a value in degrees C. The wizard automatically configured scaling and linearization for the channel.

A Ramp and a Less-than objects was added to implement a low frequency, ie 0.2 Hz, PWM signal to control the on-time of the relay used to control the heating elements of the oven.

A Digital Ouput is used to control the relay.

The above PID implementation is based on the "ideal" form, but it can changed to that of the "standard" form, which is more commonly used in commercial PID controllers. In the "standard" form the Kp (proportional) gain is applied to the output of all three terms.

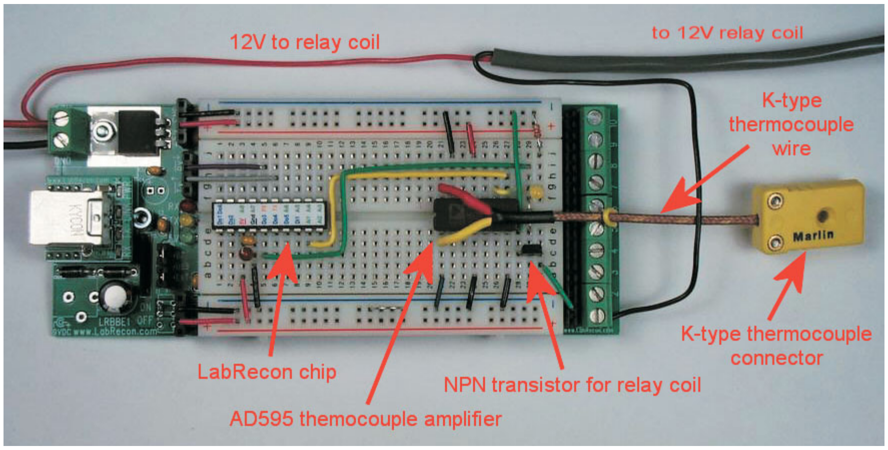
Another implementation feeds the input of the derivative term directly from the process variable with the sign corrected according to the error. This avoids a large derivative term change when a setpoint change occurs. A Moving Average Filter object can also be added before the derivative input to reduce noise, which it would amplify.

Feed-forward control can also be added by allowing a contribution of the PID output from the measurement of a disturbance source or from the setpoint value. An additional slider can be added to the panel to set the gain of this signal.

As can be seen in the above Wiring Diagram a moving average filter and output limits were added to the PWM output. The properties of this filter can be accessed to adjust the filtering.

Below is a photograph of the LabRecon chip and circuit. The breadboard shown is that of a LabRecon Breadboard Experimenter, which provides a convenient platform by including connectors, a voltage regulator, and a USB interface.

However, the circuit can be built on any breadboard with a 5V power source and an interface supplied separately. The LabRecon chip datasheet presents examples of interface methods and circuits.



LabRecon chip and thermocouple amplifier circuit

Care must be exercised with connections to the thermocouple because of the low voltages involved. A thermocouple operates on the principle of the Seebeck effect, whereas a temperature dependent voltage is created across junctions of two dissimilar metals. Any other junctions, such as connections, will essentially create "secondary" thermocouples that will produce an error with the temperature reading.

Of course there must be a point at which connections must be made with the measurement electronics and this point is termed the "cold junction". By measuring the temperature of the "cold junction" by other means, such as with a semiconductor sensor, the temperature can be corrected. This method of "Cold Junction Compensation" is a feature of the Add thermocouple amplifier chip, but to work properly the temperature of the chip must equal that of the "cold junction".

As can be seen in the photograph **K-type thermocouple extension wire** is used between the chip and a female **K-type thermocouple connector**. A male K-type thermocouple connector was attached to the thermocouple leads for convenience.

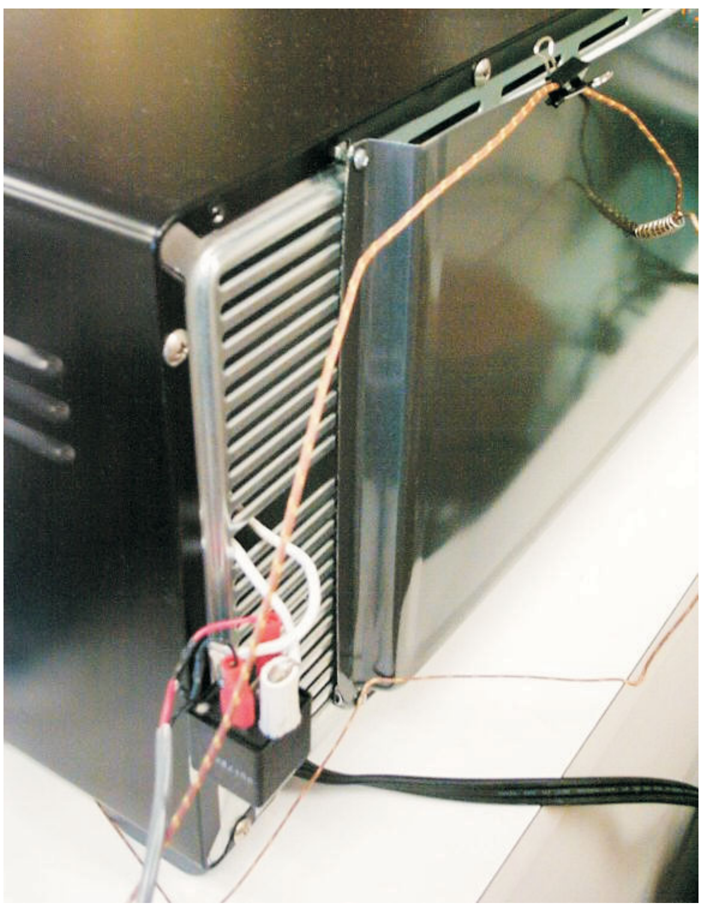
The female thermocouple connector was ordered from McMaster-Carr, 3869K34. The 24 gauge K-type thermocouple wire ordered was 6579T42. The thermocouple was purchased from meter-depot.com through Amazon.com, which came fitted with a male connector. If a thermocouple without a connector is used, a male connector (3869K35) can be ordered from McMaster-Carr.

A NPN transistor was used to drive the coil of the relay used to switch the current of the oven's heating elements. The PWM control is done at a low frequency, ie 0.2Hz, so there should not be an issue with contact wear. Alternatively a solid-state relay could be used.

Here is a picture of the oven used. It is a 1500W Black & Decker convection (air circulation fan) oven, model TRO407, which was purchased for $35.00.

The “Function” (middle) knob should be set to “toast” to power both the top and bottom heater elements.

The thermocouple can be seen just above the circuit board in the oven.



The rear of the oven is shown here with the relay visible in the lower left. A shallow baking tray was added to the rear to hold a few layers of 1/8” thick fiberglass insulation paper (McMaster-Carr 9323K21). The oven was disassembled to add this insulation paper on the top and sides of the internal oven box. The insulation helps to achieve a faster temperature rise, especially at higher temperatures.

The thermocouple wire can be seen entering a hole that was drilled through the rear of the oven. This hole was positioned to hold the thermocouple tip about an inch above the oven’s grill when the grill is in is upper position.