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Toast-R-Reflow

Assembly and Use instructions

Congratulations on moving up to surface mount technology prototyping! I grew up during the Heathkit era, when building electronic gadgets of all kinds was a fun and fulfilling hobby. With the movement of the electronics industry towards surface mount devices, it seemed for a time like the era of the electronics hobbyist was growing to a close, since the industrial methods for dealing with SMD parts was basically beyond the reach of hobbyists.

However, recently there have been new developments in low cost, low run printed circuit board fabrication and CAD software that have ushered in a new era, bringing once again into reach the ability for any hobbyist to create a device indistinguishable from one that would have been produced by an assembly line thousands at a time!

You've purchased your own piece of the revolution. The Toast-R-Reflow system is designed to allow you to construct your own SMD reflow soldering oven from a consumer grade toaster oven. With this kit, the right toaster oven, and a little time, you'll be reflow soldering in no time!

WARNINGS

This is not a project to be undertaken lightly. It involves taking apart a toaster oven, which operates on household AC power, which can kill you if you make a mistake. It also involves hacking around with AC powered heating elements, which will easily get hot enough to cause major burns and possibly start a fire.

The chemicals in solder paste, flux and the other components involved in reflow soldering are sufficiently toxic to be completely incompatible with cooking food for human or animal consumption. Once you have used your oven for reflow soldering, you should never use it - or any of the other tools or apparatuses involved - for handling food in any way. If your oven produces any smoke or flames, immediately disable the power and move away from the oven as quickly as possible to avoid breathing any toxic fumes. Reflow soldering should be performed in a well ventilated area.

Do not attempt to do anything described in this documentation if you are not qualified to do so. We cannot advise you to follow in our footsteps. Frankly, we can't believe we were foolish enough to do it ourselves.

Requirements

In order to complete this project, you'll need…

- The Toast-R-Reflow power and controller kit
- A 250 mA 6-12 volt DC power supply
- A K type thermocouple
- And, lastly, a toaster oven

Any K type thermocouple will work so long as it is long enough to reach from the inside of the oven to the controller board. Similarly, any DC "wall wart" power supply you have handy will work fine as long as it's between 6 and 12 volts DC and can supply up to 250 mA. The connector is a standard 2.1 mm barrel connector, center positive.

For the oven, you need a model that is a somewhat elusive combination of speed of heating combined with ease of disassembly. Your odds of picking a winner are higher if you stick with smaller ovens rather than larger - they have less air inside to heat, and even the smallest oven will likely have plenty of room inside for a few small boards. We selected a Hamilton Beach model 31138. It has worked out fairly well.

Contents

Your kit should contain

- A Toast-R-Reflow controller board, with all SMD parts installed and a pre-programmed controller
- A 2x16 character LCD module
- 4 2-64 1/2" bolts
- 4 #4 1/4" standoffs

- 4 #2 nuts
- A 16 pin SIP header
- A Toast-R-Reflow power board
- A 6 pin (2x3) DIP header
- A 3 position 3.5mm screw terminal
- A 2 position 2.54mm screw terminal
- 2 .01 uF capacitors
- 2 39 ohm resistors (orange-white-black)
- 2 330 ohm resistors (orange-orange-brown)
- 2 360 ohm resistors (orange-blue-brown)
- 2 MOC3020 6 pin DIP optoisolators
- 2 BTA 20 triacs
- 2 triac heat sinks
- 3 single 1/4" QD board-mount terminals
- 2 4-40 1/4" bolts
- 2 4-40 nuts
- 2 #4 lockwashers
- 4 #4 plastic or fiber washers

Assembling the power board

The majority of the soldering is in assembling the power board.

Install the 2 capacitors and the 2 39 ohm resistors (orange-white-black) first, They go near and between the two output terminals.

Next, install the 4 remaining resistors, taking care to install the two resistor values in the correct spots. With the heatsinks to the left and the optoisolators on the right, the 330 ohm (orange-orange-brown) are the upper of each pair, and the 360 ohm (orange-blue-brown) are the bottom of each pair.

Next, install the optoisolators. Be sure to place pin 1 of each in the correct orientation. With the board positioned as above, pin 1 of each is on the bottom right corner - closest to the low voltage input terminals.

Next, install the input terminal block. There is no correct orientation electrically, but you should insure that the wires are inserted from the outside edge of the board rather than the inside (you want to keep the low voltage side as isolated as possible from the high voltage side.

Now it's time to deal with the triacs. Smear a small dab of heat sink compound on the back of each triac and then bolt each to its heatsink with a 4-40 nut, bolt and lock washer. The bolt head should be on the triac side, and the lock washer and nut should be on the back of the heatsink. Now insert the triac and heatsink assembly into the board. The two pins on the heatsink should fit into the two large holes on the board, and the leads of the triac should fit cleanly into their holes without undue bending. With the board oriented as above, each triac should face the same direction - towards the bottom of the board. This is crucial - the triacs will not work installed backwards!

Before soldering the triac into place, lift out the heatsink and place one of the fiber or plastic #4 washers on each pin. This is to protect against the possibility of the heatsink scratching the solder resist layer of the board and shorting out the high voltage traces running under it. Hold the heatsink firmly in place and tack one of the triac leads to the board. Check one last time to insure that the triac and its heatsink are correctly positioned, then solder each lead on both sides of the board. A good electrical connection to both sides is critical for the current carrying capacity of the circuit design.

Now install the three QD terminals. Insert each into its position on the top of the board and liberally solder the entire bottom edge of the terminal to the board while insuring that the terminal remains straight and plumb. Turn the board over and solder each pin to the bottom side of the board. Ensuring a well bonded, low resistance connection from the terminal to the board is crucial to insure that the board and terminal do not get damaged by high temperature as a consequence of the current flowing through them.

That completes the assembly of the power board.

Assembling and testing the controller

The controller comes with all of the SMD parts pre-assembled and tested. All that remains is mounting the 4 through-hole connectors for the ISP port, the thermocouple, the select button and the output terminal for the oven, and mounting the board to the LCD panel.

You must install the through-hole components before mounting the LCD. Once the LCD is mounted, the "solder side" of the board (that is, the side opposite the components) will be inaccessible.

First, install the 2x3 DIP header in the ISP point on the board.

Next, install the 2 pin SIP header in the point on the right side of the board for the off-board SELECT button connection. You can connect a chassis mounted push button to this connector if you mount your controller in an enclosure.

Next, locate the 2.54mm two pin screw terminal and install it in the "THERMO" box. You can install the socket facing either direction, but facing the openings towards the board edge is recommended.

Similarly, locate the 3.5 mm 3 pin screw terminal and install it in the "OVEN" box. Again, facing the socket so that the openings are outward is recommended.

For model I, if you do not wish to use the board-mounted button to control the oven, you can install a 2 pin .1" SIP header in the two pin spot on the right edge of the board near the switch.

For model II, install a 6 pin .1" SIP header in the FTDI position on the right edge of the board. Install a 4 pin .1" SIP header in the button position near the top edge of the board. There are three buttons - up, down and select. Up and down are not currently used, but are available for future expansion. The serial port is currently used as a temperature data log source. Use a standard FTDI cable and configure your host for 9600 baud, 8N1.

Next, install the 16 pin SIP header on the *solder side* (that is, the side opposite the components) of the controller board. Use the short side for the controller board and insure that the entire connector is straight and flush. Do not solder the connector in place yet.

Insert a 2-64 1/2" bolt through the holes in each corner of the controller board so that the heads are on the component side. Lay the board down on your work surface with the components down. Thread a #4 1/4" standoff over each bolt. Then thread the LCD over the bolts so that the 16 pin SIP header on the controller mates with the corresponding holes in the LCD. Loosely attach the #2 nuts on the bolts to complete the mechanical assembly. Insure that the two boards are parallel and that nothing is binding or kinked, and that each pin of the connector is fully inserted into both the LCD and the controller board and only then finally solder each of the pins of the SIP header to both the LCD and the controller board.

If you wish to install the controller in an enclosure of some sort, you may remove the nuts and bolts. When you install the assembly in an enclosure, insure that the spacers are properly placed between the boards to insure that the boards are not stressed or bent when they are attached to the chassis.

That completes the assembly of the controller.

Connect the thermocouple up to its screw terminals, paying careful attention to the polarity. Connect the power to the power input and the display should light up and show “Toast-R-Reflow” and the firmware version for a couple seconds, then show the “Waiting” state and the current temperature of the thermocouple.

If the backlight of the LCD lights, but you don’t see anything else, try adjusting the LCD contrast until the text becomes readable.

If you are using model I and see an obviously incorrect temperature, then check to insure that the polarity of your thermocouple is correct and that nothing’s wrong with it. An extremely high temperature reading (depending on your controller version it could be 512 degrees, 1000 degrees or 360 degrees) indicates that the thermocouple is disconnected. You can also use a VOM to measure the DC voltage at the “Therm” test point just above the thermocouple amplifier IC. It should read 5 millivolts for every degree Celsius of the thermocouple. A good room temperature of approximately 25 degrees Celsius should result in a reading of 125 mV. Note that the standard color code for K thermocouples is yellow for positive, and (perversely enough) red for negative.

For model II, the controller will report thermocouple faults directly with a message. The fault bits are the three fault bits of the MAX31855. The three possible values are 1, 2 and 4. 1 means that the thermocouple is open or not connected. 2 and 4 mean that one or the other lead is shorted either to ground or Vcc. In any case, check your thermocouple and its wiring. If the temperature is incorrect, check to make sure that your thermocouple polarity is correct.Note that the standard color code for K thermocouples is yellow for positive, and (perversely enough) red for negative.

If you push the start button, you should see 5 volt pulses (quite probably ramping quickly up to a 100% on value) on each of the two non-grounded oven terminals.

Connecting and testing the power board

These instructions are going to need to be general in nature, as each oven will differ. What you're going to need to do is connect the hot wire of the incoming AC power to the hot terminal on the power board, and one end of each heater element to one of the output terminals. The neutral wire of the AC input should connect to each of the heater elements on the other ends. All the rest of the control and/or display wiring of the oven should be disconnected.

Some ovens have 4 heater elements instead of 2. For those ovens, you must check to see whether the pairs of elements are wired in series or in parallel. In general, you should see the neutral conductor hooked up to either one of the element and the two opposite ends of the element hooked to each other (series connection), or the neutral conductor hooked up to both of the elements, much like in the case of the two elements in a two element oven (parallel connection). Do not inadvertently convert one connection style to the other, as you will either double the voltage fed to the element (which will burn it out) or halve it (which will result in poor performance).

You can mount the board in the oven using #4 hardware in each of the corner holes. When considering where and how to mount the power board keep in mind the following:

- Keep the triac heat sinks as far away as possible from the heat of the oven.
- Keep the board away from ventilation slits in the case. There are line voltages present over most of the surface of the board, and you don't want to make it possible (or at least easy) to poke an object through the chassis into the board.
- Make sure to mount the board so that it does not contact any metallic chassis components, lest you short out any of the components.

After mounting the power board in the oven, connect a 3 conductor cable to the input terminals and route it outside of the oven, avoiding both the high voltage wiring and any heated surfaces of the oven.

Decide how you intend to mount the thermocouple and route its cable out of the oven to the control board.

Lastly, reassemble the oven and connect the 3 conductor control cable to the output terminals on the controller board.

Your reflow oven is now complete.

Use

Instructions for preparing your boards for reflow are beyond the scope of these instructions. Once your board is prepared, place it inside the oven. Either place the board(s) near the thermocouple or move the thermocouple to be in close proximity - but not touching - the boards as practicable. Close the door and press the 'start' button.

The oven will heat, proceeding through the phases of the profile compiled into the controller. Once finished, the display will turn yellow and return to the waiting state. The oven may still be hot. Once the boards are sufficiently cooled, they can be removed from the oven.

The start button understands two types of pushes - a long push or a short push. 250 ms is the dividing line between the two. In the idle mode, a short push will start a cycle. For model II controllers, a long push will change the selected profile. During reflow, a short push will swap the display between showing the duty cycle of the elements and the target temperature. A long push will abort the cycle in progress.

The model II controller comes with three profiles - SnPb is a tin-lead paste profile with a peak temperature of 230 degrees. RoHS is a lead-free profile with a peak temperature of 250 degrees. "Bake" is for dehydrating moisture sensitive parts. The Bake profile will keep the oven at 125 degrees for 12 hours.

Programming

The model I controller comes configured with a thermal profile suitable for tin-lead based solder paste. This profile consists of:

- A 90 second preheat interval, where the temperature will climb to 150 degrees.

- A 60 second soaking interval, where the temperature will more slowly climb to 180 degrees.
- The temperature setpoint will then snap to 230 degrees, so the oven will climb as quickly as it can to 230 over the course of the next interval.
- The reflow period of 75 seconds includes the ramp up to the aforementioned 230 degrees, holding it there for the duration.
- Finally, the oven will enter a 60 second cool down period down to 100 degrees. This phase is designed to prevent the oven from allowing the cool-down to go faster than allowed (lest the components suffer thermal shock). The oven likely will cool slower than this on its own.

If you want to alter the profile, you must download the firmware from the GitHub repository, alter the profile curve and upload new firmware using an AVR ISP programmer connected to the ISP port of the controller board.

Programming the controller and uploading firmware requires the Arduino IDE configured to program ATTiny controllers. For Arduino version 1.0, you must add third party ATTiny support. The best list of options is at https://code.google.com/p/arduino-tiny/

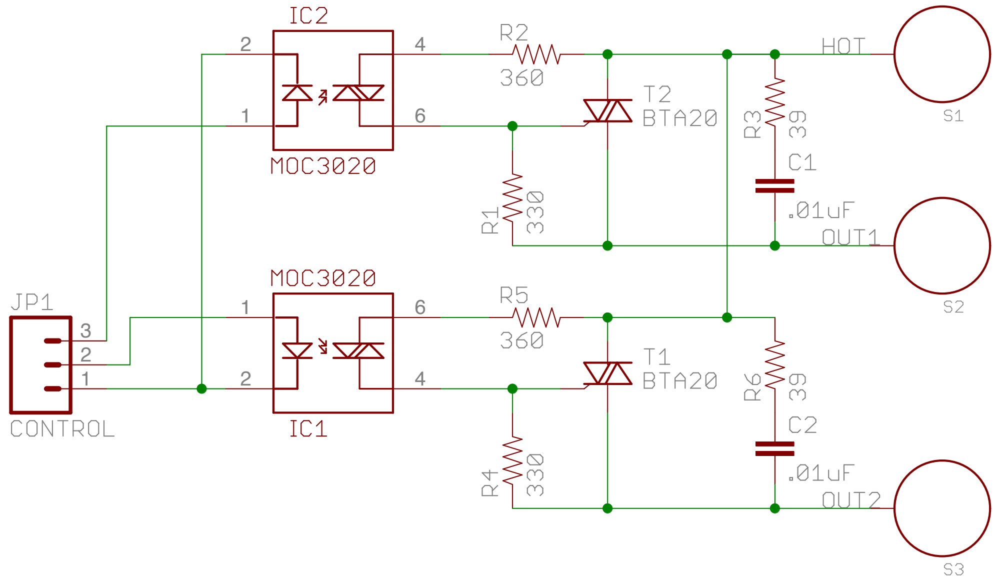
The Toast-R-Reflow sketch also requires the following Arduino libraries in order to compile:

- LiquidCrystal - the LCD display library for the LCD display
- PID_v1 - the proportional-integral-derivative controller library for thermostatic control

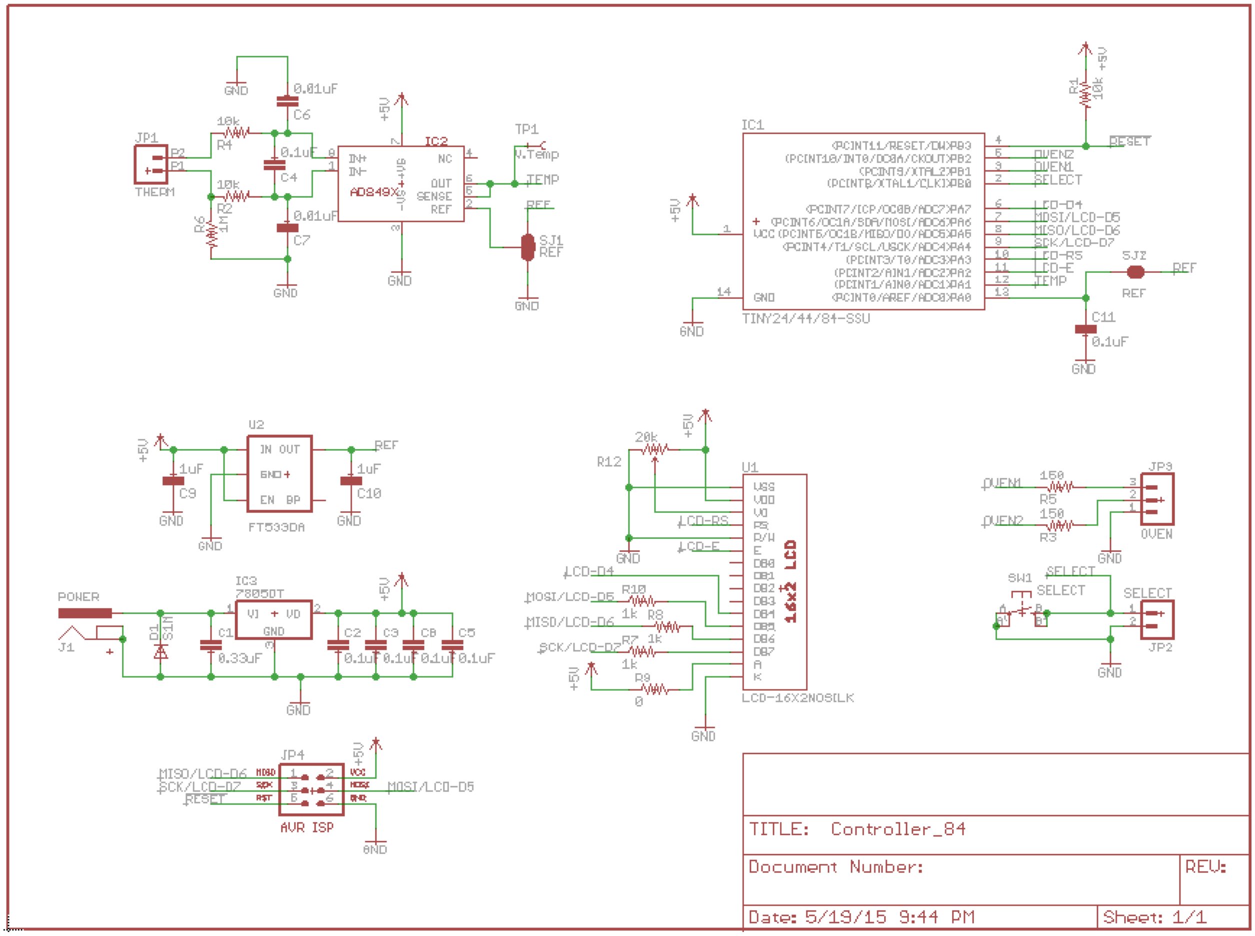
Check the Toast-R-Reflow firmware's README file (https://github.com/nsayer/Toast-R-Reflow/blob/master/README.md) for any other requirements or updates.

Specifications

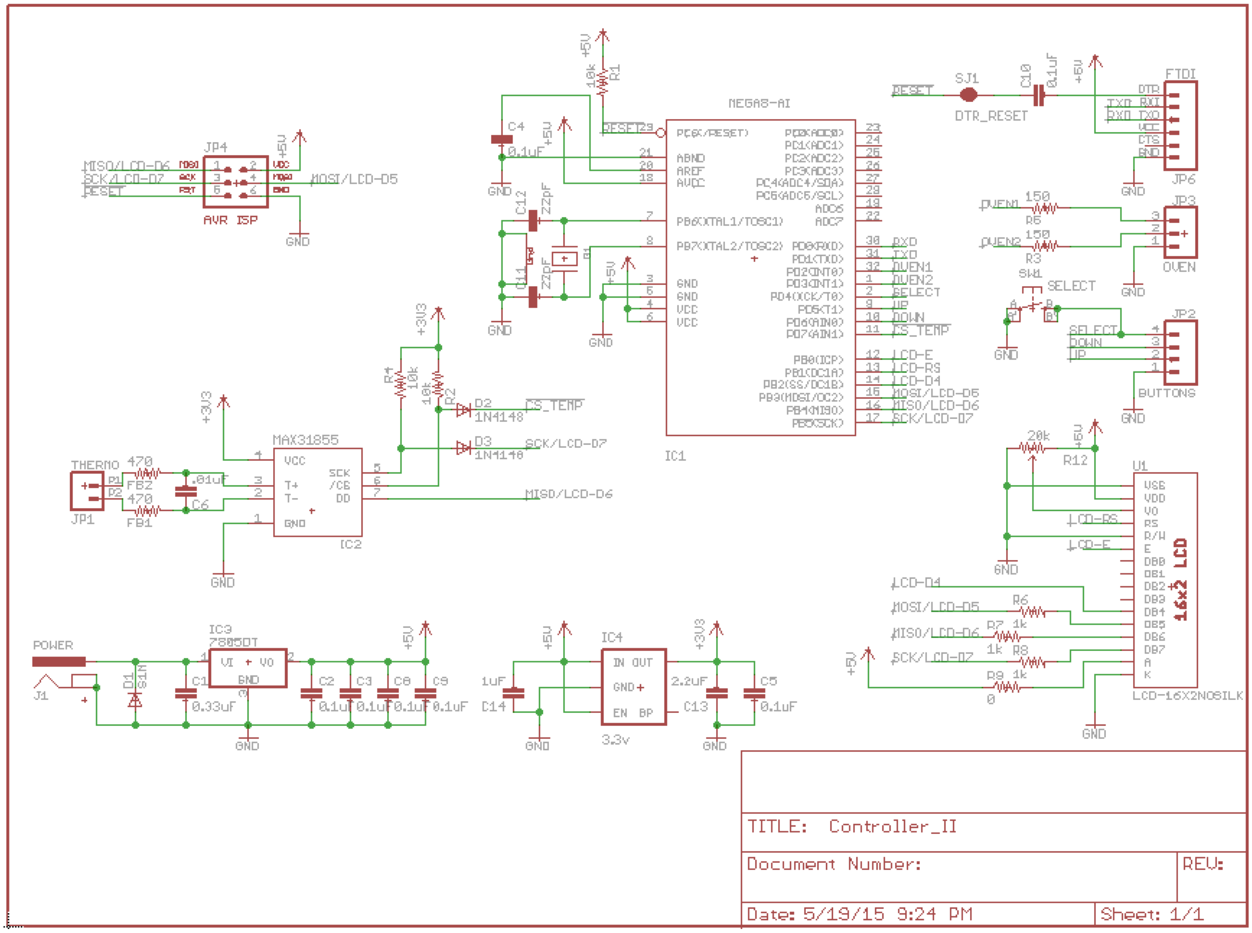
- Power board voltage: 120/240 VAC
- Power board maximum current: 8 amps per channel
- Power board maximum ambient operating temperature: 50 °C / 122 °F
- Power board control input forward voltage: 1.5 V maximum
- Power board control input forward current: 30 mA recommended, 50 mA maximum
- Control board power requirements: 250 mA @ 7-12 volts DC
- Thermocouple measurement range: model I: 0-360 ºC, model II: the entire K thermocouple range



Power board schematic



Model I controller board schematic



Model II controller board
schematic