PROJECTS by CARVEWRIGHT™

Mystery Clock

PROJECT ADVANCED DIFFICULTY

Even though every moving part of this clock is exposed for all to see, many find what makes it tick a complete mystery! The secret is a magnet embedded in the bottom of the pendulum, and a battery-operated electrical coil hidden in the base. But you don't have to tell your guests that – make then guess!

Wood gear clocks can be finicky to get and keep running accurately, but this one is quite robust. And, with the available advanced microcontroller drive circuit, it is also very accurate.

All of the wood parts are made with the CarveWright/CompuCarve machine using only the two standard 1/8" cutting and 1/16" carving bits, plus a few hand tools and a drill press.

Materials List

Project Files

- base.mpc
- bob.mpc
- frame.mpc
- half_inch_parts.mpc
- half_sled.mpc
- jigs.mpc
- pendulum.mpc
- quarter_inch_parts.mpc
- ring.mpc

Boards:

- (1) ¼" x 11½"W x 38"L Baltic birch plywood
- (1) ½" x 6"W x 12"L
- (1) ¾" x 4"W x 2"L
- (1) ¾" x 4"W x 5"L
- (1) ¾" x 4"W x 7"L
- (1) ¾" x 4"W x 25"L
- (1) ¾" x 6"W x 2½"L
- (1) ¾" x 8"W x 20"L
- (1) ¾" x 10"W x 19"L

Materials:

- sled (see instructions)
- hardware (see instructions)
- electronics (see instructions)

Hand Tools:

- small hand saw
- files
- screw drivers

Power Tools:

- Drill press

Mystery Clock

Introduction

The Mystery Clock is a wood gear clock driven by an electromagnetic pendulum. A magnet at the end of the pendulum swings past an electrical coil hidden in the base. An electronic circuit detects this, and injects a short current pulse into the coil. This electromagnetic coil then repels the magnet, giving the pendulum a small "kick" each time it passes by. This keeps the clock running.

The Mystery Clock operates safely on 4 D batteries for up to four months.

This CarveWright project's difficulty is categorized as Advanced because tools other than the CarveWright, such as a drill press, are required. Also, there are a quite a few parts to make and assemble. However, the clock has been designed to be somewhat forgiving, and a good choice for a first-time wood gear clock builder.

In addition to the wood parts that you will fabricate, hardware such as a rare earth magnet, brass threaded rod, brass tubing, bearings, and electronics are needed. You can get a complete kit of all hardware from www.carveshop.com. Visit that web site to find out how to order the hardware kit.

The hardware kit comes with all hardware parts necessary to build the clock, including the electronics. The coil is pre-wound on its own bobbin, so you don't need to machine a bobbin and wind the coil.

The hardware kit also includes an advanced pendulum drive circuit. Accuracy and stability of the clock are improved with this more advanced pendulum drive circuit. This advanced circuit is unique to carveshop.com clocks.

A schematic for a basic drive circuit is provided in the appendix for those who want to source their own hardware parts. Detailed build instructions are not provided, but the schematic should be sufficient for the typical electronics hobbyist.

Either the basic or the advanced circuit will make for a very nice clock. I've run a couple clocks with the basic circuit, but the advanced one has some nice features. Here's an explanation of each.

Basic pendulum circuit

The basic pendulum drive circuit is triggered solely by the pendulum itself and is not adjustable on the fly. Therefore, with this circuit, clock accuracy is adjustable only by the movable bob on the pendulum, which requires a manual tuning effort. It may take several days or weeks to adjust the pendulum properly, and accuracy may change over time. But the circuit does provide for a very functional clock.

Advanced pendulum control circuit

The advanced pendulum control circuit, included with the hardware kit, is run by a microcontroller with a watch crystal time base. It constantly monitors the pendulum period and adjusts the coil drive to keep the clock as accurate as the reference watch crystal, within 20 parts per million. (While the period of the pendulum in this

clock is regulated primarily by the effective length of the pendulum, the period also can be adjusted somewhat by how the electromagnetic coil is driven.)

The advanced circuit also has a simple LED indicator to help you set up your clock faster. More on that later.

Step 1

Hardware

Here is a list of hardware needed to build the clock:

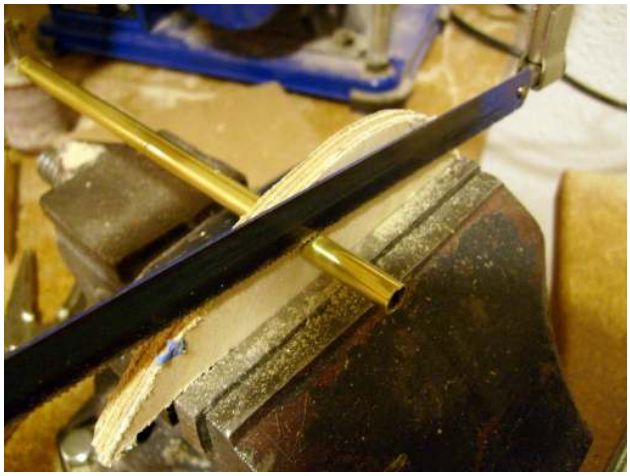
Qty	Item	Notes
1	rare earth magnet, 3/4" diam. x 1/4" thick	pendulum
1	brass threaded rod, 10-32 x 5-1/4"	pendulum
7	3/16" ID x 3/8" OD x 1/8" thick ball bearing	various
1	spring, .035 wire, 29/32 dia., 3/4 long	clutch
4	3M self-adhesive bumper, .5" x .14"	feet
2	brass knurled nut, 10-32	pendulum
2	#6 x 1-1/4" brass flat head wood screw	frame support
1	#6 x 3/4" brass round head wood screw	pawl support
1	#4 x 5/8" brass round head wood screw	driving pawl
1	#4 x 1/2" brass round head wood screw	locking pawl
2	#6 x 2" flat head wood screw	ring
7	#6 x 1" wood screw	base
2	#4x1/2" flat head wood screw	battery holder
1	# 4-40 x 1-1/4" flat head machine screw	3-arm spiral
1	M6 washer (or tubing)	main arbor
6	M5 washer (or tubing)	ratchet, lever, pivot
2	#6 washer	pawl & catch
1	3/16" diameter x" brass tubing, at least 6"	various
1	7/32" diameter x" brass tubing, at least 9"	various
1	1/4" diameter x" brass tubing, at least 15"	various
1	1/4" OD x .170 ID x 1/4" vinyl tubing	lever bearing
1	battery holder, 4 D cells	see text
1	coil, 1" dia., 3/8" long, 32AWG magnet wire	see text
1	circuit board	see text

Tubing

If procuring your own hardware, you'll need to cut several lengths of brass tubing and brass threaded rod. Refer to the chart below:

Part	Diameter	Length
main bearing	1/4	1 3/8
80 tooth gear assembly arbor	1/4	1 3/8
hour hand assembly arbor	1/4	1 1/4
jig	1/4	1 1/4
arbor spacer*	1/4	1/16
minute hand arbor	7/32	5 1/2
72 tooth gear assembly arbor	7/32	1
jig	7/32	1
30 tooth gear assembly arbor	7/32	5/8
lever spacer	7/32	3/8
ratchet, lever, & pivot spacers*	7/32	1/16
pendulum	3/16	5
72 tooth gear assembly shaft	3/16	1 3/4
ratchet wheel assembly axle	3/16	1 7/8
pendulum shaft	3/16	1 3/4
lever axle (rear)	3/16	1 5/8
lever shaft (front)	3/16	1 1/4
30 tooth gear assembly shaft	3/16	1
vinyl tube, 1/4" OD x .170 ID		1/4
threaded brass rod, 10-32		5 1/4

*or washers



To assist in cutting the tubing, drill a hole the diameter of the tubing in some scrap, and insert the tubing through the hole. Clamp the scrap in a vice. With the scrap as a guide for your hacksaw blade, cut the tubing. You may find it easier to cut if you periodically rotate the tubing. File the end of the cut piece, and remove any burrs inside and outside the tube.

You may use a tubing cutter for some tubes that are used as shafts, but other tubes must slide onto these shafts, and a tubing cutter will tend to pinch the end of the tube slightly.

Tubes in the hardware kit are precut. Just de-bur and chamfer the ends a bit with a file.

Batteries

You'll need 4 alkaline D cells to power your clock. Non-alkaline batteries will not last long. Batteries are not included with the hardware kit.

Step 2

Wood

Here is a table of the boards that you will need for this project:

Thickness		Width			
Nom.	Act.	Nom.	Act.	Len.	.mpc
1/4	1/4	12	11 1/2	31	quarter_inch_parts
1/2	7/16	6	5 1/2	12	half_inch_parts
1	3/4	4	3 1/2	2	bobbin *
1	3/4	4	3 1/2	5	pendulum
1	3/4	4	3	7	jigs
1	3/4	4	3 1/2	25	frame
1	3/4	6	5 1/2	2 1/2	bob
1	3/4	8	7 1/4	20	ring
1	3/4	10	9 1/4	19	base

* included in hardware kit

Nominal thickness and width are what you will typically see in a lumber yard or home center – for example, a 1” thick by 6” board will actually be ¾” thick by 5½” wide.

Decide what type of woods you will use for your clock.

For the large and medium gears, and other parts on the file quarter_inch_parts.mpc, I highly recommend using ¼” Baltic birch plywood. Baltic birch is special plywood that is constructed from multiple thin layers that are free of voids. This makes the plywood dimensionally stable, and gears cut from it will be flat and true. Some home centers may carry it, but it can also be ordered and shipped from many sources.

I have had good luck by applying a coat of finish – for example, polyurethane varnish – to both sides of the Baltic birch before machining it. This tends to add some strength to the wood fibers and helps prevent splintering.

For the pinions and other parts on half_inch_parts.mpc, choose a hardwood. I used hard maple. You’ll need a board that is nominally ½” thick and 6” wide, actual dimensions 7/16” thick and 5½” wide.

Here is an example of a suitable board that I obtained from my local Home Depot. It was labeled “1/2 X 6 X 3 WHITE HOBBY WOOD”, but it is actually 7/16” x 5½” maple. This is what I used for my clocks. But take care – the store also had aspen and poplar labeled exactly the same, and those species are not good choices for these parts. I can also obtain red oak in these dimensions at the local home centers, which is another good choice.

Hardwood is recommended for the frame. Again I used maple. Most any wood may be used for the base and ring. I have used both oak and clear pine for the base and clear pine for the ring.

These parts are all made from standard 1” boards (actual thickness ¾”).

Step 3

Quarter inch parts

The gears and other parts are cut from a ¼” piece of Baltic birch 11½” by 38”. This thin stock cannot be loaded into the machine by itself.

Make a simple sled by cutting a piece of ½” or ¾” plywood, and temporarily fasten the birch to the plywood. You can see from the photo of my sled that I reuse pieces of birch plywood for the ends of the sled, to minimize waste. Make sure that the plywood for the sled is smooth on the bottom, warp free, and cut square. This will ensure that the board will track properly in the machine.

Fasten the birch to the plywood base with four countersunk screws in the corners of the plywood. You may instead use tape on the plywood edges or double-sided tape on the surface of the sled. Whatever method that you use, make sure that the birch is securely attached. (Note that the project uses tabs to keep the gears in place, so double-sided tape is not required if you use screws or edge taping to secure the birch.)

Load the sled into the machine and use the quarter_inch_parts.mpc file. Respond No to Say Under Rollers? and Place on Corner if your board is oversized. At the prompt Select Cut Through Depth, choose 1) Project.

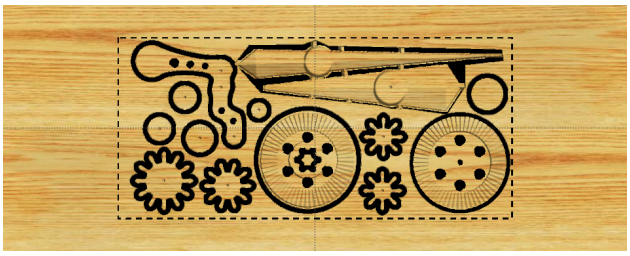
This project specifies three bits: A 1/8” vector bit, a 1/8” cutting bit, and a 1/16” drill bit. Select and load your 1/8” cutting bit for the first two.

Because the gears are going to be pressed onto brass tubing when assembling the clock, their center hole diameters must be precise – even more precise than the CarveWright is capable of doing. We need to use precise drill bits. However, we are going to use the CarveWright to drill a small 1/16” pilot hole for us to locate the positions of these critical holes.

If you have a 1/16” cutting bit, use it. If you don’t, no problem – we are going to trick the machine. When prompted to select the 1/16” drill bit, go ahead and select the 1/16” cutting bit; but when prompted to *load* the bit, load your 1/16” carving bit instead. Don’t worry; we’re only going to drill a very shallow pilot hole, and the carving bit will do just fine.

After the gears are cut, remove the plywood from the sled, and carefully remove the gears by cutting the tabs. Sand the parts as needed. Make certain that the tabs on the gears are completely removed from the teeth and flush with the nominal gear outline. This is critical to ensure that the clock will operate properly.

Step 4



Half inch parts

Because we are using nominal ½” wood which is actually 7/16” thick, we need to use a sled, as the machine requires ½” minimum thickness.

The easiest way to make a sled for this part of the project is to use a piece of ¾” plywood or MDF 20” long and 7½”wide. Carve the sled using the project file half_sled.mpc. You may upload and carve the project in draft mode to save time. Respond No to Stay Under Rollers? and Place on Corner if your board is oversized (just be sure to orient the sled the same way in the machine when you cut your parts).

To cut the parts, cut your 7/16” x 5½” material 12” long. Place it in the sled, and hold it in place by taping the edges.

On the machine main menu, press 0 for Options and 5 for Jog Touch, and then press Enter if needed to set Jog Touch (On). When running the project, touch the bit down on the 7/16” board, and not the surface of the sled, to get an accurate reading of the board’s surface. As with the previous step, use your 1/16” carving bit for the 1/16” drill bit if you don’t have a 1/16” cutting bit.

After the board is machined, cut the tabs to remove the parts. As with the larger gears, make sure that tabs on the gear teeth are completely removed and sanded flush with the gear contour. Sand all the parts. I used a folded piece of sandpaper on the clutch teeth.

Step 5

Sled or jig

The rest of the clock parts, cut from ¾” stock, are separated into several project files, in part to allow the use of different types of wood.

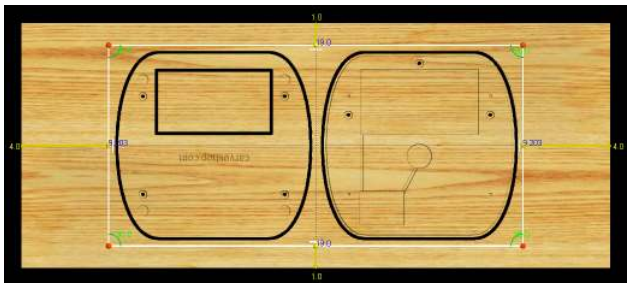
The projects could be machined without jigs or sleds, but to conserve wood, a sled is recommended. If you’re an experienced sled user, you’ll have no trouble modifying the project files to your own style of jig or sled. If not, I suggest that you study the *CarveWright Tips and Tricks Issue 7 April 2008 Carving Jigs – Carrier Boards, Sleds and Rails.* You can find this at www.carverwright.com under Learning – Tips and Tricks. Then build a sled or sleds for this and future projects.

I myself typically use adjustable sleds pictured above. Mine are similar to the type in Figure 4 of the *Tips and Tricks Issue 7*, with 1” wide side

rails and 4” wide filler pieces. The three quarter inch project files are all set up for sleds of this type.

Note that my sled is oversize, to fit a variety of projects, rather than being exactly the dimensions required for any one project. I simply respond Place On Corner to make use of the one sled for many projects.

Step 6



Base

You’ll need a 10” nominal width board (actual width at least 9¼”) by 19” and the file base.mpc.

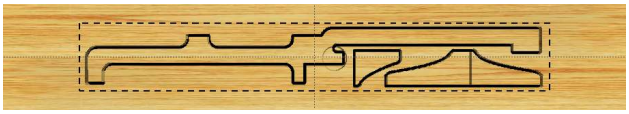
If you have a 3/16” carving bit, you can use it. Just change the bit selection on the Board settings for the project. Upload in Draft mode to save carving time, as these carved surfaces will all be hidden.

The depth of the hole drilled for the coil in the base top is critical – it must be within .05” of the surface, but not drilled through! Measure the exact thickness of your board. If it is not exactly .75”, adjust the coil drill depth in the project file accordingly. Take care handling the finished piece with this thin surface area.

If you are using the basic circuit, delete the group “LED” from the base project before carving. Otherwise, a small hole will be exposed in the top of the back of the base for an indicator LED.

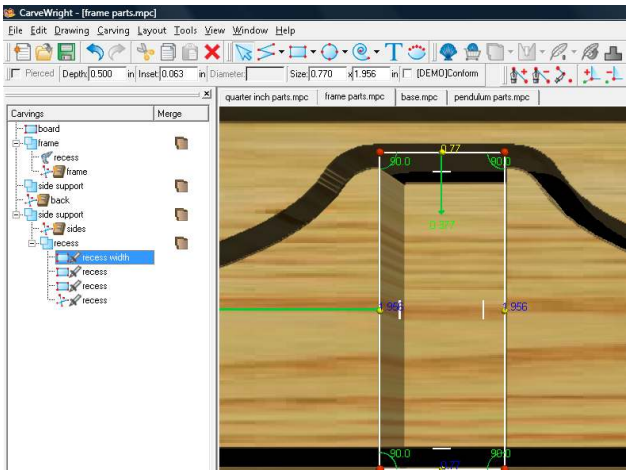
If not using the hardware kit, make sure the circuit board and battery box cutout dimensions are suitable for your parts.

Step 7



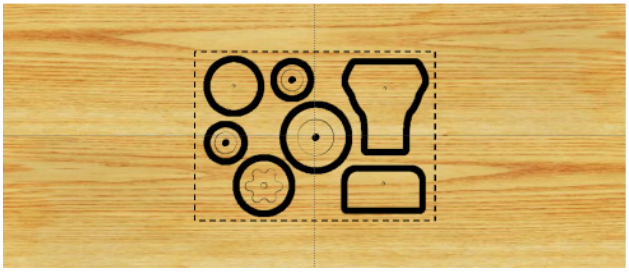
Frame

You’ll need a 4” nominal width (actual width 3½”) by 25” long and project file frame.mpc.



Before uploading this file, carefully measure the exact width of the board that you are using for the frame. If the board is not exactly ¾” wide, you’ll need to modify the project slightly. Locate and select the rectangle labeled “recess width”. Set the width of this rectangle to the width of your board. My board was slightly thicker, so I adjusted this rectangle accordingly.

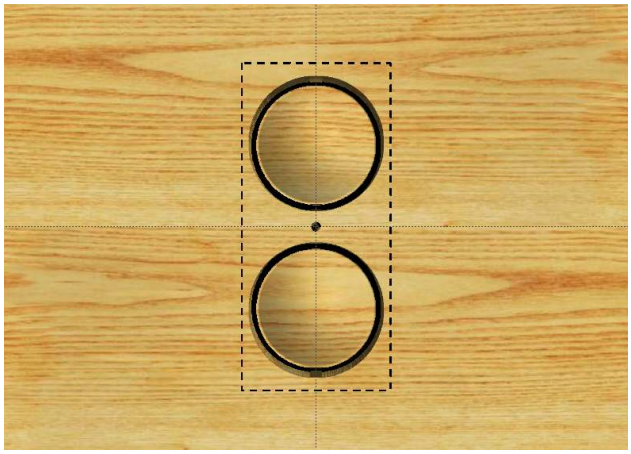
Step 8



Pendulum and hub parts

You'll need a 4" nominal width board (actual width 3½") by 5" long and the file pendulum.mpc.

As before, substitute your 1/16" carving bit for the 1/16" drill bit if you don't have a 1/16" cutting bit.



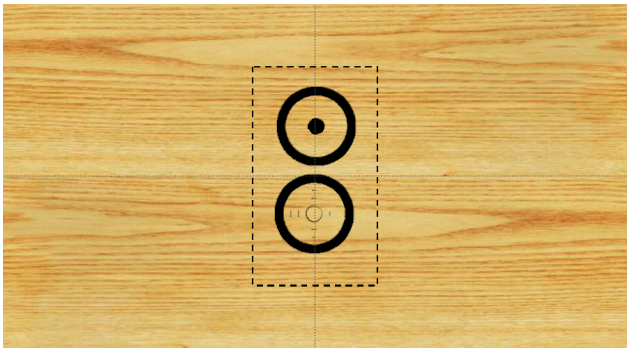
Next, cut the bob out of a 5½" wide by 2½" long board. (This may seem to be an odd arrangement, but the bob halves carve faster above-and-below than side-by-side.)

This is a two-sided operation. You have a choice.

You may used the standard CarveWright two-sided technique with the two-sided, front and back, project file bob.mpc.

But, I have had better luck manually aligning front and back using separate bob_front.mpc and bob_back.mpc project files. Carve the front first, using an oversize sled. Then, take the board out of the sled, flip the board, and put it back into the sled to carve the back. When you carve the back, choose to Jog To Position and Jog To Center from the prompts. Position the bit right over the 1/8" hole that was drilled through when you carved the front. This method works well for me.

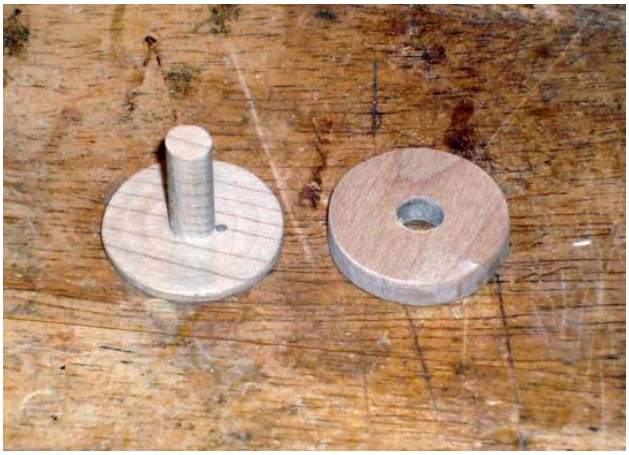
Step 9



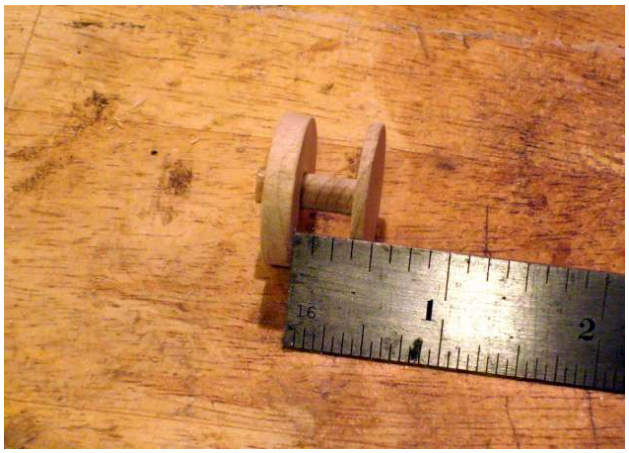
Coil bobbin and coil

If you're using the hardware parts kit, a wound coil is provided, and you can skip this step.

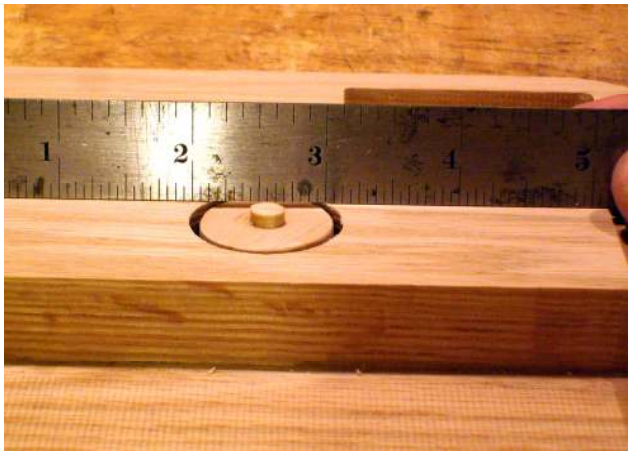
You'll need a 4" nominal width board (actual width 3½") by 2" long and the file coil_bobbin.mpc.



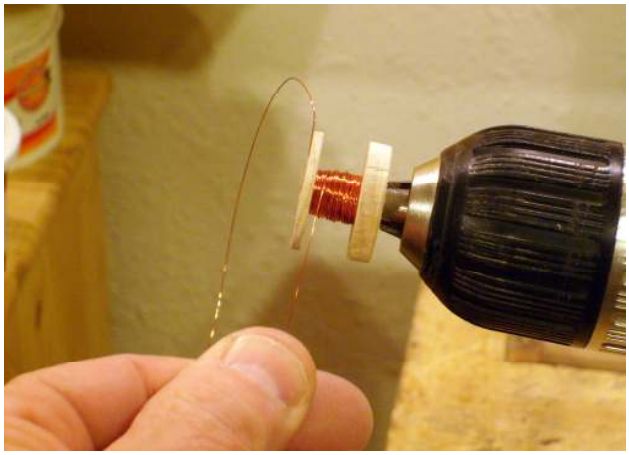
After machining, remove and clean up the two parts. Drill a 1/16" hole through the part with the post adjacent to the post.



Assemble the parts, spacing the discs 3/8” apart.



Before gluing these parts, check the coil fit into the top of the base – the disc must fit at or below the face of the base. The post will protrude, which is OK for now.



Place the nub of the post into a drill chuck and tighten the chuck. Thread about 4” of 32 gauge magnet wire through the small hole. Place the supply spool of magnet wire on a dowel so that it can turn freely. Slowly start the drill and feed the magnet wire onto the hub. Try to keep the turns of wire as close together as possible, moving back and forth slowly. Take care not to break the wire. Add turns of wire until the bobbin is nearly full, about 1” diameter. Secure the wire with tape or hot-melt glue. Cut the wire, leaving about 4” free.

Proper orientation of the coil is critical for the electromagnetic pendulum to function. Using the above photo as a reference, the wire lead out of the small hole is negative, and that end of the coil is magnetic north.

Step 10

Part	Hole size	Depth
32 T gear, 3-arm star	1/4	through
hub, 7/8" diameter, hour hand assembly	1/4	through
hour hand	1/4	through
80 T gear, 5-arm spiral	1/4	through
driver clutch	1/4	through
hub, 1" diameter, 80T 5-arm spiral to clutch	1/4	through
10 T pinion	7/32	through
30 T gear, 3-arm spiral	7/32	through
72 T gear, 5-arm star	7/32	through
8 T pinion	7/32	through
clutch hub	7/32	1/2
8 T pinion	7/32	3/8
minute hand	7/32	3/8
ratchet wheel	3/16	through
12 T pinion	3/16	3/8
cap, 3/4" diameter, 72 tooth gear assembly	3/16	3/8
hub, 3/4" diameter, ratchet wheel	3/16	3/8
cap, 1/2" diameter, lever assembly	3/16	3/8

Drill guide

I recommend that you read through the rest of the project instructions before doing any drilling. The instructions are laid out in a logical order, and include the details of what size holes to drill and where. However, after reading and understanding the assembly process, you might save time by drilling several parts that require the same drill bit all at one time. You may use the above drill guide to prepare the parts in the table.

For all drilling, use a drill press whenever possible to ensure that the holes are absolutely perpendicular to the surface of the parts.

Step 11

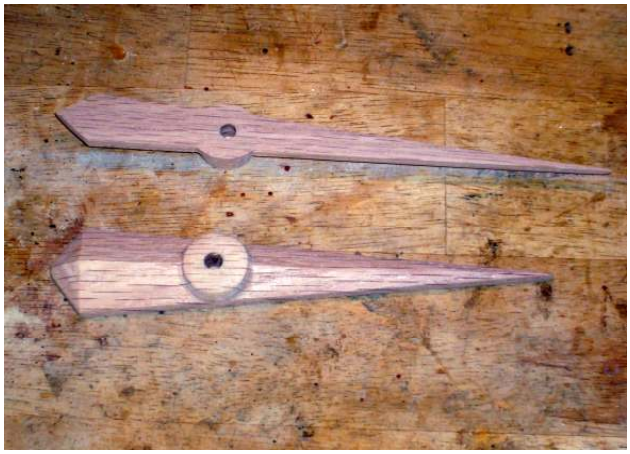
Ring

Cut the ring from an 8” board 20” long, using ring.mpc if you have the Centerline Text option or ring_carved if you don’t. Dress the ends of each ring piece flat and square if necessary, but leave the other surfaces for now. The ends must be true for a good fit. Without gluing, fit the pieces together on your workbench, and carefully trim the parts as needed. I’ve been able to use the parts straight out of the machine and get a good fit.

Lay some waxed paper down on your bench, covering the joint areas of the ring. Mix up some extended-time (60 minute) epoxy, and apply it liberally to the end of each piece. Fit the pieces together and clamp. Check to make sure that the pieces remain flat – clamp or weight them down as needed.

I find it best to let this set considerably longer than 60 minutes before removing the clamps.

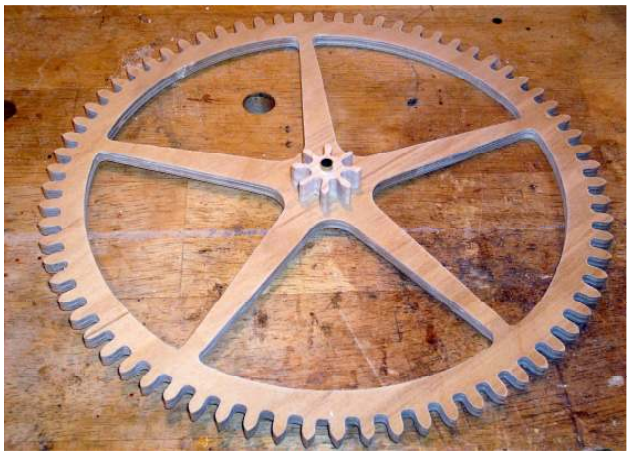
Step 12



Hands

Drill a ¼” hole through the hour hand. Drill a 7/32” hole 3/8” deep from the back of the minute hand, but don’t drill all the way through.

Step 13



70T 5-arm star gear assembly

Drill a 7/32” hole in the center of the 70-tooth 5-arm star gear, using the pilot hole as a guide. Drill a 7/32” hole in the center of one of the 8-tooth pinions.

Insert a 7/32” by 1” long tube into the pinion, with 1/8” of the tube protruding. You may need a hammer to drive it home. If so, protect the end of the tube with scrap wood.

Drill a 3/16” hole 3/8” deep, but not through, the ¾” diameter 70T star gear cap.

Apply glue to the surface of the pinion. Align the tube and the hole in the gear and press them together. The tube should protrude from the back of the 70-tooth star gear as well as from the pinion. Clamp the pinion to the gear and wipe off any excess glue. Allow the glue to set.

Step 14

80T 5-arm spiral gear assembly

Using the pilot hole made by your machine as a guide, drill a ¼” hole in the center of the 80-tooth

5-arm spiral gear. Do the same in the center of the 80T (1” diameter x ¾” thick) hub.

Insert a ¼” brass tube 1¼” long into the hub, and into the 80T gear, gluing the hub to the gear as you did for the spiral gear. (Note the direction of the spiral arms.) When finished, the tube should protrude 1/16” from the 80T gear.

Next, drill a ¼” hole through the center of the driving clutch. Press this onto the brass tube arbor protruding from the hub of the 80T assembly, and glue it to the hub. The clutch teeth face outward. Check that all these parts are square.

Step 15

Hour hand assembly

Drill a ¼” hole in the center of the 32-t0oth 3-arm star gear. Do the same in the center of the small spacer, and through the hour hand. Insert a ¼” diameter brass tube 1¼” long into the gear, and then glue the spacer to the gear. Likewise, glue the hour hand to the spacer. Align the hour hand and the arms of the star gear in a manner that is pleasing to you. Clamp and allow the glue to set.

The brass tube should protrude about 1/16” from the back of the gear and likewise from the top of the hour hand.

30T 3-arm spiral gear assembly

Drill a 7/32” hole in the center of the 3-arm spiral gear. Insert a piece of 7/32” diameter brass tube ½” long into the 3-arm spiral gear, securing it with a drop or two of superglue. Drill a 7/32” hole into the 8-tooth pinion, as deep as possible without drilling all the way through.

Step 16

10- and 12-tooth pinions

Drill a 7/32” hole completely through the center of the 10-tooth pinion.

Drill a 3/16” hole 3/8” deep in the center of the 12-tooth pinion, but don’t drill it all the way through.

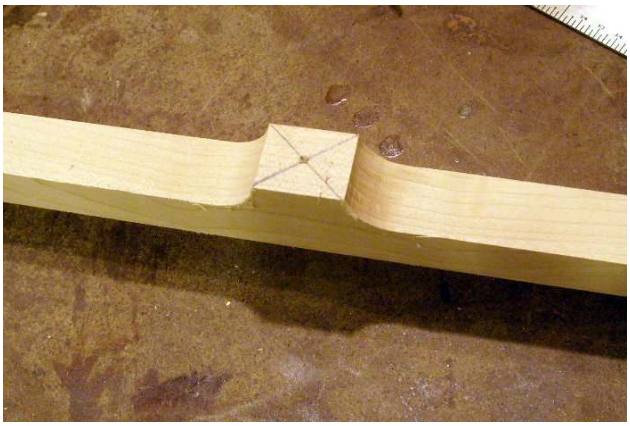
Ratchet wheel

Drill a 3/16” hole through the ratchet wheel. Drill a 3/16” hole 3/8” deep, but not all the way through, in the ¾” diameter ratchet wheel hub. Press a 3/16” diameter by 1-7/8” long tube through the center of the ratchet wheel from the back, allowing it to protrude from the front. Press the hub on from the front. Glue and clamp the hub onto the ratchet wheel, making sure that the hub, wheel, and shaft are squarely aligned.

Step 17

Main bearing

Locate the protrusion for the main bearing on the back of the frame as shown.



With a ruler and a pencil, mark the center. Using a drill press, drill a ¼” hole through the frame.

Insert a piece of ¼” diameter brass tube 1-3/8” in length into the hole in the frame. Place a piece of scrap on top of the tube, and gently hammer the scrap to drive the tube home. Or, press it in with a C-clamp. If the tube protrudes a bit from the frame, you may file it flush.

Step 18

30T gear assembly shaft hole

To ensure smooth gear operation, we're going to make and use jigs to drill critical holes in the frame. You'll need a 4" nominal width board (actual width at least 3") by 7" and the file jigs.mpc. Run the project and cut the tabs to separate the parts.

To make Jig 1, drill a ¼" hole in one end of the jigs using the pilot hole. Drill a 3/16" hole at the other end. Partially insert a length of ¼" diameter brass tube into the hole in the jig. Don't insert it fully, as you'll want to remove it later. Likewise, partially insert a 3/16" tube in the 3/16" hole.

Drill a 7/32" hole through the center of the 10-tooth pinion gear. Temporarily slide this gear onto a short piece of 7/32" tube, so that tube protrudes on both sides of the gear. Insert the tube and gear into the ¼" bearing in Jig 1.

Take the 3-arm spiral gear and slide it onto the 3/16" tube, meshing it with the pinion. Manually rotate the pinion and check the gear mesh. The mesh must not be too loose or too tight; but loose is better than tight. There can be no binding. You may need to sand some teeth for a good fit. Rotate the pinion by hand for several revolutions until you are satisfied with a good fit. The gears should mesh smoothly and not catch. At the same time, there should not be excessive play or slop in the gears (some play is normal).

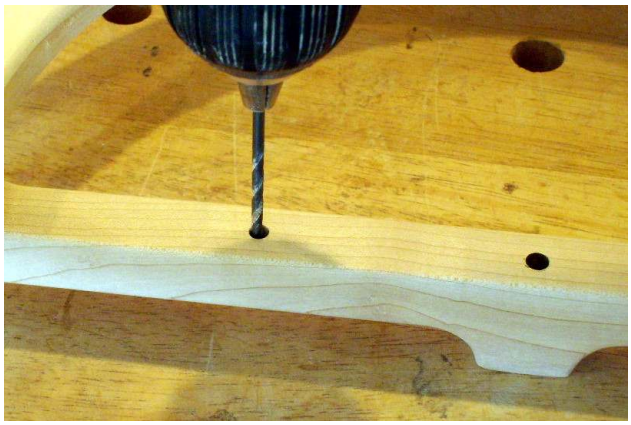
If the gears mesh too loosely or too tightly, remove the 3/16" brass tubing from the jig, and repeat the process, this time drilling a hole to one side of the bad hole, but closer or farther from the ¼" bearing as needed. Insert the 3/16" tubing and test the fit.

When satisfied with the fit, slide the 3-arm star gear assembly onto the shaft. Place the 8-tooth pinion onto the protruding tube of the 3-arm spiral gear, but don't glue the pinion. Test the fit of these newly-added gears by rotating the 10-tooth pinion. Make corrections as required.

When satisfied with the fit of both sets of gears, remove the gears and the 3/16" brass tube. Insert a piece of 7/32" tubing into the frame bushing,

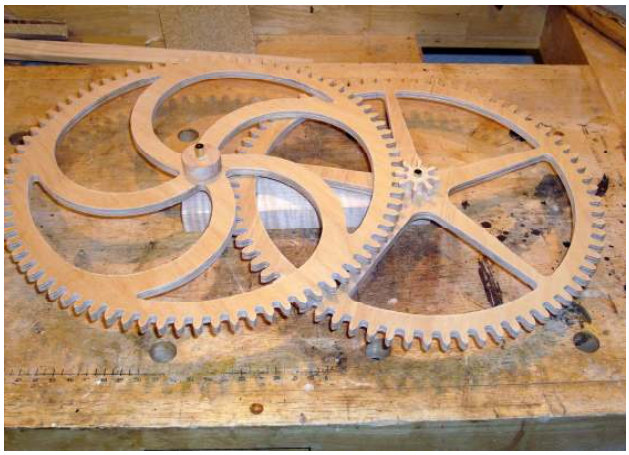
and slip Jig 1 over that tube. Center the 3/16” hole over the frame, and clamp the jig in place. Using the scrap as a guide, drill a 3/16” hole into the frame through the jig hole. Drill only 3/8” deep into the frame.

Temporarily insert a 3/16” diameter brass tube 1” long into the hole, part way so you can remove it again. Test fit the gears in the frame just like you did in the scrap. Remove the tube.



With a 3/32” drill, make a new concentric hole inside the 3/16” hole that you just drilled into the frame. Drill at least ¼” deeper than before, but take care not to drill through the back of the frame. This will be a pilot hole for a screw when the clock is assembled later on.

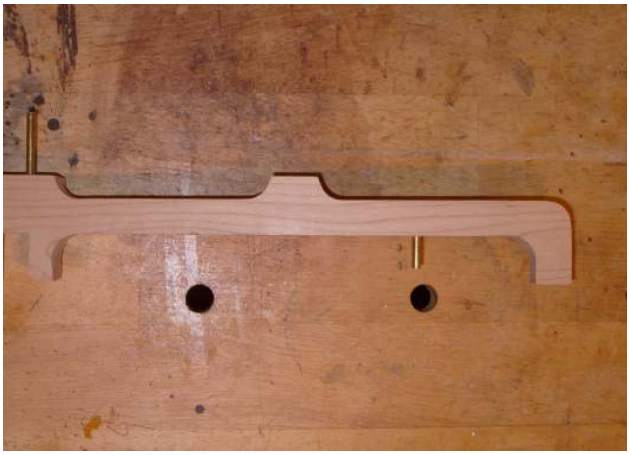
Step 19



72T gear assembly shaft hole

To locate and drill for the rear gear post, use Jig 2 in the same manner as you did with Jig 1. Drill a ¼” hole and partially insert a section of ¼” tubing in one end. Drill a 3/16” hole and partially insert a piece of 3/16” tubing in the other end. This time, slide the 5-arm spiral gear assembly onto the ¼” tubing, and the 12-tooth pinion assembly into the center of the 5-arm spiral assembly. Put the 5-arm star gear assembly on other end.

Check the fit of the gears.



After you have created the jig to locate the rear gear post hole (far right in photo), drill this 3/16” hole only 3/8” deep into the frame. Insert 3/16” diameter tube 2-1/8” long into the hole. Test fit the gears in the frame. Keep the tube in the

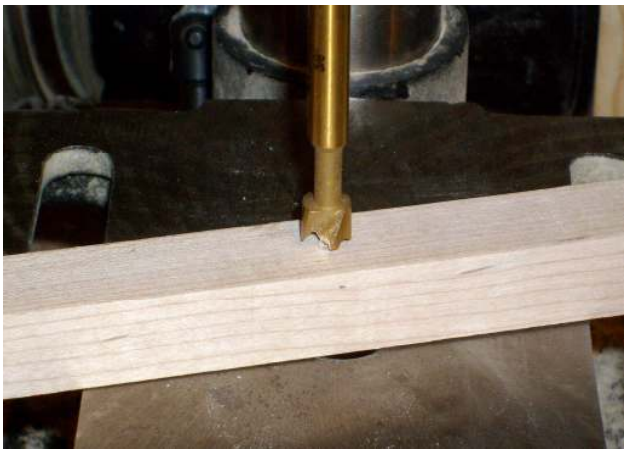
frame for the next step (after which you may wish to remove it for finishing).

Step 20

Ratchet wheel bearing holes

Drill a 3/16” hole in one end of Jig 3, and a 1/16” pilot hole in the other. Insert a 3/16” diameter tube into the first hole. Slide the the 5-arm star gear assembly onto the tubing. Because the mating 12-tooth pinion is not drilled through, we need to use a bit different procedure to locate a 1/16” pilot hole. By now you should have a feel for good gear mesh – not too loose, and not too tight. Position the 12-tooth pinion to mesh with the 5-arm star gear, and check that the hole in the pinion lines up with the 1/16” pilot hole. In my case, I measured a distance of exactly one inch as shown.

When satisfied, remove the 3/16” tubing from the jig, and slide that end of the jig onto the 5-arm gear assembly post on the frame. Locate the 1/16” pilot hole on the center of the frame. Using the jig, drill a 1/16” pilot hole through the frame.



A 3/8” Forstner bit is recommended for this next step, but if you don’t have one, a regular bit or a brad-point bit may also work. Using the pilot hole as a guide, drill a 3/8” hole 1/8” deep. Do this on both sides of the frame.

Next, drill a ¼” hole through the center of the holes that you just drilled.

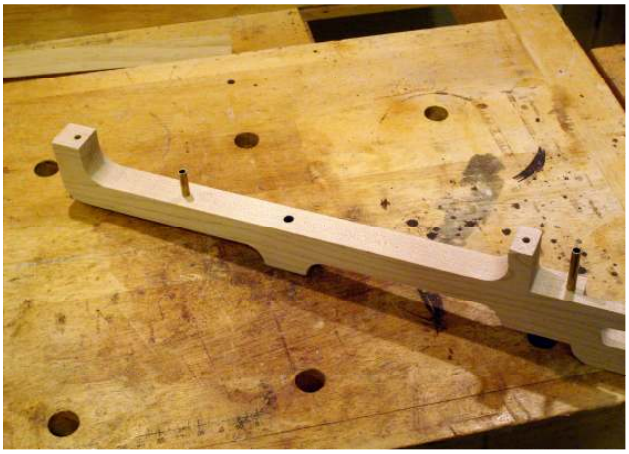
Step 21

Pivot and lever mount

Get the pivot and the lever mount. Using the pilot holes in the parts that were machined in, drill a 1/16” pilot hole through each part. Then drill 3/8” holes 1/8” deep front and back in each part, and drill a ¼ ” hole through each, like you did for the frame.

Mark the center of the bottom of the pivot. Drill a 3/16” hole ½” deep into the bottom of the pivot.

Step 22

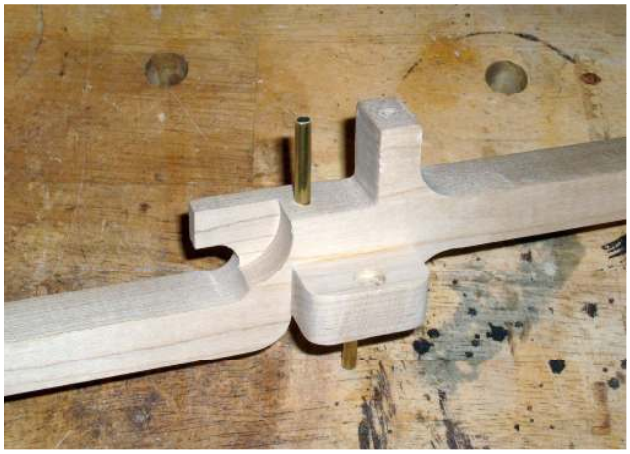


Ring mounting holes

Mark the center of the lower ring mounting arm on the frame from the front. Mark the upper arm ¼” from the bottom of the face of the arm. Drill a 5/32” hole completely through the frame at each mark.

From the back of the frame, countersink the holes using a 5/16” drill bit. Drill the countersunk holes to a depth of 1½” above the front surface of the frame. (When you insert a #6 x 2” wood screw, it should protrude about ½” from the front of the frame.)

Step 23

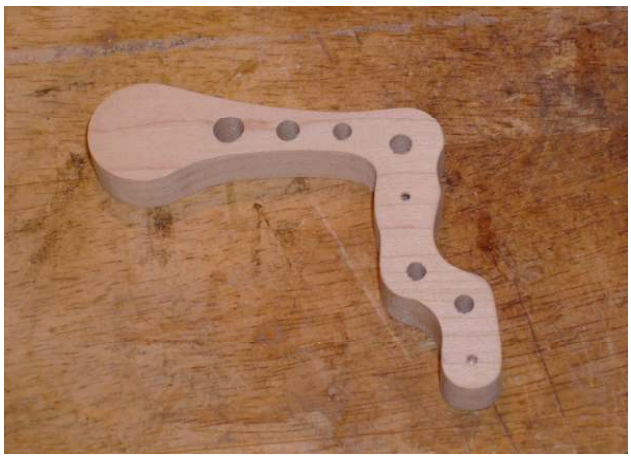


Pendulum pivot and lever mounts

Mark the center of the frame ¾” below the protrusion shown in the photo (11¾” from the bottom of the frame). The mark must be at least ¾” from the protrusion for adequate clearance for the pivot. Drill a 3/16” hole ½” deep. Insert a 3/16” diameter by 1¾” long brass tube into the hole.

Glue the lever mount onto the frame, aligning the back of the mount flush with the back of the frame, and the top flush with the top edge of the frame. The hole in the mount must be exactly ½” higher up on the frame than the pivot shaft that you just installed. This is a critical dimension.

Step 24



Lever

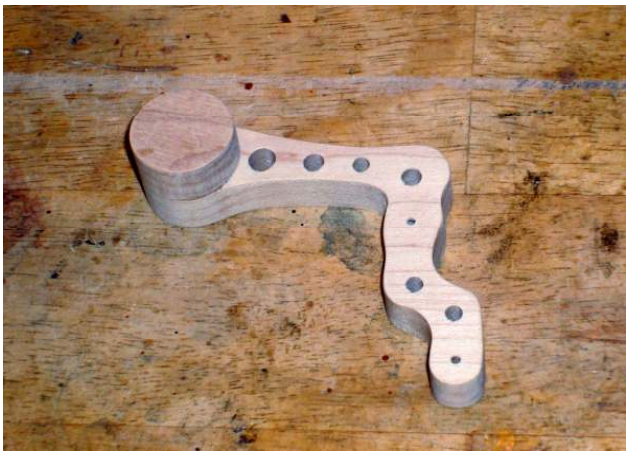
Get the lever, and locate the three pilot holes that have been machined into it (this is the back side of the lever).

Drill a 3/16” hole 3/8” deep, but not through, the lever at the knee using the pilot hole.

Drill a 1/16” hole completely through the lever at the next pilot hole.

Drill a 3/32” hole 3/8” deep, not through, the lever at its lower end.

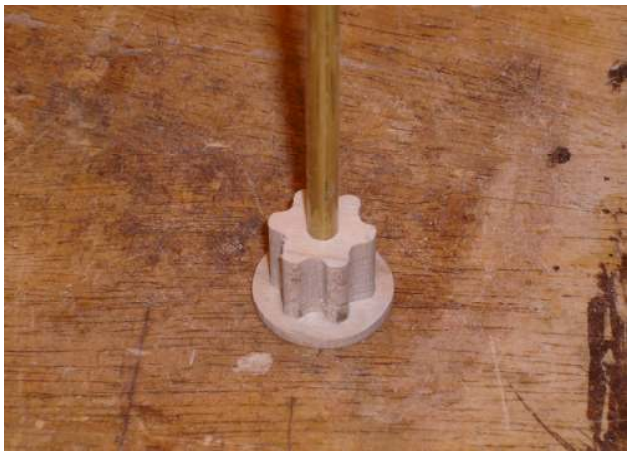
Flip the lever over. Below the knee, drill a 3/16” hole 3/8” deep, but not through, the lever using the 1/16” pilot hole that you previously drilled through from the reverse side.



Glue the round lever weight onto the end of the lever.

Drill a 3/16” hole 3/8” deep, but not through, the ½” diameter lever shaft cap.

Step 25



Clutch hub

Drill a 7/32” hole 3/8” deep into the center of the clutch hub, using the pilot hole already machined. Insert a 7/32” diameter by 5½” brass tube into the clutch hub. Glue if necessary.

Step 26

Pawls and support

Using pilot holes where available, drill a 1/8” hole through the driving and locking pawls. Drill a 9/64” hole through the bottom of the locking pawl support. From the back of the support, drill a 3/32” pilot hole into the top of the catch support, but not all the way through to the front.

Drill a pilot hole in the center of the base of the front of frame, ½” from the bottom of the frame, for the locking pawl support.

Step 27

Frame support

Clamp the rear support to the back of the cross support. Drill two 1/8” pilot holes through the cross support into the rear support. One hole should be just below center, so that it does not poke through the rear support. The other should be below that, close to the bottom.

Countersink the holes in the cross support. Fasten the two support pieces together using #6 *brass* 1 ¼” flat-head wood screws, making certain that the heads are at or below the surface of the cross member.

Glue the supports to the base of the frame as shown.

Step 28

Finish

This would be a good time to apply any stain, varnish, or other finish to the parts of your clock.

Many wood gear clock builders recommend applying no finish to the surface of the teeth of gears, as this can add friction. The Mystery Clock uses a fairly robust pendulum drive, so it is OK to apply finish to the tooth surfaces.

Step 29

Frame to base

Mark the underside of the rear frame support in the center and 3/8” from the end of the support. Drill a pilot hole. Fasten the frame to the base using a # 6 1” wood screw from the underside of the base top and into this frame pilot hole, tightening sufficiently to hold the fame in place.

From the top of the base, align the frame so that it is square. Clamp in place if needed. Drill two additional pilot holes from the underside of the base top into the frame. Secure with two additional wood screws.

Step 30

Base

Invert the base and place the battery holder in position. The battery holder is secured by screws that run through the thin top surface of the base

and into the frame. The preexisting battery holder mounting holes cannot be used. Use the two side screws that secured the frame to the base as a guide for the frame location. Drill two pilot holes in line with these screws, through the battery holder and into the base and frame. Countersink the battery holder holes. Secure the battery holder with two #4 x ½" screws.

Put the circuit board, LED, and coil in place. The LED should protrude slightly through the top of the base. Bend the LED leads.

Orient the coil with the correct polarity: the wire from the center of the coil through the small hole (magnetic north) towards the top surface of the upper base (down in this photo, as the base is inverted). Make sure that the coil, LED, and battery wires are placed into their respective slots. Secure them with tape if needed. Place a small piece of foam on top of the coil, to hold it up tight against the top of the base. The coil must not be able to move after the base is assembled.

Drill pilot holes using the four shallow 1/8" holes that have been machined into the upper base as guides. Take care not to drill through the top of the base.

Place the lower base onto the upper base, and secure with four #6 x 1" wood screws.

Attach the self-adhesive feet.

Step 31

Bearings

Install 2 3/16” ID x 3/8” OD x 1/8” thick ball bearings into the lower frame, the mid frame lever mount, and the pendulum pivot.

Step 32

Ratchet wheel assembly

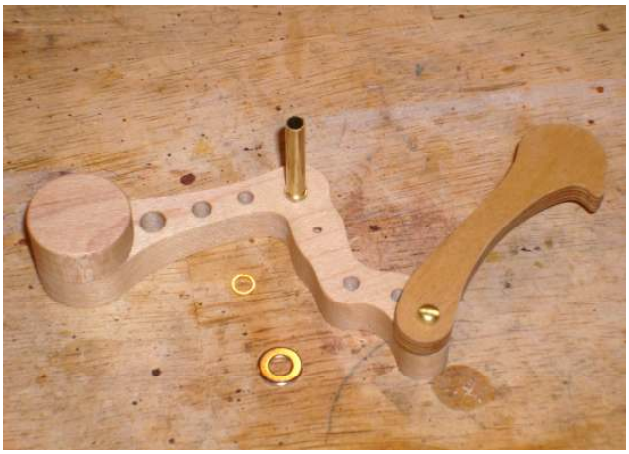
Slip an M5 washer, or a short piece of 7/16” tubing, onto the ratchet wheel shaft. (Washers are provided in the hardware kit.) Slip the shaft through the bearings on the lower part of the frame.

I’ve had mixed luck with the bearings and shafts. Sometimes the shafts slip right into the bearings, and other times the shafts need a little work with some emery cloth or fine sandpaper to get them to fit.

Slip another mM5 washer or tubing spacer on the back, and then press the 12-tooth pinion on the back. Glue the pinion if necessary.

Spin the ratchet and make certain that it turns freely.

Step 33



Lever

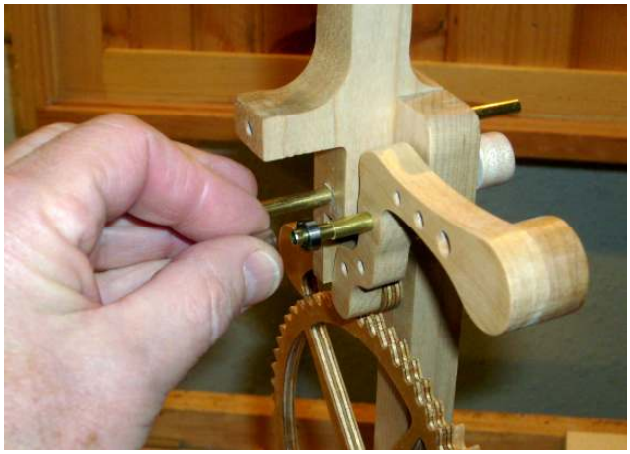
Fasten the driving pawl to the lever using a #4 5/8” screw, with a washer between the pawl and lever. Tighten the screw sufficiently so that the pawl does not wobble, but still allows the pawl to pivot freely.

Insert a 3/16” diameter by 1-5/8” brass tube into the back of the lever as shown. Secure with a drop of super glue if needed.

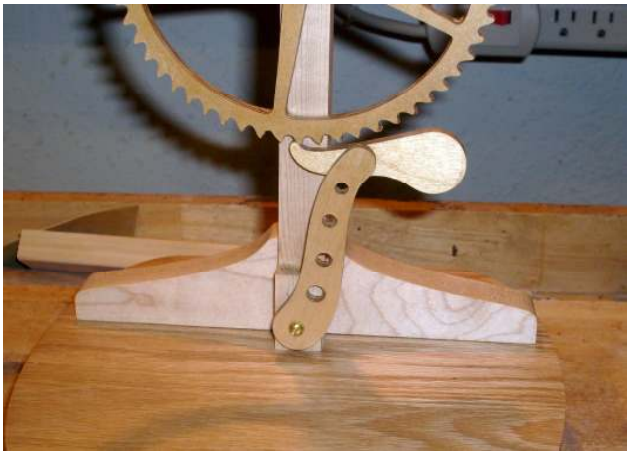
Press a 3/16” diameter by 1¼” long brass tube into the front of the lever. Secure with superglue if needed.

Use a pair of M5 washers, or a couple of very narrow spacers out of 7/32” brass tubing, to fit onto the 3/16” tubing. Slip one of the washers or spacers onto the tubing, and then slip the tubing through the two bearings on the frame. Slip another washer or spacer on the back, and then push a wooden cap onto the tubing. Secure the cap with super glue if needed. Make certain that the lever pivots freely.

Slide a 7/32” diameter by 3/8” long brass tube onto the lever tubing. Next, slide on a bearing. Finally, secure the bearing by sliding on a small piece of ¼” OD x .170” ID plastic tubing.



Step 34



Locking pawl

Using a #4 x ½” wood screw, fasten the locking pawl to the support, placing a small washer between the two parts. Tighten the screw sufficiently so that the locking pawl does not wobble, yet moves freely. Fasten the catch support to the bottom of the frame with a #6 x ¾” brass round-head woodscrew. Make certain that this screw is solid brass and not brass-plated steel – test it using the magnet. Tighten the screw just enough to hold the support for now.

Step 35

Pendulum

CAUTION - Proper pendulum operation is affected by the weight of its parts. While

attempting to accommodate variations in wood density and weight in the design, it's possible that a pendulum built to these dimensions with very light or very heavy wood may not be properly adjustable, and the size or weight of the bob or coupler may need to be changed. Be sure to test the clock for accuracy before permanently fastening the pendulum parts that capture the bob.

Glue the two halves of the coupler together, making sure that the parts are aligned. A drill bit temporarily slipped through the center hole may assist with this.

Carefully expand the pilot hole in one end of the coupler using a 9/64" drill to a depth half way into the coupler. Also drill the magnet holder to 9/64". Drill the other end of the coupler with a 3/16" drill bit, ½" deep.

The photo illustrates one method for sanding round parts like this one. I temporarily inserted a section of brass tubing into the coupler and chucked it into the drill press.

Cut threads into the magnet holder and the one end of the coupler using a 10-32 tap. (If you don't have one, you can drill the holes to 3/16" instead, and secure the threaded rod with epoxy. But be mindful that all the parts must be assembled, and the overall length of the pendulum must be adjusted, before you permanently glue.)

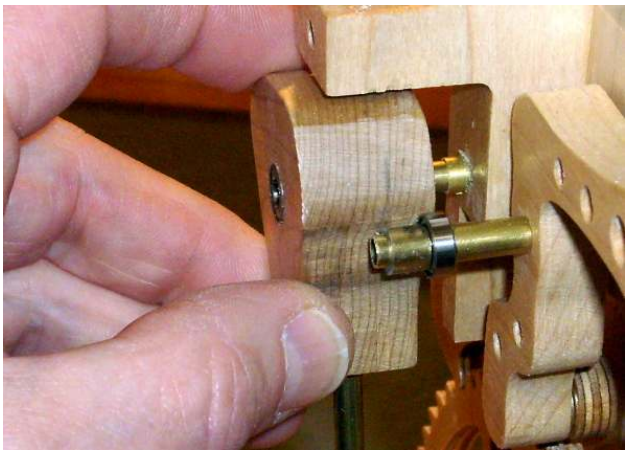
Glue and clamp the two halves of the bob together, making sure that the half hole slots in the back of each half are aligned. After the glue has dried, clean up the hole by running a 3/16" drill bit through the hole, top to bottom.

Insert the magnet into the magnet holder with magnetic north down. Magnets in the hardware kit have north marked. On the clocks that I have built, the magnet made a nice, tight press fit into the magnet holder and required no glue.

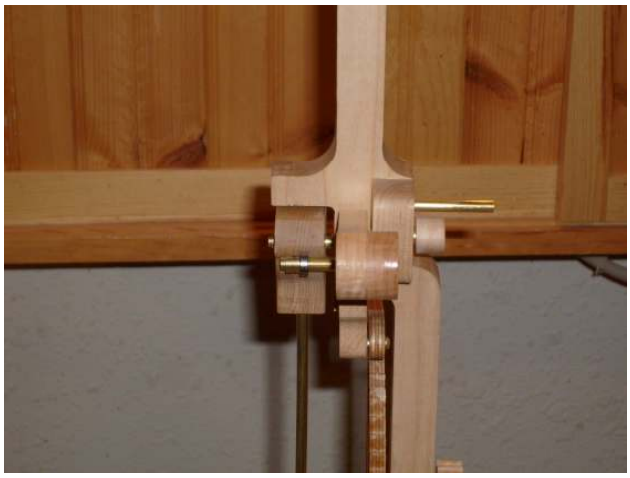
Screw a 10-32 x 5½" threaded brass rod into the coupler to at least ½". Thread a brass knurled nut onto the rod, followed by the weight, another knurled nut, and the magnet holder.

(Make sure that all of these parts are solid brass, and not brass-plated steel. The magnet will tell you!)

Press a 3/16" diameter by 4½" long brass tube into the pivot, and then press the other end into the coupler.



Slip either an M5 washer or a very short section of 7/32" brass tubing onto the pendulum shaft. Next, slip the pendulum pivot bearings onto the shaft. Follow up with another washer or spacer.



Ensure that the pendulum pivot remains clear of the frame behind and the numbers ring (to be installed later) in front.

Also, check the range of pendulum travel. It should be free to move the magnet holder a few inches past the edge of the base. If the top of the pivot contacts the frame protrusion at extreme travel, it will probably not be possible to get the clock running properly. If this happens, do not alter the pivot. Instead, bevel/trim the bottom corners of the frame protrusion slightly until the pivot has adequate clearance.

Adjust the length of the pendulum by screwing the magnet holder up or down so that the magnet holder just clears the base when the pendulum swings – about 1/16”. The magnet should be close to the base while ensuring no contact even when the pendulum expands in length slightly due to temperature changes.

If you did not tap the magnet holder and disc, use tape or other means to temporarily fasten the magnet holder to the threaded rod. *Eventually*, fasten the threaded rod to each part using epoxy glue. Fasten the rod to the coupler first, then to the magnet holder. Make a shim to elevate the magnet holder above the base and hold it in place while the epoxy sets. Be sure to have the length correct! Also, the magnet will be very hard to remove once it is installed, so make sure it is installed correctly. (If you thread the magnet holder, you can screw it up the rod to force the magnet out.)

The advanced pendulum circuit in the hardware kit has a feature to help with magnet and coil polarities. Upon inserting batteries, the LED will flash red and then green, and then the coil will be briefly turned on. If coil and magnet polarity are correct, the magnet will be repelled.

Because of the lever, the pendulum naturally rests off center to the right a bit when viewed straight on. If polarities are correct, the pendulum will be repelled to the right. If incorrect, the pendulum will be attracted to the left (center). Flip either the magnet or coil to make a correction if necessary.

Check the swing of the pendulum, making sure that the magnet holder and bob have sufficient

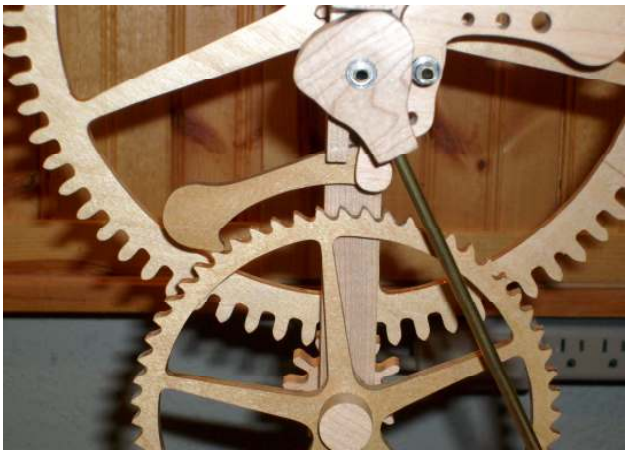
clearance at the base and frame. If not, gently bend the pendulum's brass tubing to ensure good clearance. But don't allow it to be too far from the frame either. The magnet must pass directly over the coil for good operation. This is critical – even a fraction of an inch off center of the coil can result in unacceptable side force on the pendulum and failed operation

Secure the magnet holder onto the brass threaded rod with a drop of super glue *only* after you have verified magnet polarity, pendulum clearance, and timekeeping accuracy.

Step 36

Locking pawl adjustment

Manually swing and hold the pendulum to the left. The driving pawl should rotate the ratchet wheel clockwise. Look at the locking pawl and ratchet wheel interface. The locking pawl should clear a tooth on the ratchet wheel and land about halfway onto the next tooth with the pendulum swung well to the left. Adjust the locking pawl support position until this is the case.

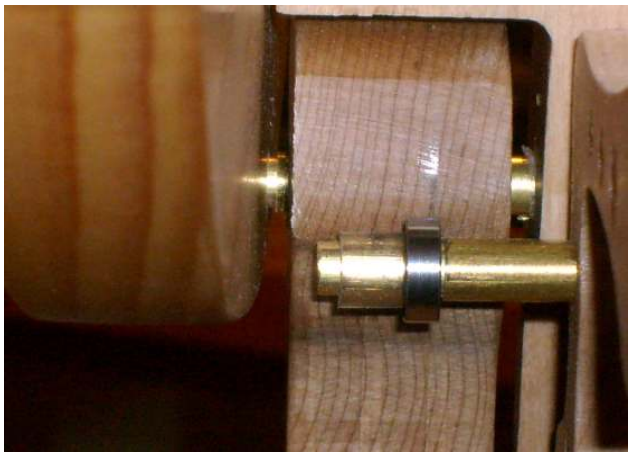


Next, swing the pendulum and hold to the right. The ratchet wheel should freeze movement, and the driving pawl should skip onto the next tooth. The driving pawl should land about halfway onto the tooth as shown.

Move the pendulum back and forth several times, and check both the driving and locking pawl for proper action. When satisfied, tighten the screw securing the locking pawl support to the frame.

Ring assembly

Mark the back of the numbers ring opposite the number 6 and ¼" from the lower edge of the ring. Drill a 3/16" hole about ¼" deep.



Align this hole with the pendulum shaft, slipping the ring over the shaft. Hold or clamp the ring into position. From the back of the frame, drill two pilot holes into the ring.

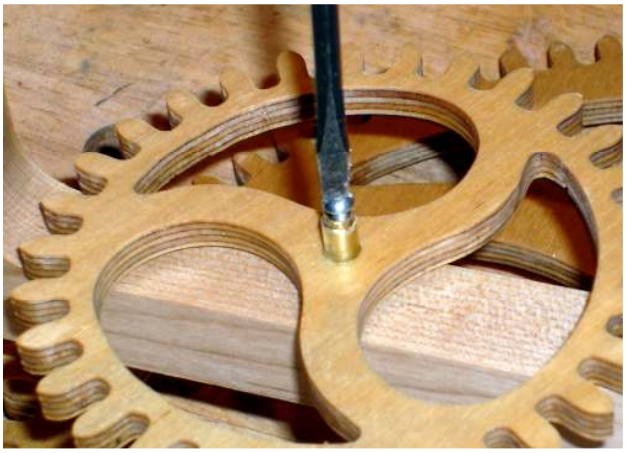
Fasten the ring with two #6 x 2” wood screws.

Step 37

5-arm star gear assembly

Slide the 5-arm star gear assembly onto the shaft at the back of the frame. Secure the assembly with a ¾” diameter round cap pressed onto the shaft. Secure with super glue if needed.

Step 38

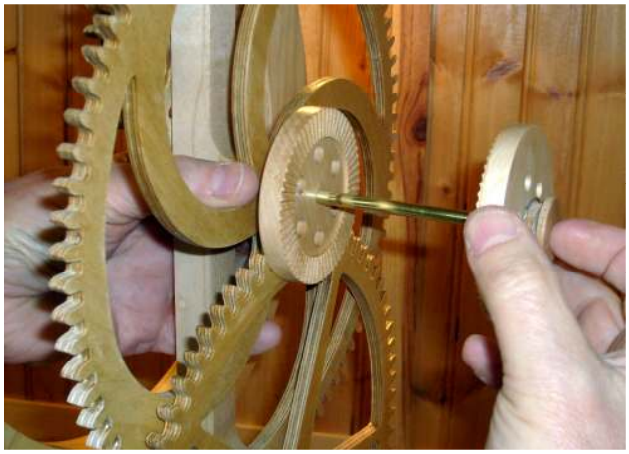


3-arm spiral gear train assembly

Slip the 3-arrm spiral gear onto the shaft at the top of the frame. Secure it with a #2 x 1” machine screw.

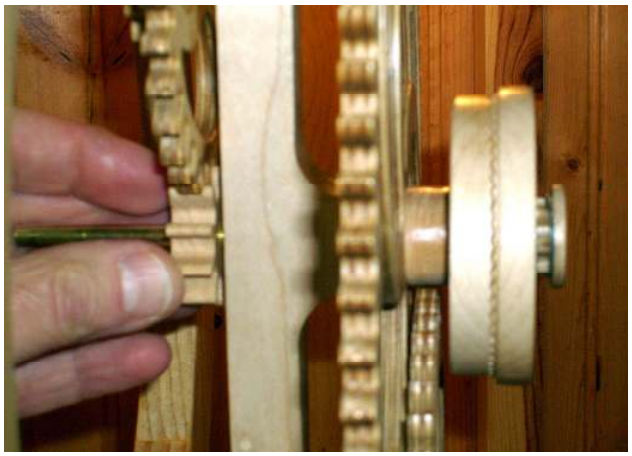
Press the 8-tooth pinion onto the shaft. Secure with super glue if needed, taking care not to get glue on the frame shaft.

Step 39

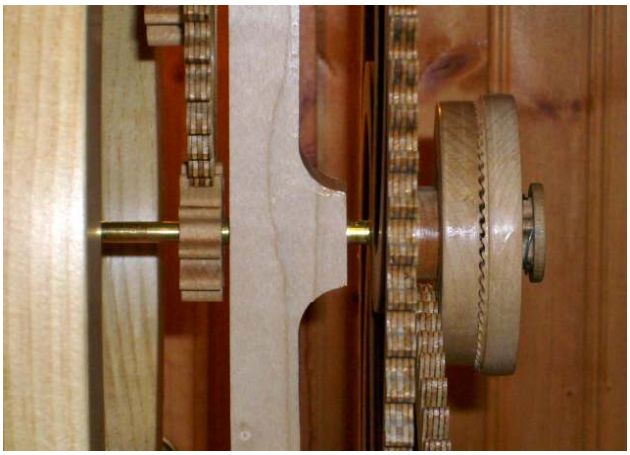


Main shaft assembly

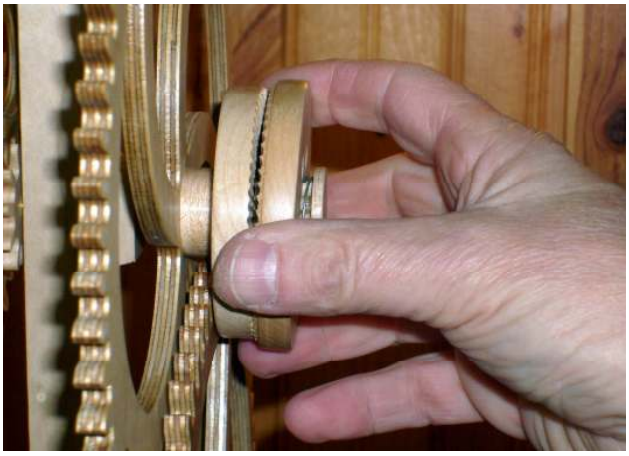
Place a large-diameter spring onto the clutch hub. Slip the driven clutch wheel onto the hub, compressing the spring. Position the 5-arm spiral gear assembly up to the frame, straddling the 5-arm star gear as shown. Slip the hub shaft into the spiral gear assembly and through the frame.



Slip an M6 washer or a very short spacer onto the front of the shaft, and then press the 10-tooth pinion onto the shaft.



Press the pinion on sufficiently to leave only 3/8” between the driven clutch wheel and the hub at the rear of the clock.



There should be sufficient clearance to pull the driven clutch wheel back to disengage the clutch and allow the hands to be moved.

Check for proper alignment and clearance of the gears on the back of the clock. The large gears especially may have some wobble and touch if holes were not drilled carefully. The large gears must not touch each other, the frame, or the clutch. If they touch, odds are the clock may run for a while but will not keep running.

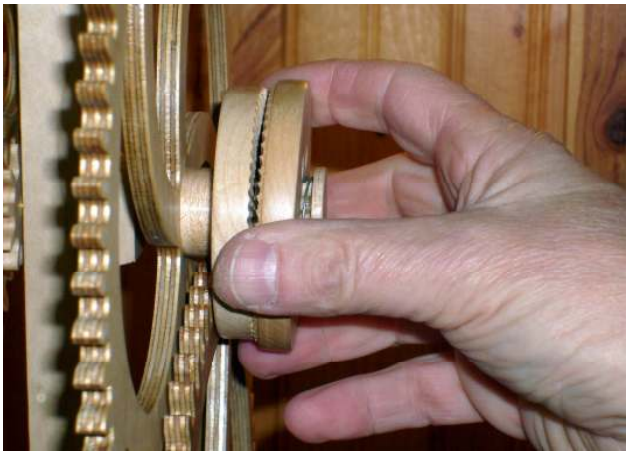
Step 40

Hour and minute hands

Slip the hour hand gear assembly onto the shaft. Align the assembly so that the hour hand points straight up to 12 o'clock, using the clutch as needed.

Press the minute hand on in the 12 o'clock position.

Step 41



Setup and adjustment

Insert 4 D cells into the battery holder. The indicator LED on the advanced circuit flashes red, then green for a second to indicate proper operation. Also, as mentioned, the pendulum should move a bit as the coil is energized once. There is no on-off switch to the clock. As long as the pendulum is not swinging, the circuit (basic or advance) draws only minimal current. The swinging pendulum triggers the circuit.

Adjust the bob to the center of its travel, and lock it in place with the knurled nuts. Give the pendulum a gentle swing. Set the time by grabbing the clutch from the rear, pulling towards the back of the clock, and turning in either direction.

<u>Advanced circuit</u>

If your clock is using the advanced microcontroller circuit board, check the LED after a minute or so. If it is consistently blinking red, the pendulum is swinging too slowly. Raise the bob to speed up the pendulum by loosening the top knurled nut and then tightening the bottom one, and then try again. Conversely, if the LED is consistently blinking green, the pendulum is too fast. Lower the bob a bit. Keep the pendulum stopped for at least 3 seconds

between adjustments to allow the electronics to reset itself.

When the LED no longer consistently lights, the pendulum is initially set using short-term measurement. (It's OK if the LED occasionally flashes red or green, as long as it is off most of the time.) The LED is disabled after 5 minutes. However, the pendulum speed is then measured with a more dependable long-term measurement. The LED may start blinking again after a period of time. If so, adjust the pendulum slightly, using as little as ¼ turn of the knurled nuts. Keep the pendulum stopped for at least three seconds after adjusting, and restart it. It's probably best to ignore the short-term measurement blinking of the first 5 minutes after this adjustment. But watch for additional long-term warnings and then adjust again if needed.

Once the LED stays off for an extended period, the electronics will generally compensate, and no further adjustment will be needed.

Simple circuit

If you are using the simpler circuit, observe the timekeeping over a period of a day or days. Adjust the bob upwards to speed up the clock if it is running slowly and downwards if it is running fast. You may also need to adjust the height of the magnet above the base, and possibly the pulse width of the driver circuit (by changing the indicated resistor).

When testing the clock before all pendulum parts are glued, make sure that your temporary fastening is secure. Any looseness or wobble in parts fit will affect the pendulum, and may make adjustment for accurate timekeeping impossible.

Due to variations in wood density and weight, you may be unable get the clock to run slow or fast enough with the bob at the extent of its travel. If the bob is all the way down and the clock runs too fast, try a bigger or flatter bob. If the bob is all the way up and the clock runs too slowly, try a bigger coupler (expand the diameter). It may be helpful to temporarily attach a weight to the coupler or bob to determine what is required. (Avoid magnetic weight near the pendulum magnet.) Once you're confident that the clock is keeping time, and there is still a bit of bob travel in reserve for future adjustment, then you may glue the magnet holder to the pendulum (it can become loose eventfully if not glued).

Troubleshooting

If you can't get your clock to run or keep running, check the following possible causes:

- Improper magnet or coil polarity
- Weak batteries
- Pendulum magnet not centered directly over coil
- Pendulum contacting frame or base
- Pendulum pivot contacting frame at large angles
- Gears not meshing properly
- Rough or misshaped gear teeth
- Faces of large gears rubbing on another gear, the frame, or the clutch
- Bearings or shafts binding

(How do I know what to troubleshoot? I've built several of these clocks, and I've had each of these problems at one time or another!)

You may find it helpful to temporarily disassemble parts of the clock to isolate problems. For example, remove the driving pawl to see if the pendulum will operate on its own. If it does, the gear train is probably binding somewhere.

If your clock runs but then stops, carefully examine the clock at the stopping point. It may be helpful to release the pawls and move the ratchet wheel or gears back and forth to locate the source of binding, rubbing, etc.

If you find the clock ticking to be too loud, you can quiet it a bit by carefully applying 1/6” thick cork pads to each of the two pawls. This can introduce some extra friction, so it’s best to get the clock running without these first.

RESOURCES...

There are numerous resources for the CarveWright/CompuCarve owner to make their experience with these machines much more enjoyable.

Every owner should join the CarveWright User Forum (http://forum.carvewright.com/index.php) where fellow users share their experiences and knowledge with these machines on a daily basis. It is a FREE service that you will surely appreciate. A handy Search Feature helps you find answers to any questions you may have.

You can also visit the forums for up-to-date status on this project.

Appendix

Electromagnetic Pendulum Drive Circuit

The Mystery Clock uses an electromagnetic drive circuit and a coil to detect the swinging pendulum with an embedded rare earth magnet, and then applies a pulse of current to the coil to repel the pendulum and keep it moving.

If you want t build your own pendulum drive circuit, refer to the schematic in this section. This circuit uses non-varying pulse duration into the coil. Clock accuracy is determined solely by the pendulum.

A more advanced, microcontroller-based circuit is available in the hardware kit, but building one is beyond the capability of many electronics hobbyists.

Operation

When a magnet of the correct polarity passes over the coil, it induces a negative, then a positive current in the coil. D1 shunts the negative current, and C1 filters unwanted oscillations. Op amp U1a is configured as a comparator. When the voltage at the coil rises sufficiently, the op amp output goes high.

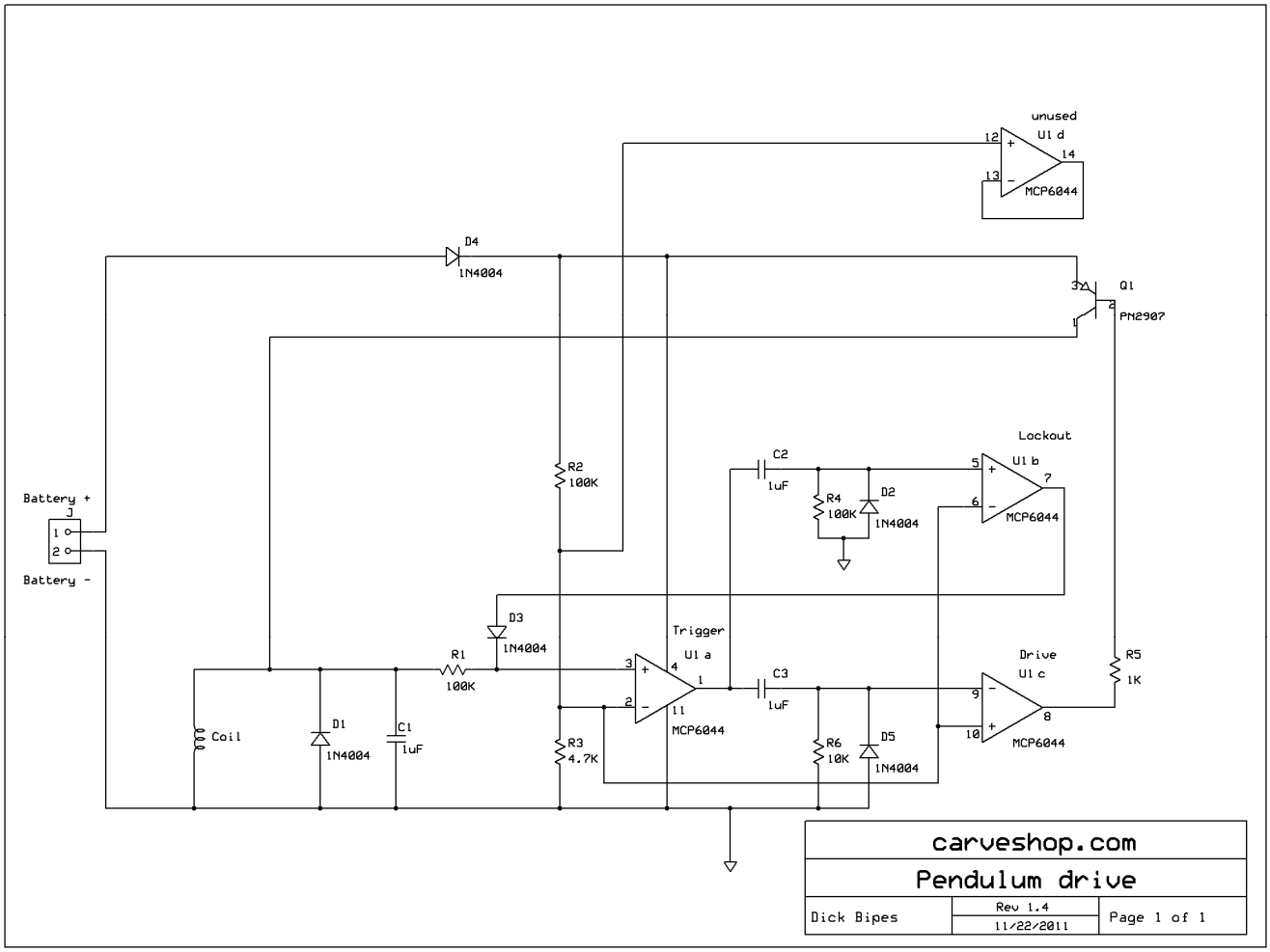
This voltage pulse is passed onto op amp U1c, also a comparator, and its output goes low. This turns on transistor Q1, which sends current into the coil.

The voltage on C3 is gradually bled off by R6. When it returns close to zero, the op amp switches and its output goes high, shutting off Q1 and the current into the coil. (The driven pulse width can be adjusted by changing the value of R6. I've used a value of 4.7K ohms for a pulse width of about 15 mS with this clock.) D1 also protects Q1 from voltage generated in the coil when the current is shut off. The corresponding drop in voltage across the coil turns off U1a, whose output is passed on through C3 as a negative pulse. D5 largely snubs this negative pulse.

As the driven pulse width is tuned narrower to conserve power, it's possible that the passing magnet may still be close enough to induce a voltage across the coil after the pulse into the coil has turned off. This could (and did for me) induce a second, undesired pulse into the coil. U2c is set up much like U1b but with a longer time constant. When triggered, it pulls the input to U1a high, and holds it there until the magnet is far away. This masks any voltage that might be generated by the moving magnet and prevents a second, undesired pulse into the coil.

Construction

Other op amps may be used, but should be rail-to-rail output and low power. Likewise, the specific diodes and transistors are not critical; others may be substituted. Layout is not critical.


unused
U1 d
MCP6044
D4
1N4004
Q1
PN2907
Lockout
U1 b
MCP6044
C2
1uF
R4
100K
D2
1N4004
R2
100K
Battery +
J
Battery -
D3
1N4004
R1
100K
Trigger
U1 a
MCP6044
C3
1uF
Drive
U1 c
MCP6044
R5
1K
Coil
D1
1N4004
C1
1uF
R3
4.7K
R6
10K
D5
1N4004
carveshop.com
Pendulum drive
Dick Bipes
Rev 1.4
11/22/2011
Page 1 of 1