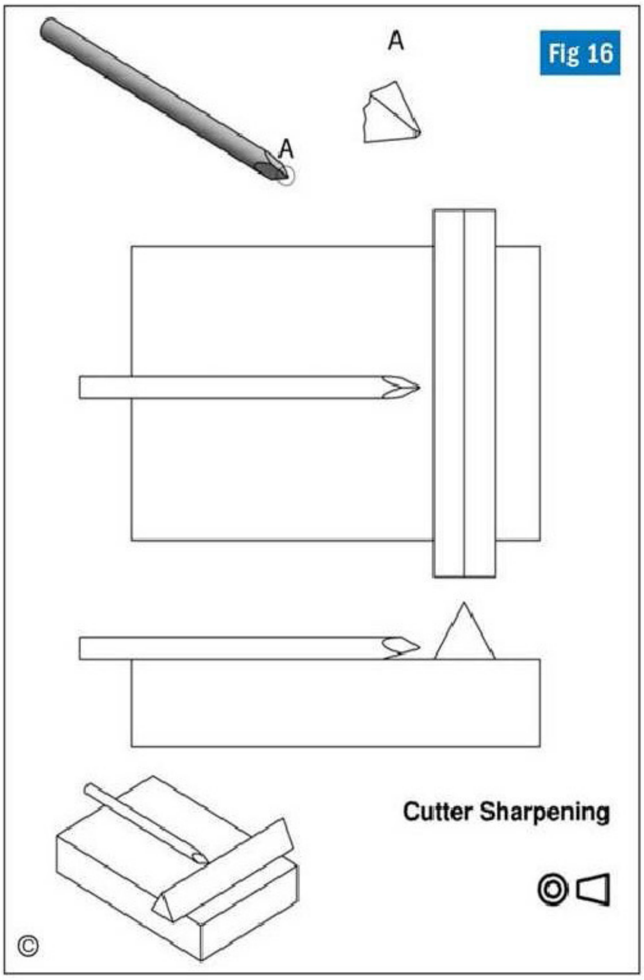
This file has been downloaded free of charge from www.model-engineer.co.uk

This file is provided for personal use only, and therefore this file or its contents must NOT be used for commercial purposes, sold, or passed to a third party.

Copyright has been asserted by the respective parties.



MAGNETIC DRIVE CLOCK

PART 5

Continued from page 571 (M.E. 4299, 11 May 2007

Richard Stephen describes his CNC method of making the clock dial, and makes the hands from titanium.

The traditional engraving cutter is a D-bit ground from HSS. These do work very well. However, if you want to have fine lines the tips become very fragile. If the tip breaks before you have finished the job it is difficult, particularly if you are using CNC, to get the subsequent engraving the same as the original.

A far better profile for an engraving cutter is a 3-sided point, that is 3 facets at 120 degrees and ground to the desired included angle (30 deg. is an excellent choice). Readers may wonder if such a profile will cut very well. I can assure you these cutters cut very cleanly in engraving brass.

Grind the three facets at the end of a length of HSS and bring the facets to a sharp point. Remove all burrs and smooth the facets with a fine aluminium oxide stone. With the cutter on a flat surface turn the cutter until one edge is central, See **fig 16.** Using a 3-cornered slip stone, with one face on the flat surface, take a few gentle strokes with the stone. This will generate a relieved cutting edge on the point.

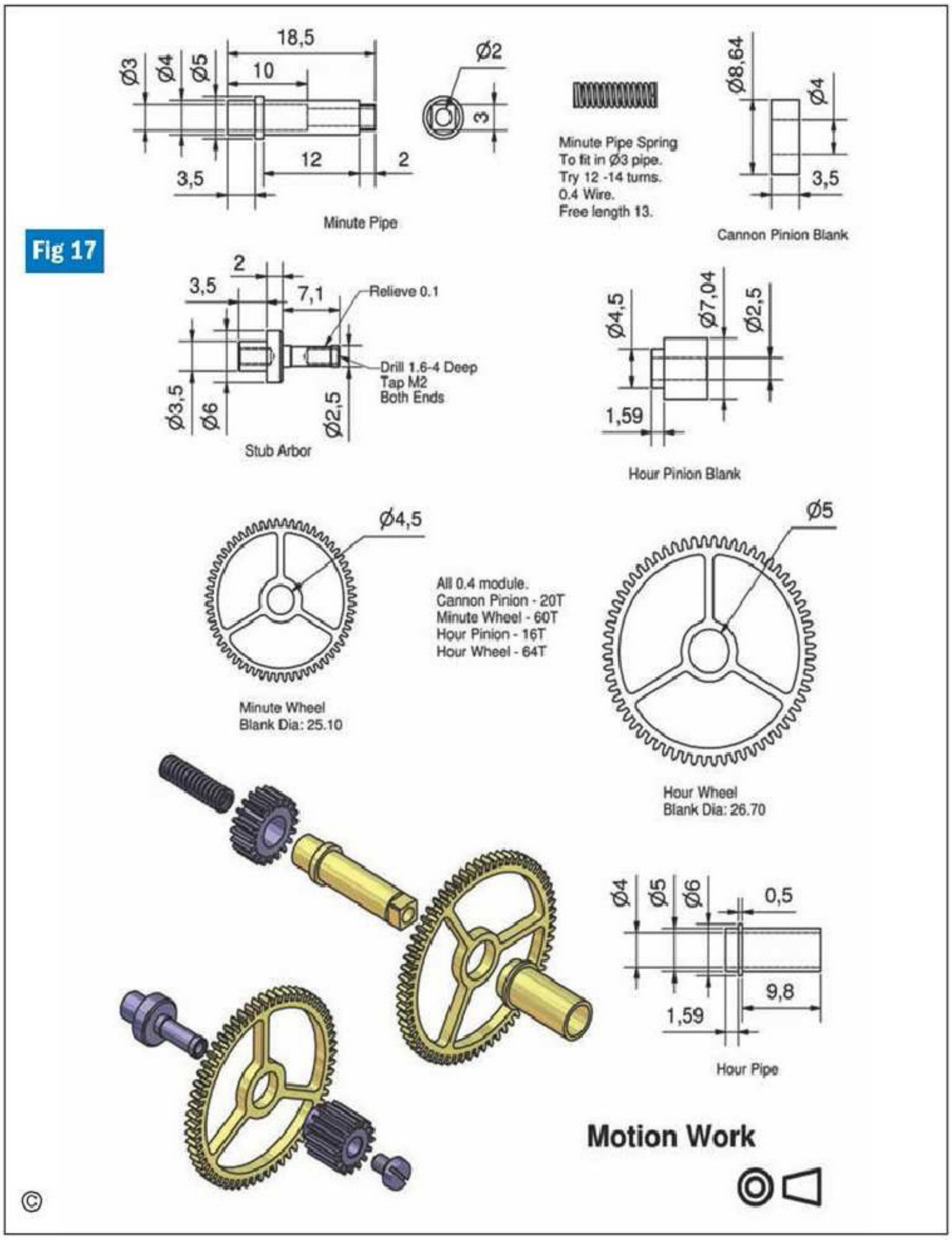
Engraving tool path

I have engraved quite a number of dials over the last few years. Each time I do one I change the procedure I use in order to improve the final result. For those readers who wish to use the file I used, a CD with the engraving file is available at a small cost. This CD will also contain all the .dxf and G-codes files required to engrave the dial. There are in all 12 separate files, one for each of the numerals.

For readers who want to generate their own set of engraving files the procedure is as follows. The dial has been drawn with the centre at the origin of the co-ordinates. Copy and shift the centre to the co-ordinate x = -50, y = 0 this will place the origin just to the left of numeral 3. Save this new drawing as Dial1.dxf.

The drawing now needs to be modified and two new versions of the dial produced. Using the erase option (object trim in Turbocad) remove all the lines that form the bars of the numerals and the 5-minute divisions. This will leave all the single lines and the minute divisions. Save this drawing as Dial2.dxf.

Open Dial1 again and again modify it by removing all the single lines (the ones saved in >>



Dial2) and leaving just the bars and the 5-minute divisions. When doing this it is worth filleting all the corners with a 0.01 mm radius fillet. This will ensure that all the bars will form a closed entity. This is necessary as the pocketing routine (certainly the one used in DeskCNC) will only work with closed drawings. Save this drawing as Dial3.dxf.

Now comes the slightly tedious part. Open Dial2. Using the Select tool select and erase everything except the lines that are part of numeral 3 and the two minute divisions on either side. Save this as 3L.dxf (L for line). Using the step back command return to the drawing as opened. Select the whole drawing and rotate it 30deg. anti-clockwise. This will place the numeral 4 in the 3 o'clock position. Repeat the above and save as 4L.dxf. Repeat until you have saved all 12 L files. Close Dial2 and open Dial 3. Repeat the above procedure starting with numeral 3. The result will be the 3 bars and the 5-minute division. Save this as 3P.dxf (P for pocket). Repeat until you have saved all 12 P files.

The tool paths for the 12 numerals can now be generated from the L and P files. Generate the tool path for the lines for each numeral first and append the pocketing tool path. I used an engraving depth of 0.15mm for both the lines and the pocketing. Use no offset for the lines and a 0.1mm offset for the pocketing. The technique described above can be used to engrave dials of any size provided you can get the dial disc under the spindle.

Motion work and hands

The details of the components for the motion work are given in **fig 17**. Make the wheels and pinions using the same techniques as used for the train components earlier. The square on the end of the minute pipe for the minute hand is made 2mm long to accommodate a collet with a square hole to which the minute hand is fixed. This collet helps hold the hand more securely than a simple square hole in the hand. The motion work tension spring is also unusual in that it is a 2mm I/D compression spring fitted inside the minute hand pipe. The spring presses against the shoulder on the centre arbor that extends through the front plate. I was introduced to this way of tensioning the minute hand by Peter Bradley several years ago and have found it superior to the more usual leaf spring.

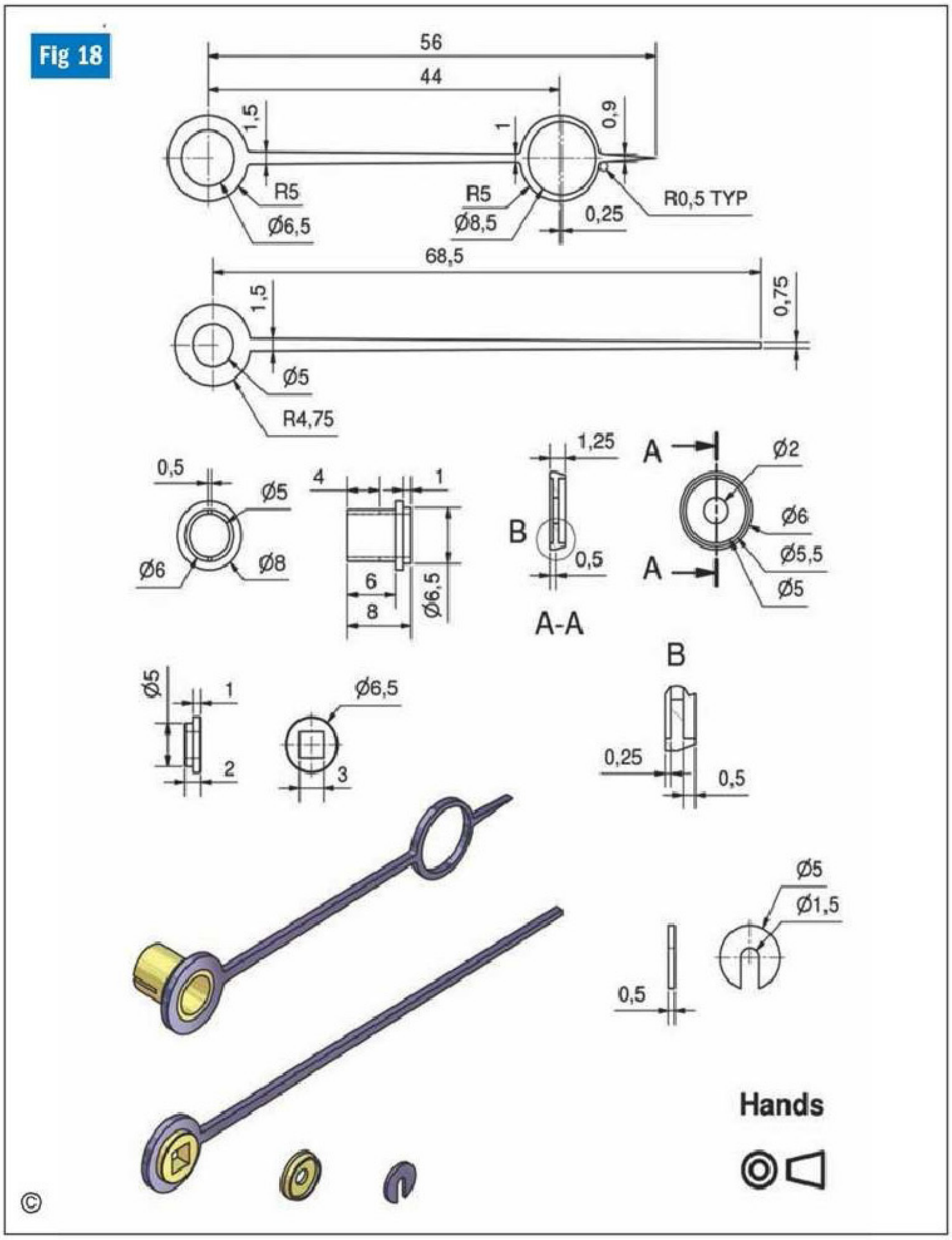
The stub arbor on which the minute wheel and pinion runs, is made of silver steel, hardened and tempered. The length of the arbor has been specified in fig 17 but measure the length of the completed minute wheel pinion and make the arbor 0.2mm longer than this. Drill and tap the holes for the 2mm screws before hardening the arbor.

When you have made all the components of the motion work depth the entire motion work on the depthing tool. To do this an extra long 2mm runner for the depthing tool will have to be made. Having depthed the motion work measure the spacing between the two arbors and make a note of the value. This is the distance between the centre arbor and the stub arbor. The hole for the minute wheel stub arbor can be drilled in the front plate. Centre the mill on the hole for the centre arbor and line up the centre line of the plate with the x-axis of the milling machine. Move the table by the measured distance and drill a 2mm hole through the front plate. Now expand the hole to 4mm from the front of the plate to a depth of 3.5 millimetres. The minute wheel and pinion are retained on the arbor by a 2mm screw. The arbor is secured to the plate with a 2mm screw.

Titanium hands

The hands are illustrated in **fig 18**. The design of hands is a real problem. After trying all sorts of design I finally settled on the simple but stylish Brueget form. I made my hands out of titanium. The advantages of titanium are

Fig 18



(*M.E.* 4297, 13 April 2007) and use a slotted washer shown in fig 18. Readers will find this a lot easier and it saves looking for the pin when you have dropped it.

The length dimensions of the centre arbor extension, minute pipe, reverse minute wheel stub arbor and hour pipe have been given. Readers are advised to use these lengths as a guide as they are best determined as the motion work is fitted to the movement.

its density (4.5) compared to steel (7.9). Titanium is as stiff as steel. It is also much easier to blue uniformly. Titanium is no more difficult to work than carbon steel from, say, an old cross cut wood saw blade (very tough steel!).

As with steel hands the quality of the blueing one gets depends on the quality of the surface finish. This is particularly the case with titanium. I use wet and dry paper finishing with the very finest I can get (3000).

To carry out the blueing you will need a DC power supply giving 30V at 1A (the current required is much less than this) and about 1 litre of very dilute sulphuric acid (a small amount of battery acid added to a litre of distilled water). The strength of acid used is so dilute that there is very little danger of harm if you get a drop on your skin. Nevertheless sulphuric acid can be dangerous so be careful and protect your eyes and wear disposable vinyl gloves.

Use a glass or plastic jar deep enough to fully immerse the minute hand and a strip of lead for a cathode. The anode is the hand to be blued. All that is required is to turn on the power and fully immerse the hand for about five seconds and withdraw a blued hand. Wash several times in clean water to remove all traces of acid and rub over with a soft cloth. The resulting blue colour is slightly different from the steel blue, most people actually like it better.

A brass collet (fig 18) with a square central hole is fitted in the 5mm hole with Loctite. This makes the fit of the hand on the minute pipe a lot more secure. As in my previous clocks the hands are secured to the centre arbor using a 3mm diameter compression spring fitted into the lower end of the minute pipe. The front of the centre arbor extension is generally cross-drilled with a 1mm hole for a pin to retain the hands. A far superior method is to cut a groove as shown in fig 11b

Clock base

The clock needs to be mounted on a base, partly for appearances and to provide a housing for the circuit board and the drive coil. I made mine out of some pieces of English walnut that I had in my collection of hardwoods. Readers could use any nice close-grained hardwood. I get all my wood from small county timber mills. These mills often have some nice pieces of various local hardwoods tucked away. For the base you will need the following finished sizes:

For the sides:
Two pieces 50mm x 20mm x 300mm
Two pieces 50mm x 20mm x 200mm

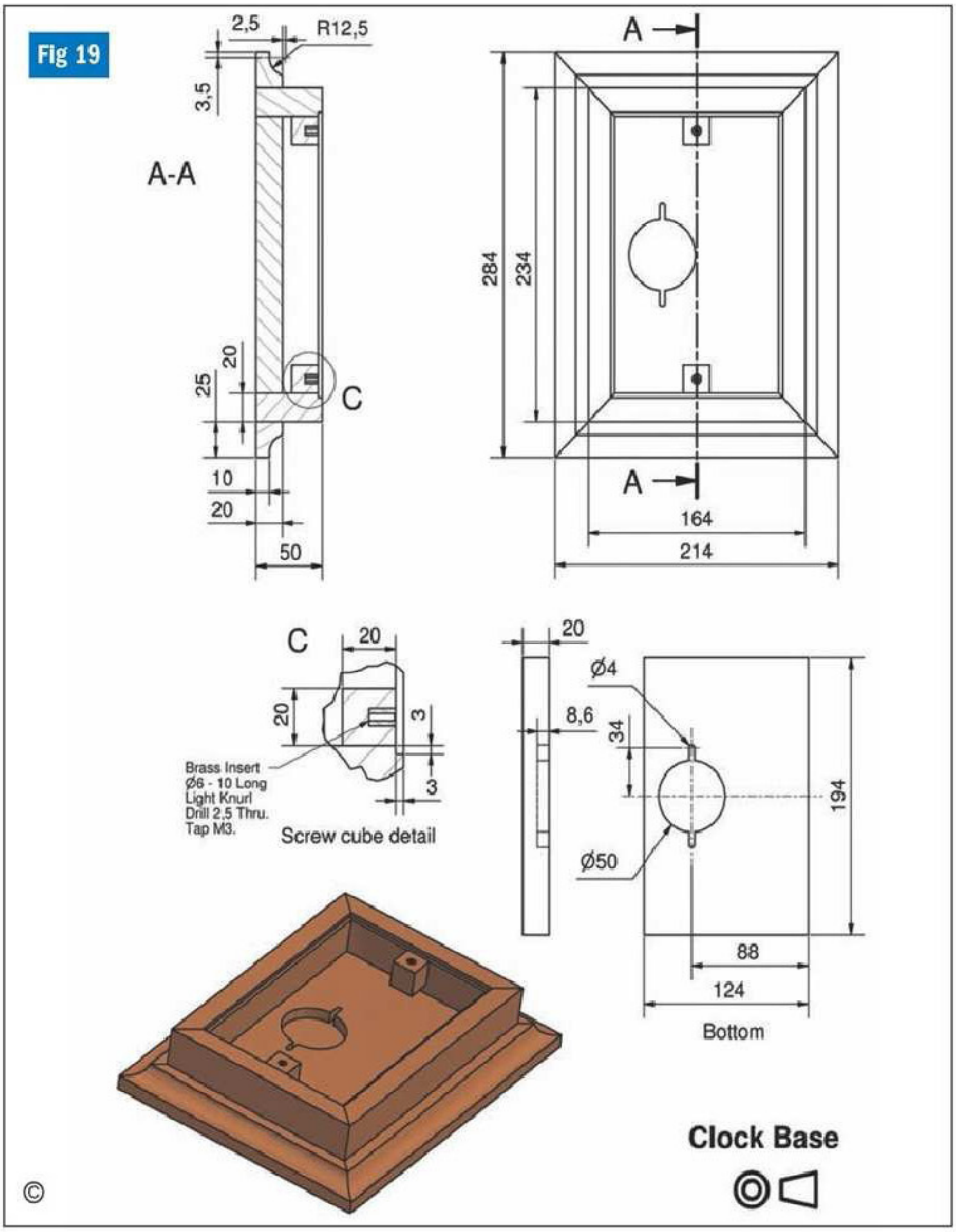
For the base bottom:
One piece 250mm x 150mm x 20mm
For the mouldings
Two pieces 25mm x 20mm x 300mm
Two pieces 25mm x 20mm x 220mm

The base is assembled entirely with wood adhesive. I strongly recommend using aliphatic PVA wood adhesive and not the PVA available from DIY shops. Aliphatic PVA sets hard and can be sandpapered. The aliphatic PVA is available from most good model shops.

The construction details of the base bottom are illustrated in **fig 19**. Start by cutting the bottom to size. The edges of the bottom must be precisely square to the surface as well as the four corners. If you don't get these precisely square you will have a lot of problems >>

when it comes to gluing on the four mitred sides. The two end grain edges should be sized with adhesive diluted with an equal amount of water. This will ensure that the glue joint at these edges is strong. Apply the dilute adhesive with a brush and allow it to dry. Rub the edges smooth with fine aluminium oxide paper. A recess for the drive coil must now be cut in the bottom. This recess must position the centre of the coil directly under the magnet on the end of the pendulum. The brass base of the movement has been recessed to a depth of 2.5 millimetres. The sides are recessed to a depth of 3mm so that when the movement is fitted into the base the distance from the recess in the movement base to the base bottom is 29.5 millimetres. To fit the coil so that it is just below the top of the recess it is necessary to cut a recess in the base bottom that is 8.6mm deep with the diameter of the coil. When the recess has been cut mill two slots as shown in fig 19 for the coil leads.

The most difficult part of making the base is accurate cutting of the mitres. I cut my mitres on my milling machine using a sharp 10mm diameter extra long series end mill. If you are unsure about cutting the mitres you could have them cut by your local picture framer. They have a guillotine designed for the job.



The mitres must be precise so that there are no gaps at any of the joints. Give the framer the base and ask him to fit the sides for you but not to glue it together. Before gluing the sides in place cut a recess 3mm wide and 3mm deep in the inside edge of each side for the brass base of the movement. Size the end grain of all of the mitres using diluted PVA adhesive. When the glue is dry rub down the mitres with fine aluminium oxide paper taking care not to round off any of the edges.

The sides can now be glued in place. Before gluing the sides do a dry trial run to check that the fit is perfect and mark the edge of the base where each side is to be glued. Glue in the sides one at a time allowing each to dry before gluing in the next one. When all the sides are in place, rub down the sides with fine aluminium oxide paper to remove all traces of glue.

The mouldings can now be glued to the sides following the same procedure used to glue on the four sides. The final task is to glue two pieces of wood on the inside of the short sides to hold the inserted brass nuts that attach the movement to the base.

These nuts are made from 10mm long pieces of 6mm brass rod. Grip a length of 6mm rod in the lathe and lightly knurl the surface for about 25 millimetres. Drill 2.5mm through and tap the rod M3. Cut off two 10mm lengths. Fit the movement onto the base and using the holes for the two screws as a guide drill 3mm holes into the base. Expand these holes to 6mm to a depth of 10mm for the brass nuts. Apply super glue to the outside of the nuts before pressing in.

The base can now be sanded smooth prior to polishing with French polish. Before applying the French polish the surface grain must be filled. The best clear sanding sealer is a spray can of clear lacquer. Give the base several coats allowing each to dry before applying the next coat. When you have built up a good layer, rub the surface down with fine aluminium oxide paper.

The base is now ready for French polishing. Apply the shellac with a lint free cloth. Apply one coat and allow it to dry. Apply a second coat and immediately put a few drops of linseed oil on the cloth and rub the surface. The oil will prevent the cloth from sticking to the shellac as well as helping to produce a fine shine. What I have described is the most basic of French polishing. As with many things, I am afraid it is a case of practice makes perfect!

NOTE: The editor will be happy to forward requests for engraving and .dxf files to the author.

To be concluded.

MAGNETIC DRIVE CLOCK

PART 6

Continued from page 692 (M.E. 4301, 8 June 2007)

Richard Stephen concludes the description of making his innovative clock.

The electronic drive basically consists of two parts, the two coils and the control circuit. The clock could be powered by batteries or by a 12 Volt regulated power supply. The drive system draws approximately 5mA continuous power. The highest capacity 12V battery (2 x 6V) has a capacity of 1900 mA hours, which doesn't give a very long running time. A regulated power supply is thus the best solution to power the clock.

The drive coils

The drive coil formers are illustrated in **Fig 20**. The formers are best made out of Tufnol rod. Tufnol rod is frequently available on E-Bay at very reasonable prices. It is also available from RS Components at higher prices.

Begin by making the drive coil first. Cut off a 40mm length of 50mm Tufnol rod and face off both ends and reduce the length to 38 millimetres. Next mill an 8mm wide slot 4mm deep in one end passing through the centre. Drill the two 1.6mm holes 6mm deep for the soldering studs and the 1mm hole for the inner end of the coil winding also 6mm deep. Drill and bore a 22mm diameter hole through the length of the rod for the sensing coil. Finally turn the recess for the coil wire.

The sensing coil is made following the same procedure as the drive coil. The sensing coil wants to be a snug fit in the drive coil. Tap the 4 holes for the soldering studs. The screws must not extend into the former as they could damage the fine wire used for the coils. Cut a fine groove, as shown, for the outer end of the wire.

The enamelled copper wire can now be wound onto the coil formers. Poke the end of the wire through the 1mm hole and pull through about 20cm of wire. Grip the former by the base (the thick end) and turn the spindle by hand to trap the wire to prevent the end from pulling out when you wind under power. With the lathe in back gear, wind the wire in even turns onto the coil former. 40 swg copper wire is reasonably strong but will break if you are not careful. Fill the former to within 1mm of the rim. Repeat the procedure and fill the second former with wire. The drive coil will accommodate approximately 5,000 turns and when fully wound have a resistance of approximately 750 ohms.

The free end of the wire is laid in the groove cut in the side of the former and secured with super glue prior to soldering the end to the solder post. There is no need to scrape the enamel insulation off the wire prior to soldering as the wire will 'tin' through the insulation. Attach lengths of PVC covered wire to the post to connect the coils to the circuit board.

Drive circuit

The circuit diagram of the drive circuit is available via the editor. Readers wishing to construct the clock can either assemble their own circuit on strip board. A PCB of the circuit is also available from Model Engineers Electronic Workshop.

The circuit functions as follows. As the pendulum drive magnet swings across the inner sensing coil it induces a small voltage in the windings of the coil. This voltage is amplified by the 071 op-amp in the circuit by a factor of 1000. The 071 op-amp has been configured to operate from a single sided supply of +12 Volts rather than dual voltage supply of ± 12 Volts. The 2kW variable resistor enables the op-amp to be biased to operate over the 12 Volt range. The 555 timers used in the circuit trigger on a falling input voltage when this voltage falls to 1/3 of the supply voltage which in this case is 4 Volts. The 2kW variable resistor is adjusted to give a bias voltage at the output of the op-amp of about 4.5 Volts.

The voltage generated by the drive magnet as it swings over the sensing coil is a bi-phasic wave i.e. the output voltage of the 071 op-amp swings above and below 4.5 Volts. The first of the 555 timers triggers when the voltage drops below 4 Volts. This 555 timer is set by the variable resistor R4 (a 400kW fixed resistor plus a 200kW trimmer) to generates a delay equal to half the period of the pendulum or for a 1/2 second pendulum 500 ms. At the end of this delay period the second 555 timer is triggered by the falling edge of the pulse. The second 555 timer then generates a pulse whose duration is set by the variable

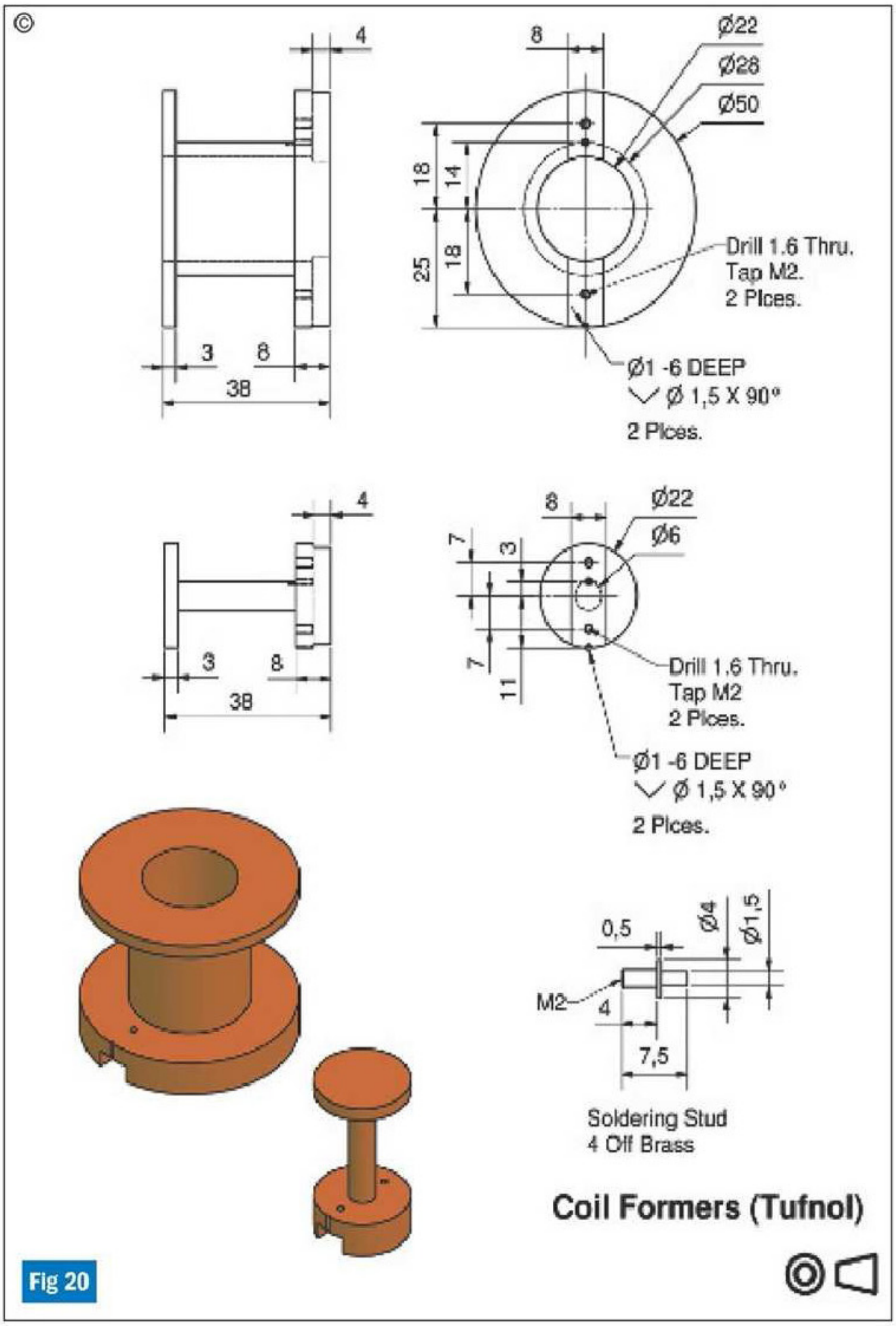


Fig 20. Drive coil formers - best made from Tufnol rod.

resistor R5. This pulse is applied to the windings of the drive coil and generates a magnetic field which impulses the pendulum. The duration, in milliseconds, of the pulses generated by both 555 timers is equal to the value of the timing resistors measured in kW. To facilitate accurate setting of the pulse durations the resistors R4 and R5 are a small variable resistor and a fixed value resistor. For a 1/2 second pendulum R4 is a 200 kW 25 turn trim potentiometer and a 390 kW resistor in series and istor and a 100 kW fixed resistor in series.

Regulating your clock

The regulation of a conventional weight driven clock is accomplished by adjusting the position of the pendulum bob. The most significant advantage of using a falling weight for driving a pendulum clock is the falling weight provides a constant impulse to the pendulum. This ensures that the pendulum amplitude will remain constant as the bob is adjusted in order to bring the clock to time.

The period of a clock pendulum increases as the amplitude of the pendulum increases (the clock runs slow). The pendulum amplitude of the clocks described in this construction series depend on a number of factors. The magnitude of the magnetic pulse generated by the drive coil depends on the number of turns of insulated copper wire used to wind the coil. The electrical resistance of coil for a given number of turns of wire depends on the diameter of the wire used. The coil resistance using Ohms Law will determine the current flowing in the coil and resulting magnetic field generated. The magnetic field generated by a coil is illustrated in **fig 21**.

The magnet attached to the end of the pendulum rod will either be attracted towards the centre of the coil or repelled from the centre. Whether the pendulum magnet is attracted or repelled depends on the direction of the current flow in the coil windings and the polarity of the pendulum magnet. The direction of the force on the pendulum magnet can be determined by using Fleming's left-hand rule. Increasing the strength of the pendulum magnet will increase the magnitude of the impulse applied to the pendulum. The distance between the pendulum magnet and the drive coil will also effect the magnitude of the of the impulse imparted to the pendulum. Increasing the distance between the pendulum magnet and the drive coil will reduce the pendulum impulse and hence its amplitude.

The amplitude of the pendulum also depends on the mass of the pendulum bob and the energy losses in the gear train. The impulse imparted to the pendulum by the drive coil accelerates the pendulum, the magnitude of the imparted acceleration being determined, by the inertia of the pendulum including the effect of the gear train, and Newton's Second law of Motion. To minimise the frictional losses in the gear train precision ball races have been used for all pivots.

To set up the clock the pendulum should first be put into beat, much as is done with a normal clock. The roller clutch >>

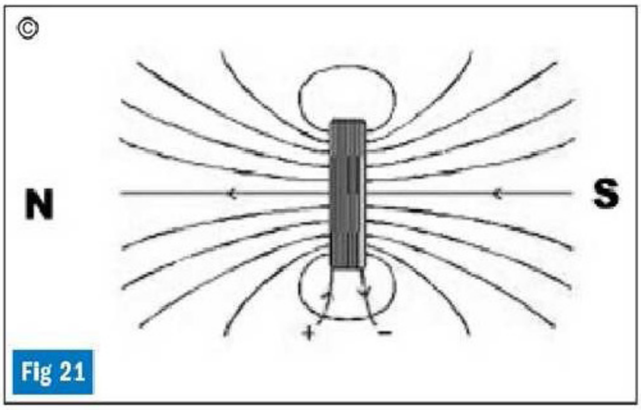


Fig 21. Magnetic field generated by the coil.

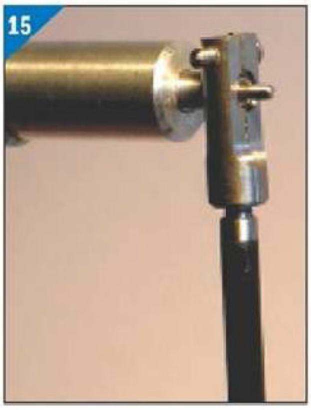
14. Suitable setup to regulate the clock.

15. Pendulum attached to arbor clamp fitted with a ball race.

grips the arbor of the pendulum as it swings in a clockwise direction and rotates the pin wheel in a clockwise direction. The catch lifts and when the wheel has turned through an angle of about 5 to 6deg. drops down behind the next pin on the wheel. The pendulum position at which this occurs should be about 1 to 2deg. to the left of the vertical. The wheel will then continue to rotate a further amount before the pendulum returns in the opposite direction. After a small amount of recoil in the train the catch locks the train until the pendulum returns in a clockwise direction. The sound generated will be a first 'tick' as the catch drop followed by a second as the catch locks the pin wheel when the pendulum returns.

Regulating the half second version

As explained earlier the pendulum in the half second version is effectively a slave whose rate is controlled by the duration of the first delay in the drive circuit. For accurate time keeping this delay must be set precisely at 500ms, the beat rate for a half second pendulum. The pendulum bob must be adjusted to beat to the same rate as the delay. If the pendulum rate and delay rate are different the two will be out of phase with each other. This phase difference will cause the pendulum amplitude to increase and decrease periodically (i.e. to be modulated), the rate of modulation being determined by the phase difference between the delay rate and the pendulum rate. It is not possible to regulate this clock by adjusting the position of the bob as the pendulum is controlled through the drive circuit. The pendulum amplitude can be adjusted either by altering the duration of the drive pulse by adjusting the duration of the second delay. Alternatively the amplitude can be reduced by increasing the height of the drive magnet above the surface of the drive coil.



The circuit set up

To set up the circuit start by measuring the DC voltage level of the output of the 071 op-amp (pin 6). Adjust the trim pot R1 to set this voltage at 4.5 Volts, this is 500 mV above trigger threshold of the 555 timer chip.

Setting up the circuit using an oscilloscope

Connect the oscilloscope probe to the output to the drive coil.

Set the oscilloscope time base to give a sweep of 1,000ms the trigger on repeat and the input on 12 Volts DC. Turn on the power and set the pendulum swinging. Adjust the trim pot R4 until the delay is precisely 500 milli-seconds. Adjust the trim pot R5 to give pulse duration of about 150 ms. Adjust the bob to give the maximum pendulum amplitude. Adjust the bob position and leave the pendulum to swing for a couple of minutes. If the pendulum is not beating 1/2 seconds you will observe that the amplitude will increase, reach a maximum, and then decrease. This is because the pendulum is out of phase with the drive circuit delay. Continue adjusting the bob position until the amplitude increases to a maximum and remains at this amplitude. The drive delay and the pendulum beat will now be in phase. The clock will now keep pretty accurate time.

Setting up the circuit without using an oscilloscope

To set up the circuit you require some sort of timing device to set the delay to exactly 500 ms to get accurate time keeping from the clock. Since an oscilloscope is not available you will have to use the pendulum as the basic timer.

Photograph 14 shows a suitable set up to enable the reader to regulate the clock. The set up consists of a stand with an extended arm fitted with a 1.5mm pivot. The pendulum is attached to an arbor clamp, see **photo 15,** bored 4mm into which is held a 1.5mm I/D ball race. Turn off the power to the circuit. Set the pendulum swinging and using a stop watch if you have one. Measure the rate of the pendulum by counting 60 of every other beat (i.e. 60 pendulum periods) Get the rate as close to 1/2 second beat as you can. The pendulum suspended on a ball race will swing for long enough to allow you to get the rate pretty close.

The duration of the drive pulse needs to be set at about half of the beat period of the pendulum which is about 150 milli-seconds (or R5 = 150 kW). This means the trim pot R5 is set at 50 kW or approximately 12 turns of the adjusting screw from either end. The delay must now be set to the beat rate of the pendulum of 500 milliseconds (or 500kW). This means the R4 trim pot must be set to value of 110kW or approximately 12 turns of the adjusting screw from either end. Turn on the 12 Volt supply and swing the pendulum. Adjust the screw on the R4 trim pot to maximise the amplitude of the pendulum. If the delay is not the same as the pendulum beat you will observe that the amplitude will increase, reach a maximum, and then decrease. This is because the pendulum is out of phase with the drive circuit delay. Keep adjusting R4 until the pendulum amplitude reaches a maximum and remains at this amplitude. Measure the beat rate of the pendulum again only this time count a lot more swings and calculate the rate. If the rate is too slow (fast) raise (lower) the bob, adjust R4 and measure it again. Keep adjusting until you have it regulated. **ME**

NOTE: *The .dxf files for this clock can be obtained via the editor.* E. **david.carpenter@magicalia.com**

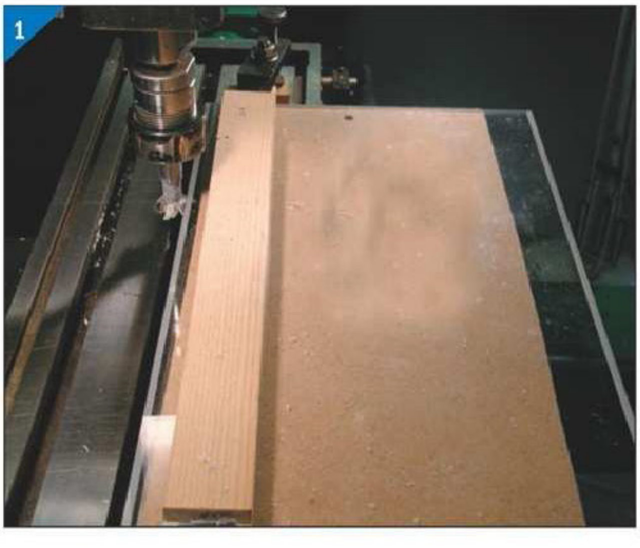
A cover for your MAGNETIC DRIVE CLOCK

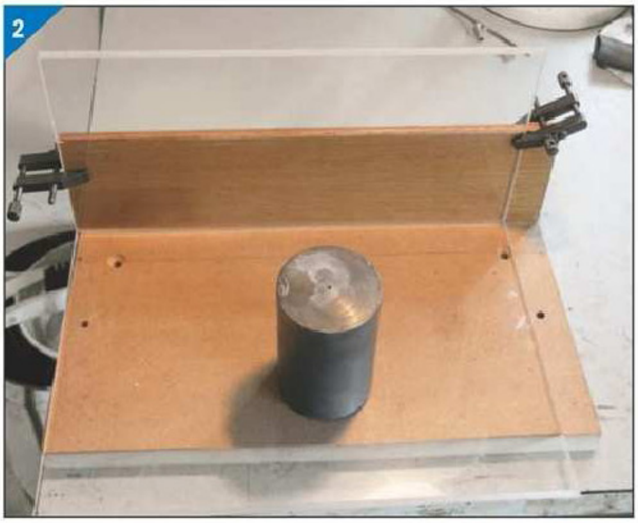
Richard Stephen describes how to make a cover for the skeleton clock which he completed in *M.E.* 4303.

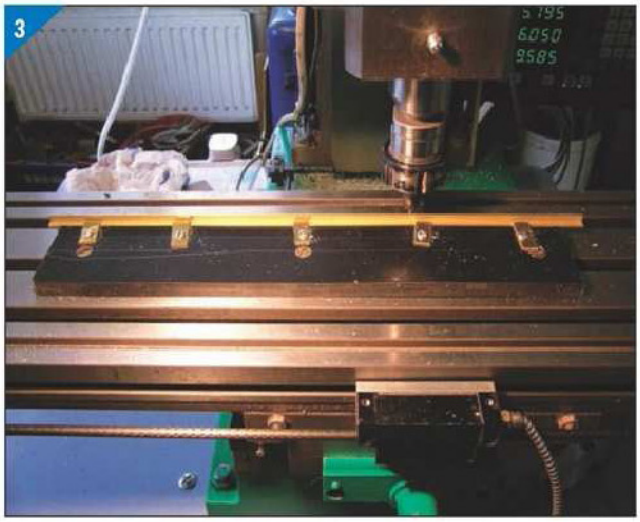
All skeleton clocks require to be covered in order to protect the polished brass surfaces. As the wooden base of the clock is rectangular it follows that the cover must also be rectangular. Readers have two possible options for a cover for the clock. The first option is to have a cover made. Plastic Design in Cherry Hinton, Cambridge will make a rectangular cover to your precise dimensions. The covers that they make are superb with completely transparent joints on all edges. I have purchased several covers from them in the past. The cost of a cover made from 3mm Perspex is in the region of £100. An alternative to Perspex is of course glass. Glass is without a doubt the best material as it does not scratch. You would have to make a glass cover yourself. There are two principal drawbacks using glass. The first is glass is very difficult to cut to a precise dimension. If you manage to cut the five pieces required to make a cover with sufficient precision then constructing the cover is also difficult. Adhesives for glass (and Perspex) are available all of which require a UV light source to set the adhesive. I have done this once and eventually succeeded in making a cover, but never again. Perspex is a practical alternative which I have used with success. The problem is making the joints. It is easy to glue the pieces together but very hard to get all the joints transparent. If 1/4in. right angle brass angle is used this covers up all the joints as well as making the cover far more rigid. A drawback with Perspex is that it scratches quite easily. Provided any scratches are not too deep they can easily be removed and the surface re-polished. I start with well-used 2000 grade using plenty of diluted washing up liquid as a lubricant and finish with 12000 grade. For a final polish I use cotton wool and a Perspex polish which I purchased on eBay.

I made my cover using 3mm thick clear Perspex. To cover the edges I used 1/4in. brass angle 1/16in. thick. The internal width of the angle is 3/16 inch. If the side were joined with a plain butt joint it is possible to see the join on one side of the angle. To overcome this difficulty I decided to mitre all the joints. This is not as hard to do as it sounds. To begin I cut the five pieces of 3mm Perspex a bit bigger than the final size. Do not remove the covering as this will help prevent scratching the surface of the Perspex. The edges of the four sides are now milled precisely square and to their final size. It is very important that the two sides as well as front and back are exactly the same size. **Photograph 1** illustrates how the Perspex pieces are secured for milling to size as well as milling the mitred edges using a 45deg. dovetail cutter.

The four sides are glued together next. Remember to remove the protective covering before you glue the sides. **Photograph 2** illustrates the jig I made out of plywood for gluing the sides together. Make sure that the two sides of the jig are precisely at 90 degrees. The best adhesive for Perspex are the UV setting adhesives as these make an optically clear joint. As I do not possess a suitable UV light source I used >>


1

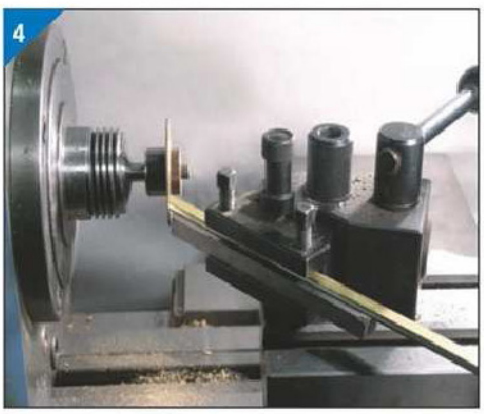

2


3

chloroform, I have tried some of the proprietary adhesives but have found them not as good as chloroform. The only problem with chloroform is obtaining some as the COSHH regulations mean that you cannot buy a small amount. I still have a small amount that I obtained many years ago. When you have glued all the four sides together the top can be fitted. The mitred edges of the top are best cut to firm the sides after the sides have been assembled. Finally, glue the top in place.

The brass edging strips are mitred and glued in position with super glue. To improve the appearance of the brass angle, I chamfered all the long edges. This isn't necessary but I was pleased I took the trouble to do the edges. **Photograph 3** illustrates how I secured the brass angle to mill the chamfers. A length of 10mm thick plastic sheet was bolted onto the table of the mill. A $^{1}/_{4}$in. slot was milled $^{1}/_{16}$in. deep was in the piece of plastic as shown in photo 3. The brass edging was secured in the groove and held in place by several hold downs again as illustrated in photo 3. With all the edges chamfered the mitres can now be cut. I cut the mitres on the lathe rather than on the mill as using the lathe enabled me to saw the mitres rather that milling them. The tool holder on the top slide of the lathe was set at 45deg. to the bed of the lathe using a 45deg. set square. The mitres were sawn with a fine tooth slitting saw as illustrated in **photo 4**. Begin by cutting the mitres for the top edges. These again will have to be individually fitted to ensure nice tight joints. To adjust the mitres to obtain a good fit I ground the mitres with fine aluminium oxide paper glued to a metal backing disc as illustrated in **photo 5**. When you have mitred all four top strips rub the sides of the edging with wet and dry paper finishing with 2000 grade paper. Glue the edges in place with a small amount of super glue. If you use too much the glue will be squeezed out onto the Perspex and will be very difficult to remove. The mitres for the four side edges are cut next. Fit each in place but do not glue them and then cut each to length. Rub down with wet and dry paper as before and then glue them in place.

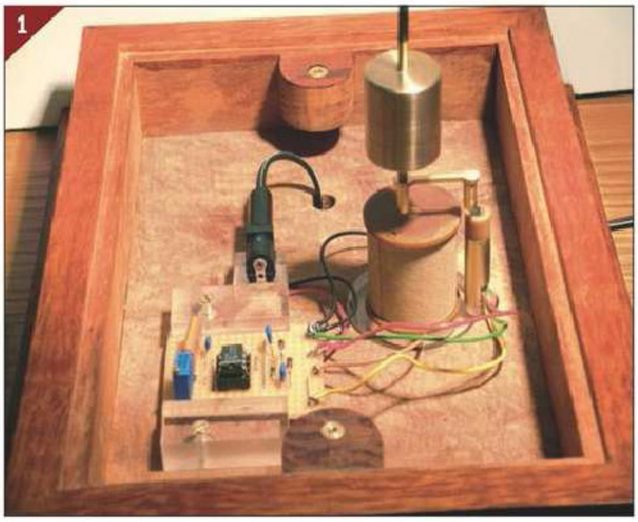
Any scratches can be removed with Perspex polish. I used some scrap Perspex for the cover I made which unfortunately was slightly scratched. It was a tedious job removing these scratches and finally polishing the cover. The final result shown in **photo 6** is okay but not as perfect as I would have liked. I guess I will probably make another and use new Perspex this time! **ME**


4


5


6

New Pendulum drive system



Richard Stephen describes an improved pendulum drive system for the magnetic drive clock recently described in these pages.

1. Drive set-up.

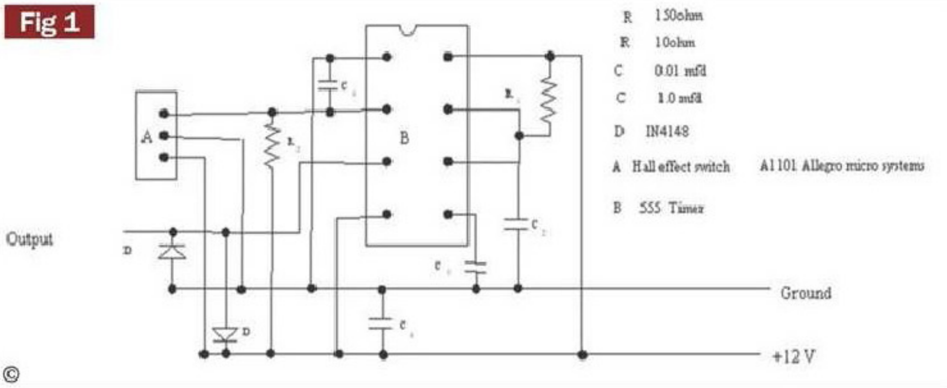
Fig 1. New drive circuit.

Since completing the writing up of the clock described in the recent series I have been developing a new drive system for the pendulum. This has required quite a lot of experimentation to sort out all the minor problems associated with the new drive circuit. The circuit originally described works very reliably, however it does have the drawback of being rather difficult to regulate the clock. With the original circuit the period of the pendulum is determined by the duration of the first delay in the circuit. For a half second pendulum this must be set at exactly 500 ms. The pendulum is then simply a slave as it is forced to follow the circuit delay. It was this aspect that prompted me to see if it was possible to modify the drive system so that the pendulum controlled the circuit and the generation of the impulse delivered to the pendulum to keep it swinging. The new drive system is illustrated in **photo 1** and the details of the drive circuit shown in **fig 1**. In photo 1 there is now only a drive coil, the sensing coil used in the previous circuit has been replaced by a device called a Hall effect switch. The Hall effect switch has be set in the top of the 8mm dia. brass post positioned directly behind the drive coil in photo 1. The Hall effect sensor used in the switch is sensitive to a south (S) magnetic pole. In the position shown for the Hall effect switch the magnetic field generated by the drive coil has no effect on the switch. The pendulum has now been fitted with two magnets, the one attached at the end of the pendulum rod is the drive magnet that impulses the pendulum. A second switching magnet is attached to an arm fixed to the pendulum rod. As the pendulum swings the rear magnet passes over to centre of the brass post containing the Hall effect switch. The Hall effect switch used in the drive circuit will only switch when a S magnetic pole passes over the surface of the device. The output of the Hall switch, in the absence of a S magnetic pole, is held at +12V, the circuit line voltage. When the switching magnet passes over the Hall device the output is momentarily grounded (i.e. fall to 0 volts). The negative voltage change triggers the 555 timer in the drive circuit. The output pulse of the 555 timer, turned on for a time set by the values of R1 and C1, energises the drive coil and impulses the pendulum.

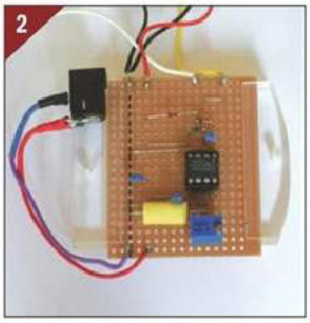
When I was experimenting with the above circuit I experienced the following unexpected problem. As the pendulum swings across the brass base plate of the clock as illustrated in the series, the drive and switching magnets induce in the surface of the plate circulating electric currents, referred to as eddy currents. In exactly the same way as the drive current that flows through the windings of the drive coil induce a magnetic field the circulating eddy currents also induce a magnetic field. These eddy current magnetic fields oppose the motion of the pendulum or in effect reduce the effective impulse delivered to the pendulum. These eddy currents will also affect the switching of the Hall effect sensor. I was aware of the effect the eddy currents could have on the switching of the Hall effect sensor when I started to experiment with the drive system. To overcome this problem the sensor was exposed, flush with the surface of the base plate. Fortunately the drive coil I had made was large enough and had sufficient number of turns of wire to generate a pendulum impulse of sufficient magnitude to swamp the opposing eddy current fields.

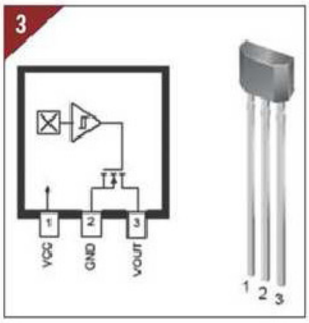
I have since been experimenting with the overall design of the clock and have made a slightly smaller version >>

Fig 1

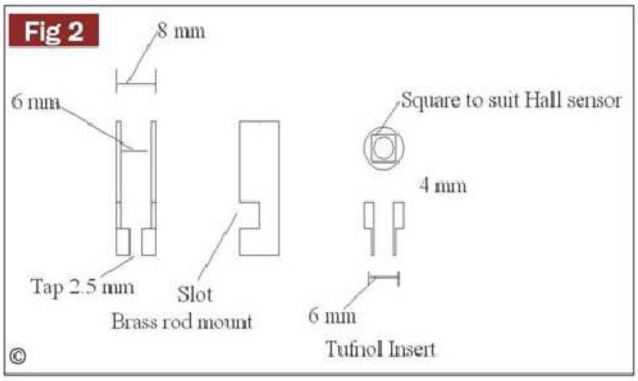


©

2


3


4


Fig 2


2. Circuit component layout.
3. Hall effect switch connections.
4. Hall effect mounting.
Fig 2. Hall effect mount.
Fig 3. Coil support.
Fig 3a. Base cut-out.

of the clock. I reduced the size of the drive coil in order to fit it in the smaller wooden base I made. The coil was more than adequate to drive the pendulum when I tested the circuit in the absence of the brass base. With the base plate fitted the pendulum simply stopped. There were two possible solutions to the problem of the eddy current braking of the pendulum. Increase the size of the drive coil or replace the brass base plate with a one made from a non-conducting material. In fact I have done both. The base plate has been made of the same wood as the wooden base. This has enabled me to secrete both the coil and the Hall effect sensor in the base. The wooden base plate solved the problem of eddy current braking but created another problem. I found that it was very difficult to regulate the pendulum amplitude. Over time the amplitude would slowly increase until it was so large that the pin (or ratchet) wheel rotated past two pins (or teeth) instead of only a single one. I spent some time trying to adjust the drive but was not able to get the pendulum amplitude to remain constant. It eventually occurred to me (in the middle of the night!) that the eddy currents induced in the brass base which I had considered a problem could actually be the solution for regulating the amplitude. I placed a small piece of 1.5mm brass sheet on the surface of the wooden base on both sides of the pendulum. By adjusting the positions of the pieces of brass I was able to regulate the amplitude by inducing the appropriate amount of eddy current braking and so prevent the problem of double pulsing. I still need to fit the two pieces of brass in the wooden base plate.

Moving house to the Channel Islands has halted all work in the workshop. I should be up and running again quite soon. I have also tested the clock with the brass base plate, the impulse is now sufficient to overcome the eddy current braking of the pendulum.

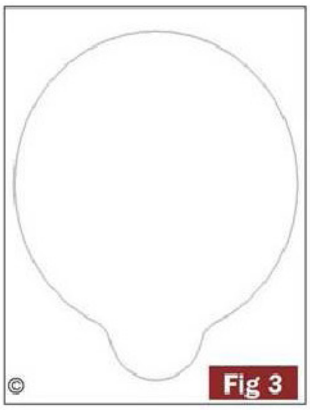


Fig 3

Fig 3a

Adjusting the pendulum amplitude

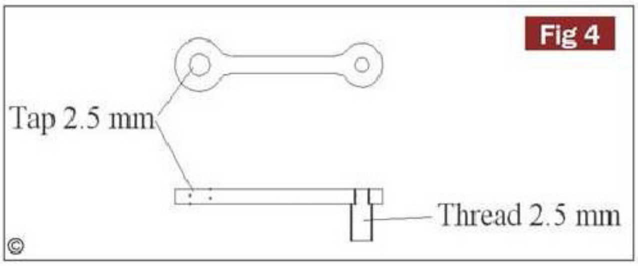
The amplitude of swing of the pendulum depends on the size of the impulse delivered to the pendulum. As the switching magnet swings over the Hall effect device the 555 timer is turned on. The voltage pulse generated is applied to the drive coil and a magnetic field is generated by the electric current flowing through the coil. Suppose that the direction of the current flow in the coil produces a S magnetic pole at the top of the coil. A S magnetic pole at the end of the pendulum placed in the coil field will be repelled away from the centre of the coil and will impulse the pendulum. If the coil connections were reversed and a north (N) pole generated at the top of the coil the drive magnet at the end of the pendulum would also have to be reversed in order to have a N pole at the end of the pendulum rod.

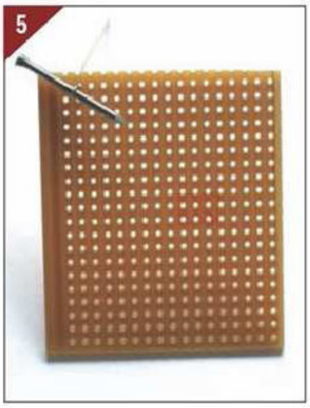
The magnitude of the pendulum impulse depends on four basic factors, the size and strength of the drive magnet, the size, number of turns in the drive coil and the circuit line voltage, the 555 timer pulse duration and lastly the distance between the drive magnet and the surface of the coil. The last factor occurs because the strength of a magnetic field decreases as the distance away from the pole increases.

Constructing the Hall effect drive system

The circuit diagram for the drive system is illustrated in fig 1. It is a relatively simple circuit to construct. If you have not used a 555 timer before it would be worth consulting the wealth of information on 555 timers available on the Internet. I made up my circuit on a piece of strip board (Vero board). To do a neat soldering job on strip board a needlepoint soldering iron is, I have found, essential. The layout of the components on the board is illustrated in **photo 2**.

The Hall effect sensor connections are illustrated in **photo 3**. The flat surface of the sensor is the switching surface and this surface must be placed uppermost across which the switching magnet passes. In photo 1 the sensor is shown placed at the top of an 8mm mounting tube. To fit the sensor in this position the three leads of the sensor need to be bent at 90deg. to the active surface of the sensor. As the sensor is placed some distance from the circuit board the leads of the sensor have to be extended by soldering to each lead a length of light PVC-covered stranded wire. Use red green and yellow wire for VCC (12V), ground (0V) and the output. Solder on the wires before you bend the leads. The solder joints and the exposed leads of the sensor must be insulated to prevent the leads shorting. You will need to find some fine wall sheathing for this. I used some fine PVC tube which I stretched to reduce its diameter to achieve the required diameter.





5. Forming the connections.
6. Testing the pendulum drive.
Fig 4. Magnet arm.

The Hall effect sensor is fitted into a short length of 8mm dia. Tufnol rod (see **photo 4**). If you don't have any rod you can turn up a piece out of an off cut of 12mm thick sheet. You could use grey PVC rod if you can't find any Tufnol. The details of the mounting tube are illustrated in **fig 2**. The square at the end of the piece of Tufnol can be formed either with a square punch or using a suitable file. The other end of the Tufnol rod is turned down to 7mm dia. to fit into the end of the brass section. Bend the leads at 90deg. and fit the Hall effect sensor in place. Glue the sensor in position with slow set epoxy resin. The brass section of the mount is made from a length of 8mm brass rod. The overall length of the mount has not been shown as this will depend on the dimensions of the wooden base of the clock. It is essential that the Hall effect sensor be flush with the surface of the brass base plate or at the same height as the drive coil if a wooden base is used. Drill a 7mm dia. hole leaving about 6mm at the one end. This is then drilled and tapped for a 2.5mm mounting screw. A 6mm slot is cut in the side as shown for the wires for the sensor leads to exit.

The Hall effect sensor is placed adjacent to the drive coil (see **photo 4a**). Fortunately in this position the sensor is unaffected by the magnetic field generated by the drive coil. Photograph 1 illustrates the mounting of the drive coil and the Hall effect sensor. The details of the support are shown in **fig 3**. I made my support out of a scrap of 10mm thick Perspex. The support fits into a recess, of the same shape as the support, in the bottom of the wooden base of the clock. I used CNC to cut out the support and to mill the recess in the base for the clock. I have not given any dimensions for the support as these will depend on the dimensions of the drive coil and the wooden base. If you are using a brass base plate for the clock a recess will have to be milled on the base plate. For a 3mm base plate the recess for the coil will need to be approximately 2.5mm deep. The Hall effect sensor will have to be just over 0.5mm higher than the top of the drive coil so that it can just project through the brass base plate (**fig 3a**).

Assembling the circuit

The circuit board is not difficult to assemble. The component layout is illustrated in photo 2. You will need a needle point soldering iron and some resin cored solder. Apart from the components listed on the circuit diagram you will need about 1m of 24swg tinned copper wire, an 8-pin dil socket for the 555 timer and a piece of strip board 50 x 50 millimetres.

Begin by stretching the length of copper wire to straighten it and then cut it into three 30mm lengths. The 8-pin dil socket is soldered in place first. Position the socket in the centre of the board and hold it in place with a piece of masking tape. The tracks between the pins of the socket must first be cut through. This is best done with a sharp 4mm dia. twist drill. Make sure after cutting the tracks that there are no tiny pieces of copper track that could cause a short. Solder the socket in place using the minimum amount of solder to ensure a good connection. Orientate the board so that pin 1 and pin 8 are on the right-hand side and pin 1 uppermost. Count three tracks in from the left of the board and draw a line using a black, indelible, felt tip pen from top to bottom on the upper surface of the board. This track will be the ground or 0V line. Count a further three tracks in and draw a red line. This track will be the 12 V line. These lines I find very useful when assembling a board. Connections to the 0V and 12 V lines at both ends of the tracks are added next. **Photograph 5** illustrates how to form the most satisfactory type of connection to track board. Using a tapered broach enlarge the holes at both ends of the two tracks. Double over a 50mm length of copper wire in the middle and push the two ends into the enlarged holes. Push a piece of 1.5mm rod through the loop formed in the wire. Grip the ends of the copper wire and pull hard to form a neat round wire loop and solder the wire to the track. Trim off the excess wire. Further similar connection will need to be added later to connect the coil and the Hall effect switch.

Using suitable lengths of copper wire connect pin 4 and pin 8 of the socket to the 12 V line. Leave one hole vacant when making the connection for pin 8. Connect pin 1 to the 0 V line. Next connect pins 6 and 7 together with a loop of wire. Use masking tape to hold the wires in place when soldering them. Next connect a 10nf capacitor between pin 5 and 0 Volt. Connect the 1nf capacitor between pin 6 and 0 Volts. The variable trim potentiometer is added next. The resistance value required depends on the pendulum period. For a seconds pendulum use a 500ohm trim pot and for a ½ second pendulum use a 250ohm trim pot. Solder the trim pot connections to pins 8, 7 and 6. Note pins 6 and 7 are already connected which means that the variable resistance is only between pin 8 and pins 6 and 7. This completes the connections to this end of the board.

The Hall effect switch requires a 10ohm pull-up resistor connected between the output of the device (lead 3) and the 12V input voltage (lead 1). The output of the Hall switch is connected to the input of the 555 timer (pin 2). The pull-up resistor is connected between pin 2 and pin 4 (previously connected to 12V). Use a 0.125 Watt rated resistor for the pull-up. The Hall effect switch also requires two 10nf by-pass capacitors. These capacitors are connected between the output and ground (0V) (leads 2 and 3) and between the input voltage and ground (leads 1 and 2) of the Hall device. The appropriate connections on the board are between pin 2 and pin 1 for the first by-pass capacitor and between the 12V and 0V lines.

Finally, the two protection diodes have to be fitted. If the diodes are examined you will observe that there is a black band on one end of the diode. This band corresponds with the line on the drawing of the diode in the circuit diagram and is the >>

positive end of the diode. The diodes are connected between ground and pin 3 the output of the 555 timer and the second diode between pin 3 and the 12V line. When soldering in the diodes keep the leads at least 6mm long.

Attach connection loops to the board to pin 3 the timer output. As the input to the timer is on pin 2 the connector loop is move to one side a few holes and connected to pin 2 by a length of copper wire (see photo 2). This completes the board.

Before testing the board carefully check all the connections against the circuit diagram. Then check all the solder joints making sure that there are no 'dry' joints and there are no shorts between any of the copper tracks.

Mounting the board

The board is mounted between two pieces of 12mm Perspex. Cut and mill two pieces of 12mm Perspex 50mm long and 12mm wide. Mill a 3mm deep slot in the middle of the long side of each piece 1.5mm wide using a slot drill. The board will be a nice tight fit in these slots (see photo 2). Drill a 2.5mm hole in each piece for the 2.5mm screws to attach the board to the base. The power supply for the board is a 12 V regulated DC mains adaptor.
To connect the power supply to the board you will need a socket that fits the plug on the end of the power supply lead. This socket is glued to one of the Perspex pieces (see photo 2) with super glue. Connect the socket to the lower board connectors (see photo 2).
Connect the Hall effect switch to the board, the output to pin 2, VCC to 12V and ground to ground. The ground line of the coil has also to be connected. Bare the ends of the two ground lines and twist together and solder to the loop connector. The remaining coil connection is attached to pin 3. The board is now ready for testing.

Testing the board

To test the board you will need to use an oscilloscope. Do not insert the 555 timer into the socket to begin with. Connect the 'scope ground to the ground on the board and the live lead to pin 2, the output of the Hall switch. Turn on the power. The 'scope should read 12 V. Pass a S pole of a magnet over the Hall switch. The 'scope beam should drop to 0 V and return to 12 V after the magnet is removed. This indicates that the switch is functioning correctly. Turn off the power and insert the 555 timer. Connect the live 'scope lead to the output of the 555, pin 3. Using a small screwdriver set the trim pot to the middle of its range. Turn on the power again. The beam of the 'scope will be at zero. Pass the S pole of the magnet over the Hall switch. A 12V pulse of duration set by the trim pot resistance should be seen. For a 500ohm pot the width will vary between 0 and 500ms. This indicates that the circuit is functioning correctly. You now need to check that the drive coil is generating a magnetic field of the correct polarity to repel a S magnetic pole. Suspend a magnet on piece of thread at the side of the coil, level with the top of the coil. If the coil connections are correct the magnet will be repelled. If it is attracted the connections to the coil will need to interchanged.

The drive, switching magnets and magnet arm

Neodynium magnets are the best to use for the drive and switching magnets. These are available on ebay at a very reasonable price. A 5 x 5mm cylindrical magnet is ideal for the switching magnet as this will operate the Hall switch up to 6mm from the device. For the drive magnet you will need to experiment with the size to find one that will give the appropriate pendulum amplitude. A 4 x 3mm cylindrical magnet is a reasonable start. The design of the magnet arm is shown in **fig 4**. The dimensions will depend on the distance between the centre of the coil and the centre of the Hall device. I used 1.6mm engraving brass for my arm. A 5mm length of 2.5mm screw rod is attached to one end of the arm to attach the switching magnet. The design of the magnet holders has been given in the clock series.

6. Testing the pendulum drive.

Getting the clock running

The pendulum amplitude needs to be approximately + - 4 degrees. This allows the pendulum to rotate the pin wheel just enough for the catch to lift over one pin in the wheel. If the pendulum amplitude is much larger than 4deg. the catch may well lift over 2 pins. To avoid this problem the pendulum impulse need to be set at just the right value. Begin with the pendulum swinging on its own suspended as illustrated in photo 6. The pendulum swings on a 1.5mm pivot at the end of the horizontal bar in Fig (10).
To attach the pendulum to the 1.5mm pivot a modified arbor clamp (see the series) bored 4mm to hold a 1.5mm I/D. ball race. The Hall effect sensor will trigger reliably with a 5mm dia. x 5mm cylindrical neodynium magnet at a distance of up to 6 millimetres. I usually set the distance at about 3 millimetres.

The size of the drive magnet required depends on the circuit line voltage. For a 12V supply a 4mm dia. by 3mm neodynium is a good starting size. Begin with the magnet about 1mm above the coil. Turn on the power and swing the pendulum. The pendulum will not start of its own accord. Increase the drive pulse width until the pendulum starts to impulse. It is likely that the amplitude will increase beyond 4 degrees.
To decrease the amplitude the size of the drive magnet can be reduced as well as increasing the distance of the drive magnet above the coil. The switching magnet must remain at about 3mm above the Hall effect switch. Neodynium magnets are sintered and are quite hard. The can be easily machined in the lathe using a sharp carbide tool. By carefully adjusting the size of the magnet, the height above the coil and the drive pulse width the amplitude can be set to the required value. This can take some time and adjustment. **ME**