Make: PROJECTS

DIY COFFEE

Coffee Roaster
Bottomless Portafilter
Toaster Tea Popper
Hot on the Spot
Automate Using X10

Larry Cotton
Will O'Brien
Johnathan Nightingale
John F. Murphy
Dave Mabe

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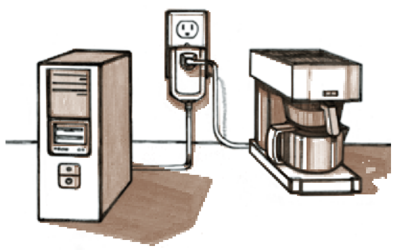

COFFEE ROASTER

By Larry Cotton

Photography by Larry Cotton

THE NIRVANA MACHINE

Lots of folks think that quaffing a cup of coffee from boutique beans comes close to nirvana, but roasting your own beans will bring you even closer. That's why I call this roaster the Nirvana Machine.

I didn't drink coffee for most of my life, and I even survived without it in the Navy. But when my son introduced me to a cup of legendary West Coast java (OK, Peet's), I began to understand what all the fuss was about. Soon, I too became fussy about excellent coffee.

Beans lose flavor after they're roasted because all of those delicious but volatile aromatic compounds dissipate and break down. Roasting your own beans guarantees ultimate freshness, putting all the flavor into the cup; you will not drink fresher, more satisfying coffee!

Home roasting is easy and inexpensive. Top-quality green beans cost less than roasted beans and have a much longer shelf life. You can have fun fine-tuning your roast's darkness and developing your own blends. Indeed, a growing selection of countertop roasting appliances are now sold, but they're pricey, non-portable, and very noisy.

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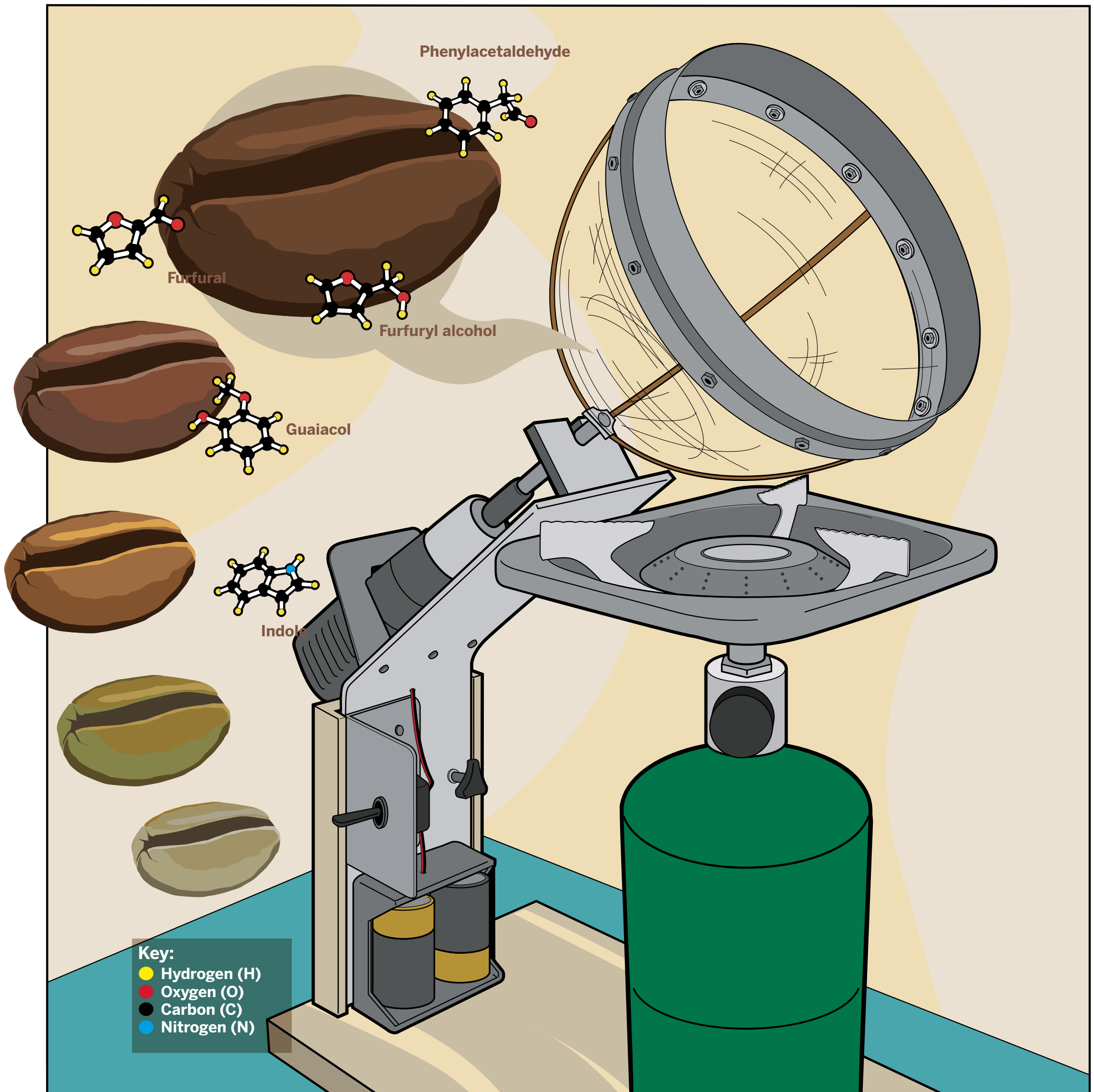
Larry Cotton is a retired power-tool engineer, musician, part-time math teacher and full-time coffee devotee who lives in eastern North Carolina.

D.I.Y. COFFEE

JAVA IMPLEMENTATION



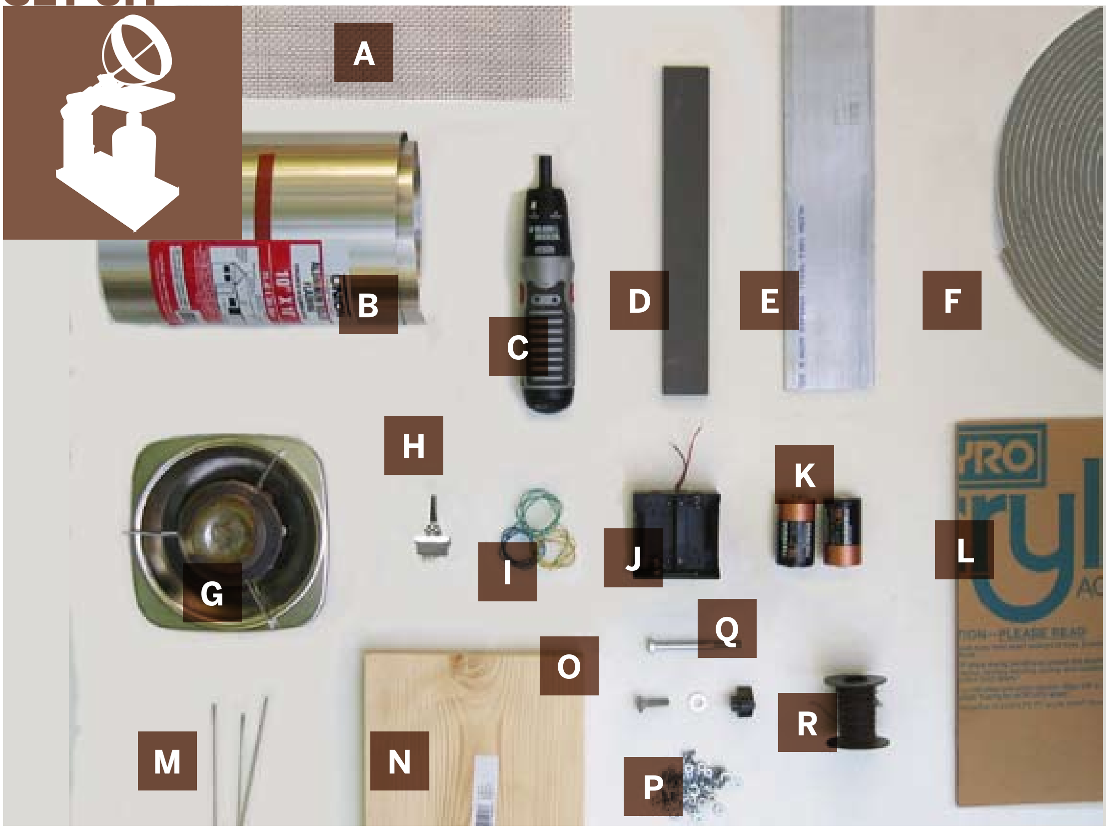
The Nirvana Machine uses a battery screwdriver to tumble beans over a camp stove. Unlike commercial machines, the basket is tilted and open-ended, which makes it easier to load the beans and to see and smell their progress during roasting.

When you roast coffee, sugars caramelize, water vaporizes and makes the beans expand, and aromatic compounds are produced, including the ones shown above. The compounds develop at different rates, so varying the roasting time and temperature lets you balance which you want more or less of, to determine the resulting flavor.

The Version 1 basket was a cheap strainer, but the beans broke through that and caused a fire!

Illustrations by Tim Lillis

SET UP.



MATERIALS

[A] 1' square stainless steel wire cloth, .025" wire diameter Do not substitute. McMaster-Carr part #9238T523 mcmaster.com

[B] Unpainted aluminum flashing 10'×10"×.010"

[C] Battery-powered screwdriver I used a Black & Decker AS600.

[D] 1½"×¼" piece of aluminum, at least 4" long Cut from McMaster-Carr part #6023K231

[E] 3"×⅛" aluminum bar, 3' long Cut from McMaster-Carr part #8975K833

[F] A few inches of adhesive foam weatherstripping

[G] Single-burner propane camp stove The Century 2058 Trail Scout is best.

[H] Simple on-off (SPST) switch RadioShack part #275-701

[I] 2' insulated wire, 22-gauge minimum Telephone cable wire works well.

[J] Twin D-cell battery holder RadioShack #270-386

[K] D-cell alkaline batteries (2)

[L] Two pieces of acrylic or other hard plastic, at least 3" square each, one ⅛" thick and the other ¼" thick Cut from McMaster-Carr part #8589K41 and #8589K81

[M] 3'×3/32" brass brazing rod From a welding supply house

[N] Scrap plywood 8"×8"

[O] Matching 1" long carriage bolt, washer, and knob, ¼" threaded

[P] Matching ⅜" long machine screws, washers, and nuts, 6-32 threaded (16)

[Q] Matching 3½" long hex-head bolt and nut, ¼" threaded

[R] Uninsulated wire, 24-gauge solid McMaster-Carr part #8870K16

[NOT SHOWN]
Standard 16.4 oz disposable propane cylinder

¼" long machine screws, 6-32 threaded (4)

Wood screws, ½" long flathead #10 (2) and ½" long #6 (8)

Scrap 1×8 lumber or plywood At least 18" long

Scrap wood block About 6" cube

8" wood or plastic dowel, ¼" diameter

Wood glue or 5-minute epoxy

Paper For templates and caution label

See a list of tools for this project at makezine.com/08/roaster.

MAKE IT.

BUILD YOUR COFFEE ROASTER

START **Time:** **A Weekend** **Complexity:** **Medium**

1. MAKE THE METAL PARTS

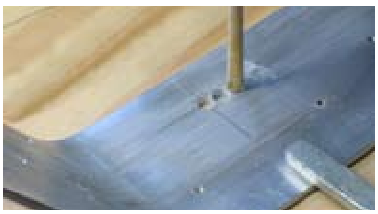
This project has blueprints with complete measurements of all the parts at makezine.com/08/coffeeroaster. Start by downloading and printing them all. Then you can easily follow along and make the metal parts, the wood and plastic parts, and the bean basket.

1a. For the support plate, saw a 14⅛" piece off of the 3' aluminum bar and drill and tap 12 holes as shown in the support plate blueprint. File the cut surface smooth after this and all other cuts.

1b. Clamp the plate in the vise between two 2×4s and use the C-clamp to bend it widthwise, 6⅞" from the bottom, to an angle of about 127°.

NOTE: you could also start by making the basket (Step 3, page 117). That's the hard part, and then you can go back and make the other parts to fit afterwards.

1c. To cut the height adjustment slot, drill four or five ¼" or 5/16" holes as close together as possible, then saw or file the slot until it's even.



1d. Make the drive shaft bearing. Drill a ¼" hole in one end of 1½"×¼" aluminum bar, then saw or drill and file the slot in from the end. Saw the piece off the bar to measure 1¼" — it's easier to machine the slot before trimming the bearing down to final size. File the cut end smooth, and drill and tap two 6-32 holes.

NOTE: Refer to bearing blueprint.

1e. The trickiest bit of metalwork is the triangle piece, which connects the basket to the driveshaft. To start, I drew a paper template with the dimensions shown on the blueprint, and taped it to the leftover ¼" thick aluminum bar.

NOTE: Refer to triangle blueprint.

1f. Drill 4 holes in the aluminum, tap the large one, and saw the 3 slots to the small holes before cutting the triangle to shape. This piece is small and fairly precise, so go slowly and be safe. Then saw the triangle shape, file smooth, and put it in a vise to drill and tap the 3 clamping-screw holes.

1g. Thread 3 screws into the part and check its clamping action on small pieces of the 3⁄32" brazing rod. It should hold the rods parallel and tight.

NOTE: Hold the triangle in a vise for drilling and tapping.

1h. For the reinforcing ring, draw a 5¼" circle as a template. Cut a strip of the ⅛" aluminum bar, about ⅜" wide and 19" long, and slowly hand-bend it into a circle, comparing against the template as you go.

NOTE: Use a vise to get a good grip for bending the very ends.

1i. Saw or file an overlapping joint at the ends, then drill a ⅛" hole and use a pop rivet tool and a short rivet to join the ends together.

1j. Using a compass, mark at least 6 evenly spaced hole locations in the reinforcing ring. Drill the holes to 9⁄64".

1k. For the appearance ring, use metal snips to cut a strip of the aluminum flashing about 20" long and 1" wide, or wider to make the basket hold more beans. Mark the strip to match the locations of the holes on the reinforcing ring, and snip pairs of ¼" notches to flank each hole. Bend the metal back and forth in the notches until the tabs break out.

2. MAKE THE WOOD AND PLASTIC PIECES

2a. For the base, cut a 13" length of the 1×8 and drill and countersink two 3⁄16" holes 2½" apart and 1⅛" from one end, with one hole 1 13⁄16" from one side.

NOTE: Refer to base blueprint.

2b. For the height adjustment block, cut down another piece of the 1×8 to 6⅝"×3½". Use a table saw or router to cut a 3" channel ¼" deep down the block, to just fit around the support plate.

NOTE: Refer to height adj block blueprint

2c. Nest the support plate in the height adjustment block, stand them up together on their bottom ends, and mark the very top of the slot on the block by tracing through plate. Drill a ¼" hole through the block at this mark, for the height adjustment bolt.

2d. On a piece of ¼" thick plastic, trace the screwdriver hold-down shape from the blueprint online, and saw it down to shape. The interior dimensions are fairly critical, to securely hold the screwdriver. Clamp it in a vise, and drill and tap two 6-32 holes matching the pair of holes at the top of the support plate.

NOTE: Refer to hold-down blueprint.

2e. For the switch bracket, cut a 3"×3" square of ⅛" thick plastic. Saw or file 2 edges round, and drill two 5⁄32" holes matching the holes near the slot on the support plate, and a larger hole on the other side to fit your switch.

NOTE: Refer to switch bracket blueprint.

2f. For the bracket, wrap foil around the plastic to shield all but a ⅛"-3⁄16" wide bend-line. Holding the plastic with a gloved hand, heat it gradually over a stove. Press on it periodically, and when it's soft enough, remove it from the heat, bend and hold it at a right angle, then run cold water over the bend to harden the plastic again.

2g. Remove the battery chamber of the powered screwdriver and drill a clearance hole in the end, angled to miss all internal parts. Thread two 1' lengths of insulated wire through the hole and solder one to each battery contact. Note the polarity of the wires and replace the battery chamber. Test the connections by touching the wires to one or two 1.5V batteries in series and switching the screwdriver on.

2h. For the drive shaft, carefully mark the edges of the bolt's head with a marker, then use a grinding or cutting wheel to cut it down so that it fits the chuck of the screwdriver, about ¼" across. The new hex-head must be concentric with the shank of the bolt.

3. CONSTRUCT THE BEAN BASKET

3a. Make the pressing ring tool using the circular template from Step 1h. Cut a 5¼" diameter circle out of plywood by drilling in the center and then sawing out. File the inside edge of the ring on one side to make it round and smooth.

Then make a round form out of a wood block, 5" diameter and approximately spherical or hemispherical. You can turn the form on a lathe, but the shape doesn't have to be perfect, so you could also just cut down and shape it with a saw and a coarse rasp.

NOTE: The form also needs something in the bottom that you can clamp in a vise. I epoxied a ¼" dowel into the hole in its flat face.

3b. Draw an X in the exact center of the 1' square wire cloth. Mark the front tip of the form, then drill a hole and screw the center of the cloth to the tip of the form with a ½" #6 wood screw.

3c. Center the pressing ring, rounded edge down, above the form and wire cloth square. Apply downward pressure until the cloth looks like a bean basket. This is easier said than done. Gradually push a little, guide a little, and compress the wire cloth a little below the ring to help it go down.

NOTE: The square holes in the wire cloth will deform into diamonds of various size and shape; this is as it should be.

3d. Towards the end of pressing the wire cloth, it will help to have a friend drive more small #6 screws in along the way, to hold the screen against the form. It also helps to cut off some of the excess material at the bottom with metal snips, but leave about 1" all around, past the flat end of the form. Now take a break!

3e. Remove all the shape-holding screws, leaving just the one at the tip. It's OK if your basket is distorted at this point; the reinforcing ring will circularize it. Lay the pressing ring and reinforcing ring on top of wide-open vise jaws. Flip the form and wire cloth assembly upside down and re-press it through the rings. Attach the reinforcing ring to the bean basket with 6-32×$\frac{3}{8}$" machine screws, washers, and nuts.

For each attachment point, wedge a piece of scrap wood between the form and the basket and drill a $\frac{9}{64}$" hole through both the reinforcing ring and the basket before installing the screws. The basket should be a mini-

Note: With all screws tight, trim the excess wire cloth as close as possible to the ring.

3f. Cut and bend the $\frac{3}{32}$" brazing rod into 3 pairs of ribs that reinforce the basket, extending out from its center point inside and out. On the 3 outer pieces, leave an extra bend as shown, to fit into the aluminum triangle piece.

Attach the rod pairs to the basket and each other by twist-tying them together with short lengths of uninsulated wire. Use at least 3 wire loops per pair. The pairs should converge close to the center inside and out, forming three 120° angles.

NOTE: Refer to the brazing rod piece blueprint.

3g. Push the 3 outside pieces into the triangle, and tighten the 3 clamping screws securely. Make sure the bean basket assembly cannot be pulled off! Cut and file the ends of the rods flush with the face of the triangle.

3h. Thread the ¼" nut onto the driveshaft bolt until at least ¼" of thread protrudes. Using pliers to keep the nut from turning, thread the triangle onto the driveshaft until it jams tightly against the nut.

3i. Loosen (but do not remove) all the reinforcing ring screws, and insert the appearance ring between the reinforcing ring and the raw edge of the wirecloth. You may need to shorten it first. Re-tighten the screws.

4. FINAL ASSEMBLY

4a. Stain, paint, or varnish the base as you wish, then attach 4 small feet cut from adhesive foam weatherstripping under the corners.

4b. Make a caution label (or print out the one online), and glue it to the base.

4c. Screw the height adjustment block to the base with two #10 ½" long flathead wood screws.

4d. Attach the D-cell battery holder, wires pointing upward, to the bottom end of the support plate with two ¼" machine screws. You may have to enlarge the holder's mounting screws.

4e. Mount the switch in the switch bracket, and mount the bracket to the support plate with two ¼" machine screws.

4f. File off any screw threads that protrude from the back of the support plate.

4g. Mount the bearing to the support plate with two ⅜" machine screws.

4h. Attach the support plate assembly to the height adjustment block with the carriage bolt, washer, and knob.

4i. Thread the 2 screwdriver wires through the hole in the support plate's bend. Use the hold-down and two ⅜" screws to mount the screwdriver to the plate, with its chuck pointing up. Make sure the sleeve adjacent to the screwdriver chuck is set to "Power" position.

4j. Thread a ⅜" screw into the bottom of the support plate, under the screwdriver's central switch button. Tighten it enough to fully depress the button. This screw keeps the screwdriver switched on internally, and helps hold the tool. Briefly touch the 2 screwdriver's power wires to a battery to make sure that it runs.

4k. Slide the bean basket's shaft through the slot in the bearing and into the screwdriver chuck until it stops. You may have to adjust the bearing's position slightly so the shaft doesn't bind.

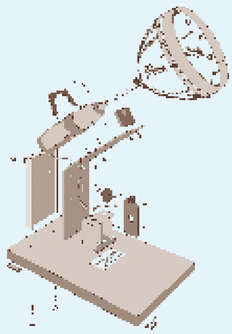
4l. Thread a piece of uninsulated wire through the support plate and wrap it around the screwdriver near the chuck. There's even a convenient groove for this. Finger-twist and trim the wire ends. Avoid over-tightening, which would put an extra load on the motor.

4m. Lean the assembly on its back and, noting the wires' polarity, solder the switch in series with the battery holder and the screwdriver wires.

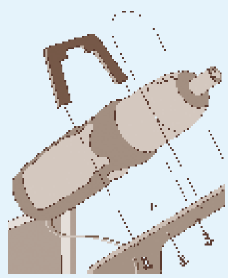
4n. Put 2 fresh D-cell alkaline batteries in the holder.

4o. Make sure the camp stove is off, then screw it onto a standard 16.4-oz. disposable propane cylinder and center it onto the base with one of the burner's flat sides toward the support plate. Position the propane flow-control knob so you can reach it easily.

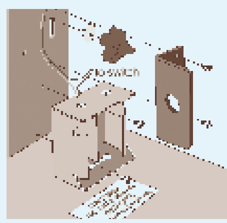
4p. Flip the switch on, and check that the bean basket rotates freely, doesn't wobble, and seems sturdy and safe. Use the height adjustment knob to position the basket at 1" above the burner. Your Nirvana Machine is ready to roast!



Support plate holds assembly together and slides along the height adjustment block attached to base in back.



Plastic hold-down and wire loop secure the screwdriver while another screw keeps its On button pushed in.



Knob adjusts basket height while switch (not shown) turns the screwdriver on/off to rotate the basket.

Illustrations by Larry Cotton

FINISH X

NOW GO USE IT »

USE IT.

ROAST YOUR COFFEE BEANS

PROPER NIRVANA PROCEDURE

1. Take the Nirvana Machine to a well-ventilated place, preferably outdoors.
2. Make sure the batteries are fresh, and put a drop of oil on the shaft bearing.
3. Load up to ½ cup of green coffee beans into the bean basket.
4. With the burner off, switch the screwdriver on and observe the beans' rotation pattern. The 3 ribs inside should cause the beans to tumble nicely. The bulk of the tumbling beans should be centered above the burner. Green beans expand as they roast, so they should stay well away from the opening, to leave room for expansion.
5. If the beans tumble properly, light the propane burner and set the gas-flow knob on low. The beans should begin to yellow in a couple of minutes, and should roast in 10 to 15 minutes.
NOTE: Never roast coffee unattended, keep kids at a safe distance, and use plain old common sense.

As the beans darken, they will make cracking sounds and shed thin, parchment-like chaff, which drifts out of the opening, making somewhat of a mess. To me, this just adds charm to the experience, but your significant other's opinion may vary.

If you roast outdoors in cool or breezy weather, you may have to crank up the heat, reduce the clearance between the flame and the basket or shield the basket from the elements. I've used aluminum flashing, but any windbreak should do.

As the beans turn even darker, you'll hear lighter crackling. This is about when I think the beans are perfectly roasted. If you keep going, the beans smoke more, caused by the oil which seeps from the beans (this oil also makes the beans shinier). The smoke may smell great to you, but the odor can linger, which is another good reason for ventilation. Be careful not to scorch the beans!

When the beans are done to your liking, turn the screwdriver off and remove the burner. Beans like

to be cooled fairly rapidly, so let them continue to rotate for a few minutes in the cooler air.

Dump the beans into a container and seal it. Purists say to wait anywhere from 4 to 24 hours before grinding the coffee. You will be amazed at how good it is. Good luck!

RESOURCES

Green bean sources: sweetmarias.com, burmancoffee.com

Coffee and home roasting information: coffeegeek.com, thecoffeefaq.com, homeroaster.com, ineedcoffee.com/roasting

Roasting color guide: sweetmarias.com/roastedcoffee_grindVSsurfacecolor.html

THE BOTTOMLESS PORTAFILTER

Mod your espresso maker's filter holder for a tastier cup. By Will O'Brien

In my office at home, one end of the room is devoted to computers, electronics, and my assorted projects. The other is the home of the holy grail of caffeine: my espresso bar. That's where I measure, grind, and tamp my way to produce some beautiful espresso. I've been tuning and tweaking my setup for the last six months or so, and there's no end in sight. My most recent modification involved some power tools and my portafilter.

The portafilter is the chrome-plated coffee filter holder that most people only notice as the spent grounds are being beaten from its shiny grasp. In this case, I drilled, cut, and ground out the bottom of it to get what's known as a "bottomless" or "naked" portafilter.

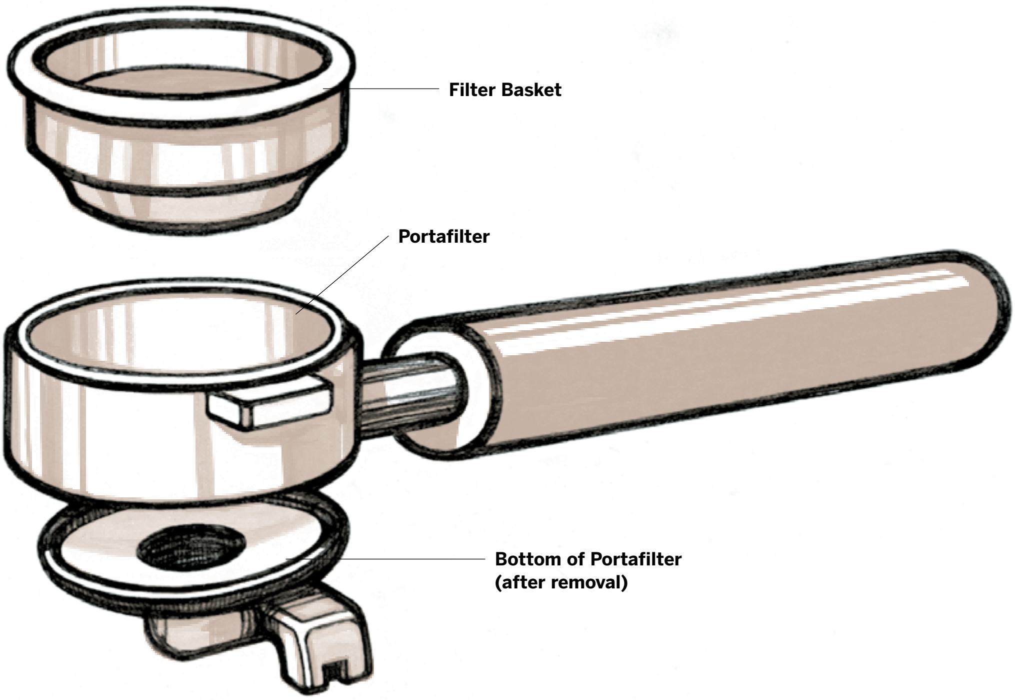
No stock machine comes with a bottomless portafilter. The modification can sometimes result in espresso going in strange directions — like the wall on the other side of the room. The only side affect I've observed is a tiny amount of spatter on the top of my espresso cup. So why go bottomless? For some, it's simply so they can fit a triple basket in the stock portafilter. The espresso industry refers to the bottomless portafilter as a "training tool." You can even buy your own from espressoparts.com.

As a training tool, the bottomless portafilter is excellent for checking your tamping

By removing the bottom of your espresso maker's filter holder, you get more prized "crema."

Photograph by Will O'Brien

D.I.Y. COFFEE



technique. As an espresso machine modification, I've found that my espresso has increased crema, better mouthfeel, and it's just tastier.

Just about every good quality portafilter is made of chromed marine brass. Inside is a tensioning spring collar that grips the basket, which contains the coffee grounds.

The basket should be removed by pulling or gently prying loose. You can probably leave the spring intact while you perform the modification.

Some people have had good success using a hole saw, but due to the uneven design of the portafilter on my Gaggia coffeemaker (probably the worst product name ever), I chose a different route. After removing the basket, I took the portafilter to my drill press and drilled a circle of holes just inside the walls of the portafilter. Once I'd drilled the 25 or so holes, I took up my Dremel tool and cut the remaining material in between the holes. Finally, I knocked out the center of the filter. After that, some time with the Dremel tool or grinder of your choice will flatten out the edges. When you're satisfied with the finish of your mod, wash it thoroughly to remove any remaining brass dust.

Once the modification was complete, I pulled a fresh shot of espresso. The flow of the dark amber liquid was enchanting to watch. You may now partake of the art of Espronography: reading the espresso as it flows from the bottom of your new bottomless portafilter. Several weeks later, I still can't resist watching each shot flow from the filter. As a bonus, I can now easily clean all of the coffee residue from the bottom of the basket.

FREQUENTLY ASKED QUESTIONS ABOUT CREMA

What is crema? It's the delicious reddish-brown colored froth on the top of a well-made shot of espresso.

Why doesn't my espresso have crema in it? Several factors could be at play here. The quality of the coffee, the fineness of the grind, the degree of tamping, the temperature of the water, and the espresso maker itself can effect crema production. Visit sweetmarias.com/espresso-crema.html and then practice. Remember: "No crema, no serva!"

Will O'Brien pulls espresso and modifies innocent kitchen appliances somewhere in middle Missouri.

Illustration by Damien Scogin

TOASTER TEA POPPER

Perfect brew by the clock. By Johnathan Nightingale

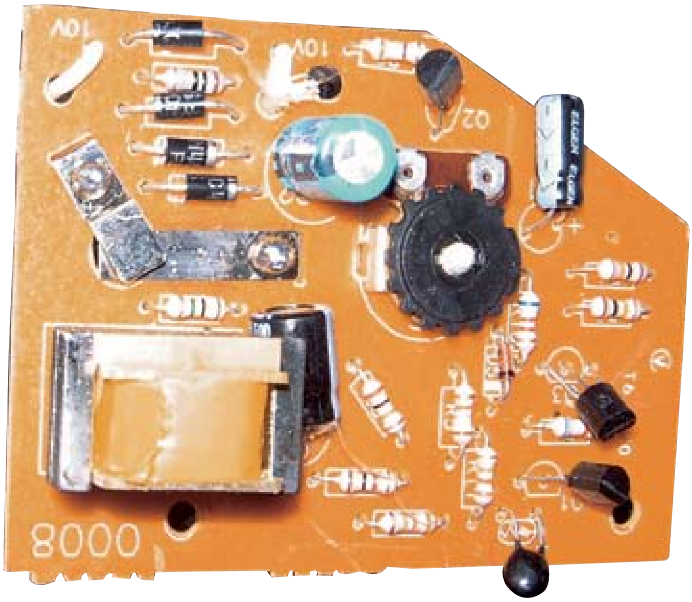
I didn't used to care about tea timing. In general, I have found that I can prepare tea of adequate quality by simply leaving the teabag in for "a while." Recently, though, I was persuaded to begin timing and have been convinced that doing so yields a better and more consistent brew. Conventional tea timers have a common failing though, be they hourglass, mechanical, or, in my case, Palm: they require user intervention. At work, I inevitably became distracted by a conversation or got called away to fix something only to return to a patiently beeping timer and some very overdone tea. What I needed was a timer that could remove the teabag on its own.

I found my salvation in a toaster. A toaster is, after all, an easily obtainable and very cheap device that has, at its core, a variable timer controlling a mechanical lifting arm. Most modern toasters use a simple electronic circuit: when the lever is depressed, current flows to the heating elements and to an electromagnet. The electromagnet holds the lever down against the tension of a spring in the handle. While the toast is toasting, a trickle of current flows into a capacitor at a rate controlled by the "darkness" dial, which is nothing more than a variable resistor or "rheostat." When the capacitor is filled, the electromagnet disconnects, the lever pops back up, and current is cut to the heating coils. With all this work already done for us, a basic ability to solder and some simple parts should be all that's needed for this project.

To begin, take the toaster apart. As you remove the front panel, you will see the various components described above: the arm, including

After a set amount of time, the toaster tea popper lifts the bag from the cup.

Photography by Johnathan Nightingale



Only one style of toaster will work for this project. Here's a simple thrift-store test: push the handle down with the toaster unplugged. If it stays down, you have the wrong kind of toaster — an electromagnetic toaster (the kind you want) will pop back up immediately if no power is flowing to the magnet.

a metal tab that the electromagnet grabs; a switch that the arm depresses allowing current to flow; and a circuit board with the electromagnet and rheostat (connected to the toaster's darkness dial). The toaster's frame and the heating coils can be discarded, but this is easier said than done: my toaster was built like a tank. A Dremel cutting wheel, tin snips, or some other metal cutting tool will help here.

Of course, we don't want to have to plug this into the wall. The vast majority of a toaster's energy consumption goes into generating heat in the toasting coils. We don't want that and neither does the circuit board; it's counting on having most of the voltage dropped by the heaters. Your circuit board will likely be stamped with something like "10V"; regardless of the appliance voltage, the circuit wants to receive no more than 10V. Since most people like tea to steep a little longer than they like toast to toast, a 9V battery will work well here — the lower voltage will slow the rate at which the capacitor charges, and that's just fine. The problem of how to convert the toaster from alternating current (wall socket) to direct current (battery) is also solved: the toaster circuit contains a bridge rectifier (a simple circuit for converting AC to DC.) Our DC battery will pass straight through, unaltered.

Putting it all together is easier if you can find a suitable container; I used an unfinished wood box from a local craft store. Cut most of the original power cord, attached to the lever switch, and solder the ends to a 9V battery holder. Solder the other lines from the lever switch to the power leads on the circuit board — thanks to the bridge rectifier, polarity doesn't matter. Now arrange the pieces in your box as they were in the toaster. For the arm, I used a wooden dowel with a brass hook. To make a cup of tea, tie the teabag onto the hook, push the lever down to immerse the tea bag, and place your trust in the machine.

As the battery runs down, the timer will slow even more, but not to worry. By the time the battery gets that low, the voltage will have dropped low enough that the electromagnet no longer holds. I estimate that a regular 600mAh battery should be good for at least 8 hours runtime, about 80-100 cups for a 5-minute steeper.

Johnathan Nightingale is an IBM coder by day, reality hacker by night, and habitual over-thinker.

HOT ON THE SPOT

Get consistent shots by adding precise temperature control to your espresso maker.

By John F. Murphy

The art of espresso making is fraught with many variables — coffee bean origin and blend, degree of roast, fineness and consistency of grind, tamping force and technique, and on and on and on. The temperature of the water used to brew the shot is one of the most important variables. In most espresso machines, the brew temperature is controlled by a wildly inaccurate thermostat.

However, control over the brew temperature is key to espresso quality. Different blends of espresso beans and different degrees of roast develop different flavors when brewed at different temperatures. Malabar Gold may taste sweet at a temperature that makes DSB taste sour. Control over the brew temp allows the skilled barista to coax the best flavor from each blend and each roast. In a stock Silvia espresso maker, relative brew temperature is roughly guestimated by "time surfing," or pulling the shot a certain number of seconds after the stock thermostat turns on the heating element. Surfing does work, but it requires careful attention and lacks accuracy.

A better way is to use a PID controller. It's easy to use (just set the desired temp and let the PID do its thing) and highly accurate, meaning the brew temperature of the next shot can be very nearly the same — if not exactly the same — as the last shot. And consistency from one shot of espresso to the next is the holy grail of espresso fanatics.

Photography by John F. Murphy

The Rancilio Silvia outfitted with temperature control.

PID BASICS

In simple terms (which is about all I can understand), a PID controller is a precise, computer-controlled thermostat. PID is an acronym for "Proportional, Derivative, Integral," which has something to do with how the controller holds the boiler (in this application) at a precise temperature.

Here's an analogy that explains how the PID works and why it is a good thing. Imagine you are driving your car down the street at 60mph. Ahead is an intersection controlled by a stop sign. If you continue to travel at 60mph until you reach the intersection and then slam on the brakes, your car is going to shoot past the stop sign before coming to rest. If, on the other hand, you gradually apply the brakes well in advance of the stop sign, you can come to a controlled stop right at the intersection. (This analogy is paraphrased from an explanation in the Fuji PXV3 manual.)

The stock brew thermostat in the Silvia is like the driver who slams on the brakes at the stop sign. The stock thermostat supplies full power to the boiler's heating element until it reaches a certain temperature, and then cuts the power off completely. When the power is cut, the heating element continues to heat the boiler water for some seconds until the heating element cools off; this is like the car skidding through the intersection. On my Silvia, the stock thermostat turns off the heating element at around 220° F, but the water continues to heat up until it reaches about 238° F. This is called "overshoot."

The PID controller is like the driver who gradually applies the brakes and slows down as he approaches the intersection. The PID controller turns the heating element on and off at one-second intervals. As the boiler approaches the desired temperature, the PID turns the heating element on for shorter intervals — like a driver braking harder the closer he gets to the stop sign (this is where the proportional, integral, and derivative calculations come in). Thus, the PID is able to hold the boiler at the desired temperature with very little overshoot. I usually see a 1° F or less overshoot with my PID'd Silvia. Compare that to the 18-degree overshoot with the stock thermostat.

Once the boiler is at the desired temperature, the PID cycles the heating element on and off at intervals calculated to maintain the boiler very close to that temperature. Mine fluctuates by about 1° F. The stock thermostat, by contrast, has a fluctuation of at least 40° F!

THE RANCILIO SILVIA

If you're going to be finicky enough about your coffee that a few degrees variation in brew temperature is a big deal, you'd better start off with a decent espresso machine. The internet is replete with raves about Rancilio's Silvia, so I'll just touch on one key feature: temperature stability. Silvia contains a lot of heavy brass in the boiler, the grouphead, and the portafilter. Once all that brass gets up to operating temperature, it tends to stay there.

When you pull a two-ounce double, the hot brass of the grouphead and portafilter keep the brew water from cooling off before it hits the coffee grounds. Likewise, the brass boiler stays hot even as cool water from the reservoir replaces the water used to make the shot. Without good temperature stability during a shot, accurate temperature control is useless, if not downright impossible.

PID SHOPPING LIST

Fuji 1/32 DIN PID controller	PXR3-RCY2-4V	TTI Global	$129.00
Solid-state relay (230V/40A out, DC in, zero switching)	RS1A23D40	TTI Global	$26.00
Type J thermocouple, washer probe, at least 30" long	WTJ1-G06-AGN-030AN	TTI Global	$8.25
14-gauge wire (50' spool)	n/a	Home Depot	$3.59
4mm washer and nut	n/a	Home Depot	$0.50
Double-sided foam tape	n/a	Home Depot	$3.00
Lamp extension cord, 6'	144983	Home Depot	$0.97
Crimp-on connectors	64-3038	RadioShack	$1.69
Lighted rocker switch	275-692	RadioShack	$4.00
Project box, 5"x2.5"x2"	270-1803	RadioShack	$3.69

I also used the following tools and supplies that I had on hand: wire stripper/crimper (RadioShack sells them for under $8), soldering iron, solder, heat-shrink tubing, coping saw, and various small screwdrivers. (The last three items were all used solely for installing the optional switch.)

INSTALLATION

Note: I did not actually follow these steps in the order presented. I did a lot of trial fitting, testing, etc., before I arrived at the final assembly. But if I had it to do all over again, this is the way I would do it.

1. Prepare the enclosure. Fitting the PID into the project box was a bit tricky for someone of my limited craftsmanship. The screw towers and circuit board holders in the enclosure interfered with the placement of the PID. I ended up cutting a slot through one end of the enclosure with a hand miter saw and a coping saw. The distance between the circuit board holders molded into the enclosure is very close to the height of the PID, so I simply cut down along the circuit board holders, broke out the piece of plastic between the cuts with a pair of pliers, and reamed out the opening with a power drill until the PID fit.

I also drilled a ¼" hole in the back of the enclosure to run wires to the PID and a ¾" hole in the top towards the back to mount the (entirely superfluous) lighted rocker switch. Actually mounting the PID in the enclosure is simple enough once the opening is prepared: slip the white mounting collar over the PID, slide the PID into the enclosure, then cinch the mounting collar up tight against the inside of the enclosure. This is easier to do than it is to describe.

2. Open Silvia. (Unplug it first!) Silvia is a breeze to open — especially compared to my first machine, a DeLonghi, which was held together by hidden tamper-proof screws.

2a. Remove the water reservoir. Shake the excess water out of the two water hoses into a towel or sink.

2b. Remove the four screws that hold on Silvia's top. Set the top aside.

2c. Remove the two screws that hold on the front splash panel. Set the splash panel aside.

3. Install the thermocouple. Now that Silvia's innards are exposed, you can see the bronze-colored boiler with many wires and two blue cylinders attached to it. The blue cylinders are the thermostats. The thermostats are attached to the boiler by three screws. Remove one of the screws, slip the washer end of the thermocouple under the "ear" of the thermostat, and then replace the screw through the thermostat and the thermocouple washer (see Fig. 1 next page). I test-mounted the thermocouple under the leftmost screw, but later moved it over to the rightmost screw, which is closer to where the cold water enters the boiler. I'm not sure it makes any difference in operation.

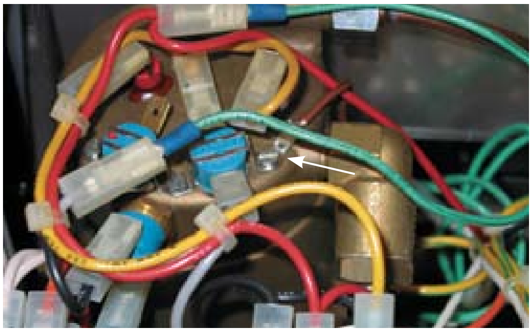


Fig. 1 Thermocouple washer installed under screw of steam thermostat.

4. Remove wires from brew thermostat. The brew thermostat is the blue cylinder on the left. Unplug both connectors from the thermostat (see Fig. 2).

Fig. 2 Removing brew thermostat connectors.

5. Attach heater circuit wires to the solid-state relay (SSR).

5a. Cut two pieces of wire about 12" long. Strip the ends of both wires.

5b. Crimp a connector onto one end of each wire.

5c. Plug the connectors into the wires detached from the thermostat in step 4 (see Fig. 3).

5d. Run the other ends of the wires through Silvia's chassis so that they protrude down behind the splash-guard.

5e. Attach the bare wire ends to the SSR. There are four terminals on the SSR; on mine, they were labeled L1, T1, A2(+), and A2(-). Attach the wires to L1 and T1. It does not matter which wire goes to L1 or which to T1. My SSR has screw/clamp terminals; simply slide the wire into the terminal and tighten the screw to hold it in place. If necessary, trim the wires before attaching to the SSR so there is not an excess of wire behind the splashguard (see Fig. 3).

Fig. 3 Boiler detail with thermocouple and SSR wires installed.

6. Attach the PID control wires to the SSR.

6a. Cut two more pieces of wire, about 36" each. They need to be this long because I decided to run the wires out to the PID. Strip the ends.

6b. Since all of the wire I used was the same color, I marked both ends of one piece with tape so I could identify it later.

6c. Run one end of each wire from the boiler compart-ment down to the SSR.

6d. Attach the wire marked with tape to the '+' termi-nal on the SSR. Attach the other wire to the '-' terminal (see Fig. 4).

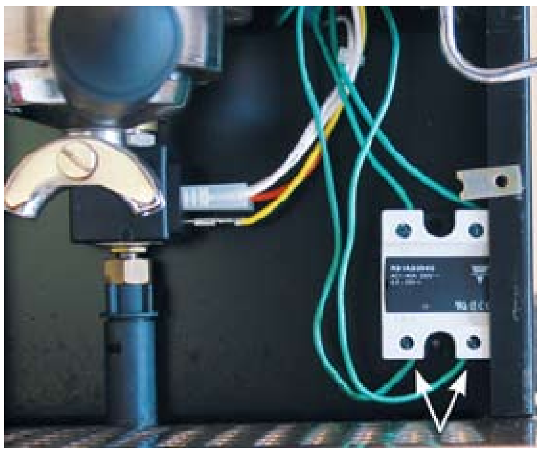


Fig. 4 SSR wiring detail.

7. Run control wires and thermocouple wire out to the PID. I did not want to cut a hole for the wires in Silvia, so I decided to run them out of an existing gap in the bottom left corner at the back of Silvia.

7a. Remove the panel that fits between the water reservoir and the boiler compartment. It is held on with two small machine screws and lock washers on the water reservoir side. The panel is angled and may need a bit of fiddling to get it to slide out (see Fig. 5).

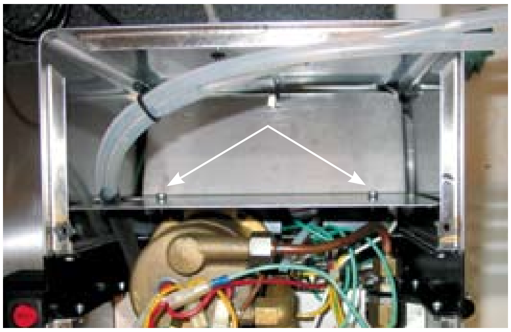


Fig. 5 Reservoir panel.

7b. Run the cycle time (TC) and control wires (the ones attached to the + and - terminals of the SSR) out of the boiler compartment, along the bottom of the water reservoir compartment, and out the opening in the bottom corner of the water reservoir compartment (see Fig. 6).

7c. Reinstall the panel removed in step 7a.

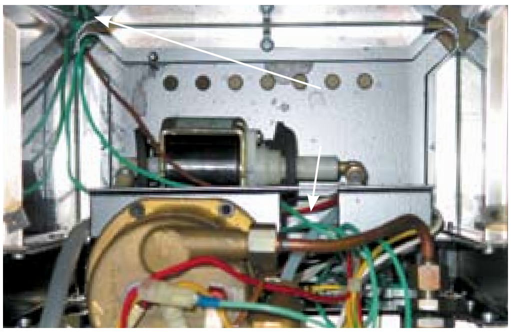


Fig. 6 Wire path out of Silvia.

8. Wire the PID.

8a. Cut the receptacle end (not the end that plugs into the wall) off of the extension cord and strip the ends of the wires about ¼".

8b. Run the extension cord, TC wire, and SSR control wires through the hole drilled in the back of the enclosure.

8c. Slide the white mounting collar over the back of the PID (it must go on before the wires are attached, for obvious reasons).

8d. Attach the wires to the PID as follows (see Fig. 7). The PID has simple screw clamp terminals, so just slide the wire into the appropriate terminal and tighten the screw.

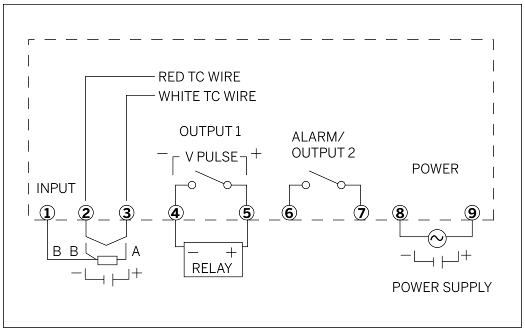


Fig. 7 PID pinout.

8e. The ends of the thermocouple wire go to terminals 2 (red wire) and 3 (white wire). The first time I wired up my PID, I had the leads reversed. When the PID turned on the heating element, the temperature readout started to drop instead of rise.

8f. The ends of the SSR control wires go into terminals 4 and 5. Be sure to match the + wire from the SSR to the + terminal on the PID, and the - wire to the - terminal. That's why I marked the wire with tape in step 6b.

8g. The ends of your power cord go into terminals 8 and 9. (Note: The lighted rocker switch, if used, gets wired between the power source and the PID. I left that step out because the switch is totally superfluous.)

8h. Terminals 1, 6, and 7 are unused.

9. Mount the PID in the enclosure. Slide the PID into the enclosure. Cinch the mounting collar snug against the inside of the enclosure. Screw the cover onto the enclosure. I attached the enclosure to Silvia with double-sided foam tape. Not the most elegant solution, I guess, but it is cheap, fast, simple, and reversible.

10. Secure the SSR, and reinstall the splash panel. Behind Silvia's front splash panel is a bolt that can be used to secure the SSR. I did not have a 4mm washer and nut (available at your local hardware store) to use for this purpose, so I simply hung the SSR on the screw, and then put the splash panel back in place.

11. Reinstall Silvia's top and water reservoir. Put the top back on, tighten up the four screws that hold it down, and reinstall and refill the water reservoir.

12. Fire up! Plug Silvia in, plug the PID in, and turn Silvia on. The PID should display the boiler temperature after a second or two. Press the SEL button on the PID to see the setpoint temperature; use the up and down arrow buttons to adjust the setpoint to 230° F.

TUNING

In order for the PID to work its magic, various parameters must be set on the controller itself. Fortunately, the PID controller takes care of the hard parts through a process called "autotuning"; through trial and error, the PID determines its own optimum settings necessary to hold the boiler at the desired setpoint. There are a few parameters, however, which need to be set by hand.

Manual Settings

Make the following settings by hand. There are about 50 parameters that can be set manually; I only changed 5.

1. Primary Menu: Press and hold SEL key for 3 seconds. The only item of interest on the primary menu is autotune, which is discussed in the autotuning section below.

2. Secondary Menu: Press and hold SEL key for 7 seconds.

TC (cycle time): I have mine set to 1.
P-n2 (input type): Make sure this is set to 2 for type J thermocouple or 3 for type K.
P-dP (decimal point resolution): Set this to 1 to display temps in one-tenth degree increments.
3. Factory Presets Menu: Press and hold SEL for 9 seconds.

P-dF (input filter constant): This setting filters out quick changes in thermocouple readings and slows down PID responses, which is a bad thing for our application. I have mine set to 0.
FUZY (fuzzy logic): Helps eliminate overshoot. Set to On.

Autotuning

Autotuning is the process where the PID controller determines how output to the heating element affects boiler temperature. After autotuning, the PID sets its own proportional, integral, and derivative parameters so you don't have to worry about it.

To activate autotuning:
1. Turn on Silvia and the PID and let her warm up for, say, an hour.
2. Run some water through the portafilter or steam wand to lower the boiler temp.
3. Press the SEL key for 3 seconds, and then the down arrow key until AT (looks like A7) appears on the PID display.
4. Press the SEL key once to select autotuning.
5. Press the UP key once. The PID should display 1. The autotune LED on the PID will start to blink.
6. Wait a while (about 7 minutes in my experience). When autotuning is complete, the PID will return to the current temperature display.

That's all there is to it. Silvia is ready to go.

NOTE: *The modifications described on these pages reflect the author's own experience and are not intended to serve as a guide or instructions for others. These modifications involve tampering with high-wattage electrical circuits in a wet environment, which could result in electric shock, burns, other serious personal injury, or death, as well as fire, explosion, and other property damage. The author is not an electrician and the fact that his modifications were successful was purely a matter of luck. The author and/or MAKE is not responsible for injury or damage to or caused by anyone foolish enough to follow his example. Before you tinker with an espresso machine or any home appliance, make sure you know what you are doing or get help from someone who does. Modifying Silvia voids any warranty provided by the manufacturer and/or retailer.*

John F. Murphy is a government lawyer in Fort Worth, Texas, who relies on espresso to fuel him through the work-a-day drudgery.

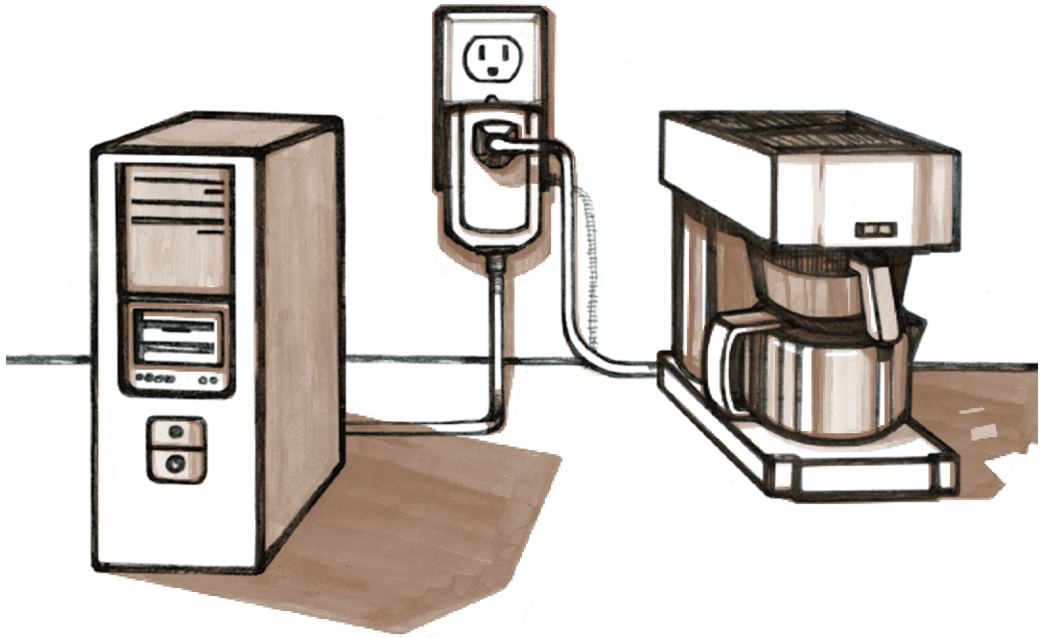


Illustration by Damien Scogin

AUTOMATE YOUR COFFEE POT USING X10

What good is a coffee pot if it can't be controlled from the internet? By Dave Mabe

If you're anything like most geeks I've met, you probably have a coffee pot that gets a lot of use catering to your caffeine addiction. I decided to play around with X10 technology and an open source software program called MisterHouse to automate my coffee pot and make it more user friendly.

I wanted to wake up to freshly brewed coffee, and I'm too lazy to remember to turn off the pot after a period of time to prevent burning. Sure, you could buy a fancy coffee pot that has some of the features I wanted built in, but even the most expensive coffee pot can't touch the flexibilities you can create with a little Perl code.

MisterHouse (misterhouse.net) runs on Windows, Mac, and Linux, and lets you write simple Perl code to control a variety of hardware. To control your coffee pot, you'll need to buy an X10 PC interface and an appliance module (less than $50 new — even less on eBay). You'll plug the appliance module into the electrical outlet and the coffee pot into the appliance module. You'll need a coffee pot with a mechanical switch — it needs to be able to be turned on and off simply by controlling the power supplied to it. The PC interface connects to a computer's serial port and plugs into any electrical outlet.

Add some Perl code to your morning brew and discover the difference it makes.

Once the hardware is connected, configuring MisterHouse is a breeze. There are detailed instructions in the misterhouse.ini file included with the software on the website.

Rather than schedule the time to start brewing, I wanted to schedule the time my coffee pot completed the brew so I could know the instant my coffee was ready. First, I timed how long my pot takes to brew our standard amount of coffee (8 minutes until the last drip). I created a file called coffeepot.pl in MisterHouse's code directory on my PC with the following code in it (MisterHouse creates an event loop and executes your code a few times every second):

```
# C2 is the code I set on the appliance module
my $coffee_pot = new X10_Appliance("C2");
my $morning_coffee_time = "5:15 AM";
my $brew_duration = 8;
my $start_brew_at = time_add("$morning_coffee_time
– 00:$brew_duration:00");
my $coffee_timer = new Timer;
my $coffee_brew_timer = new Timer;
my $coffee_pot_on_duration = 40;

if (time_now($start_brew_at)) {
    set $coffee_pot ON;
    set $coffee_timer ($coffee_pot_on_duration * 60);
    set $coffee_brew_timer ($brew_duration * 60);
}

if (expired $coffee_brew_timer) {
# do some optional notification here
}

if (expired $coffee_timer) {
set $coffee_pot OFF;
}
```

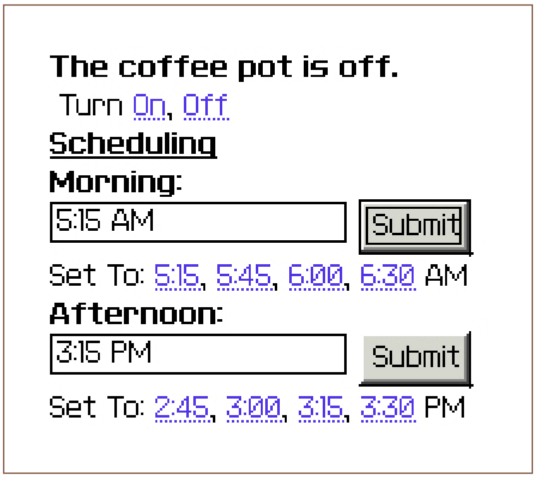
This way, MisterHouse knows to start brewing at 5:07 a.m. if I want to have coffee at 5:15 a.m. A timer is started for the brew time ($coffee_brew_timer) and for the automatic shutoff ($coffee_timer). Once the coffee timer expires, the coffee pot is automatically turned off (Smokey the Bear would be proud).

I drink coffee twice a day — one cup in the morning and one in the afternoon, so I added code for the afternoon brew with some notification features as well. I've placed some motion detectors ($25 each) throughout my home and external home office. Depending on which room there has recently been motion in, MisterHouse turns a light on and off when the coffee's ready. For the early morning brew when there's no motion in the house, I turn on a light near my bedroom that acts as a gentle alarm clock. If the house is motionless at any other time of the day and the brew completes, I send an email to my BlackBerry with a "Turn Off Now" link, in case it's been turned on in error.

MisterHouse comes with its own built-in web server that allows most any object to be accessed and modified using a browser. Along with a fairly comprehensive default web interface, there is full documentation on how to easily roll your own. I wanted to be able to schedule my coffee pot as well as turn it on and off from my BlackBerry, so I created a custom site that looks decent on a mobile browser.

I've also added some vacation logic. My morning brew is automatic — after I schedule it once, it happens daily. However, if there hasn't been motion in the house during the previous evening, MisterHouse knows I'm probably on vacation, so the morning brew doesn't kick off.

Well, there go the lights — it's nectar time!



Learn more about Misterhouse and how it can help you do more than brew a great cup of joe by visiting the wiki at misterhouse.sourceforge.net.

Dave Mabe is the author of *BlackBerry Hacks* from O'Reilly and lives in Chapel Hill, N.C.