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MYFORD LATHES PROFILE

MIDLAND 3F LOCOMOTIVE BUILD

SIMPLIFY PLATE WORK

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NEW SERIES

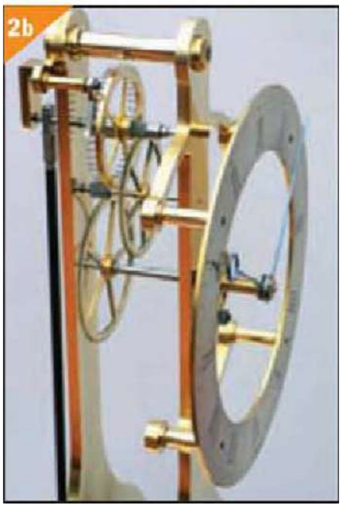
PART 1

Richard Stephen describes a most interesting, different, and attractive new clock to challenge readers.

1. *Big balance version.*

2a. *Hair second pendulum clock.*

2b. *Side view or pendulum clock.*



Magnetic drive CLOCK

Several months ago I decided to construct a large balance wheel clock. The design of the clock was particularly interesting as it presented a number of interesting challenges. Initially I wanted the clock to be weight-driven with a lever escapement. The clock was eventually constructed. Unfortunately the weight required to run the clock was excessive and the use of weights to drive it had to be abandoned.

I was reluctant to toss the whole thing into the scrap box and so I began thinking of using a magnetic drive for powering the movement. I wanted to use modern electronics for the drive circuit and. in particular, I did not want to have to use any electrical contacts. These contacts, nearly always, eventually give problems.

I was aware of a possible technique using two concentric air cored coils, which might fit the bill. It did!

This drive system works as follows: The inner coil is used as a sensing coil. A magnet attached to the bottom of a pendulum sweeps over the sensing coil and generates an electromotive force (e.m.f.) in the windings of the coil. This e.m.f. is used to generate a delay of duration equal to half the period of the pendulum (balance). As the pendulum passes the centre point of the two coils the delay triggers a pulse in the outer coil, which repels the pendulum and generates the required impulse. **Photo 1** illustrates the big balance version of the design. The arm attached to and extending below the balance arbor carries the drive magnet. The two coils are placed under the base plate, which is recessed to reduce the distance between the magnet and the coils to about 1 millimeter.

With all the drive system hidden in the base, the clock appears to have no motive power, an aspect that adds to the interest of the design. A further feature of the design is that unlike traditional movement trains which are 'wheel' driven this train is pinion driven from a pinion attached to the balance or pendulum arbor. The pinion drive used in this movement, as far as I am aware, has not been used before. More of this later.

As the design proved so successful I decided to develop a version using a half second pendulum and a further version with a seconds pendulum instead **of** the balance wheel. The pendulum is attached directly to the pinion drive arbor and is thus suspended on bail races. This version is illustrated in **Photos 2a and 2b.**

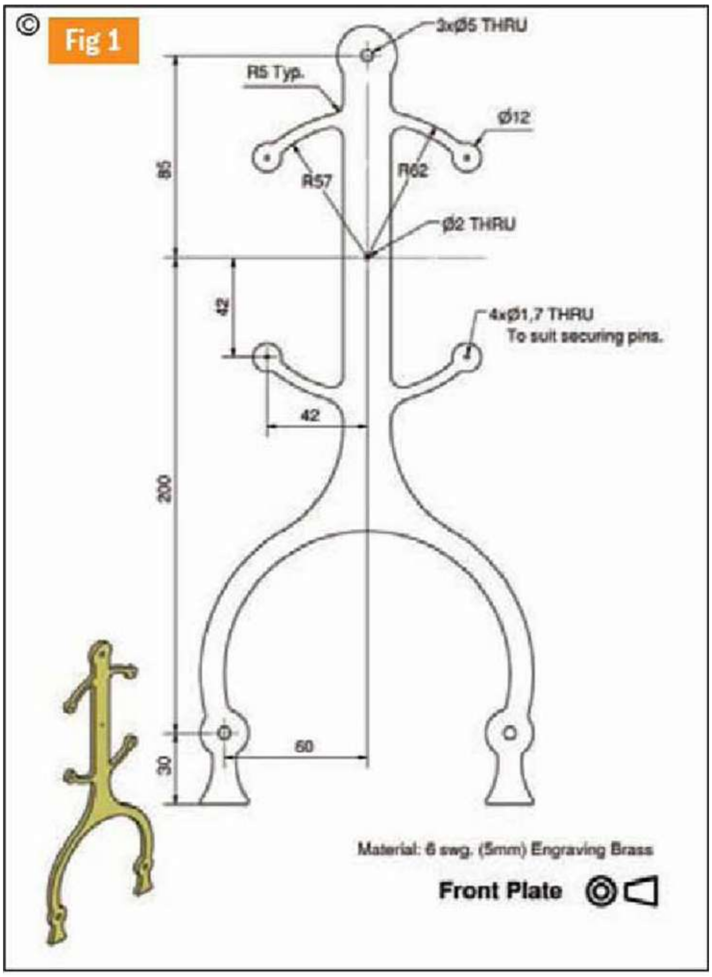
Of the two versions the pendulum one is I think the most successful as it is relatively easy to construct and a clock that should appeal to most amateur makers. The construction is very straightforward as it requires only two wheels and two pinions apart from the drive wheel and the motion work.

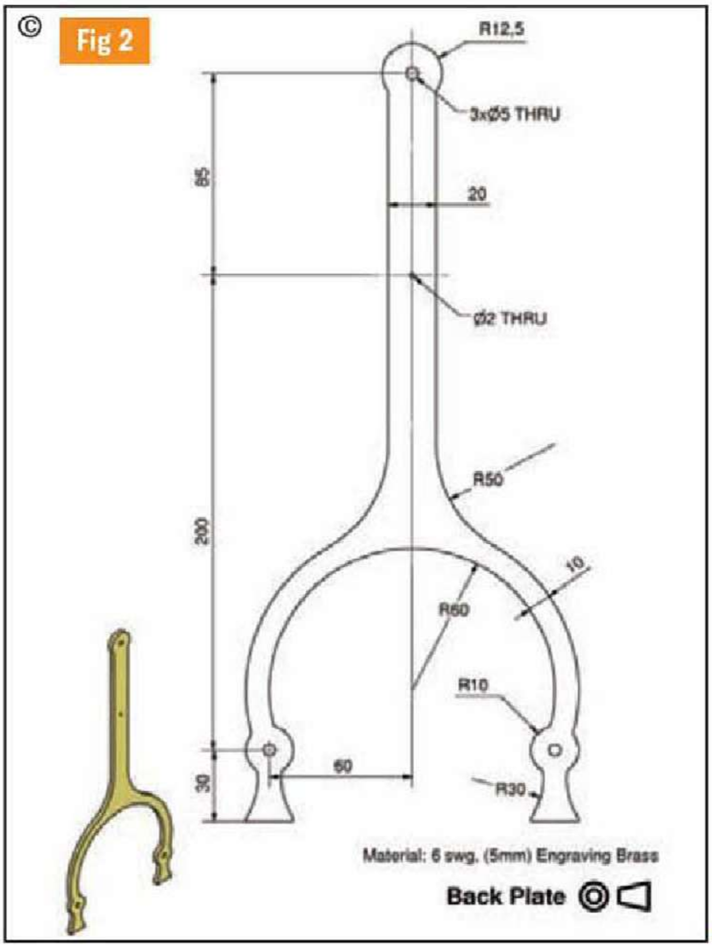
MATERIALS REQUIRED FOR THE HALF SECOND VERSION

Plates:	Two pieces of 6 gauge (3/16in. or 5mm) engraving brass sheet 350 mm x 160 mm.
Base:	10 gauge (1/8in, or 3mm) engraving brass 200mm x 120mm
Feet blocks:	120mm of 30mm diameter brass rod
Pillars:	200mm length of 12mm diameter brass rod
Dial Pillars:	150mm length of 8mm diameter brass rod
Wheels and Dial:	16 gauge <1/16in. or 1.5mm) engraving brass sheet 300mm x 160mm
Drive wheel:	30mm x 50mm engraving brass 6.0 mm thick
Bearings:	For the half second pendulum version
5	1.5mm Ld. shielded stainless steel ball races (681XZZ)
1	3mm Ld. shielded stainless steel ball race (MR63ZZ)
1	3mm i.d. roller clutch {HF0306KF). The roller clutches are only supplied by INA.
Drive magnet	Half second pendulum version: 7 mm diameter 4 mm long samarium-cobalt magnet DCSC01454 These magnets are supplied by Magnet Developments Tel: + 44(0)14793 833200.
Silver steel:	300mm lengths of 2,5mm, 3mm and 4mm diameter rod
Carbon fibre rod:	a 1m length of 4mm diameter tube for the pendulum rod
Pendulum Bob:	30mm of 25mm brass rod
	Pivot steel 4, 1 mm diameter 100mm lengths. 1 length of 1,5mm pivot steel.
Drive PCB	The drive PCB is available from Model Engineers Digital Workshop Tel:- +44 (0)1386 852122
Drive coil:	50mm length of 50mm diameter Tufnol rod.
Sensing coil:	50mm length of 25mm diameter Tufnol rod
Wire for the coils:	1 500 gram spool of 40 SWG.(~36AWG or 0.125mm) enamelled copper wire. Available from Scientific wire Co. http://www.wires.co.uk/acatalog/ListO5R2c.pdf

In addition to the above you will need some short lengths of EN1A (Free cutting with sulphur but no lead) mild steel 10 mm, 8 mm and 6 mm diameter and 12 mm, 6 and 4 mm brass rod.
Sphinx micro drills are available from Fenn Tools http://www.fenntool.co.uk/html/products.html. These drills are best for drilling small accurate holes.

The construction series will begin with the half seconds pendulum version. As in my previous series, CNC has been extensively used in the construction of the components of the movements.





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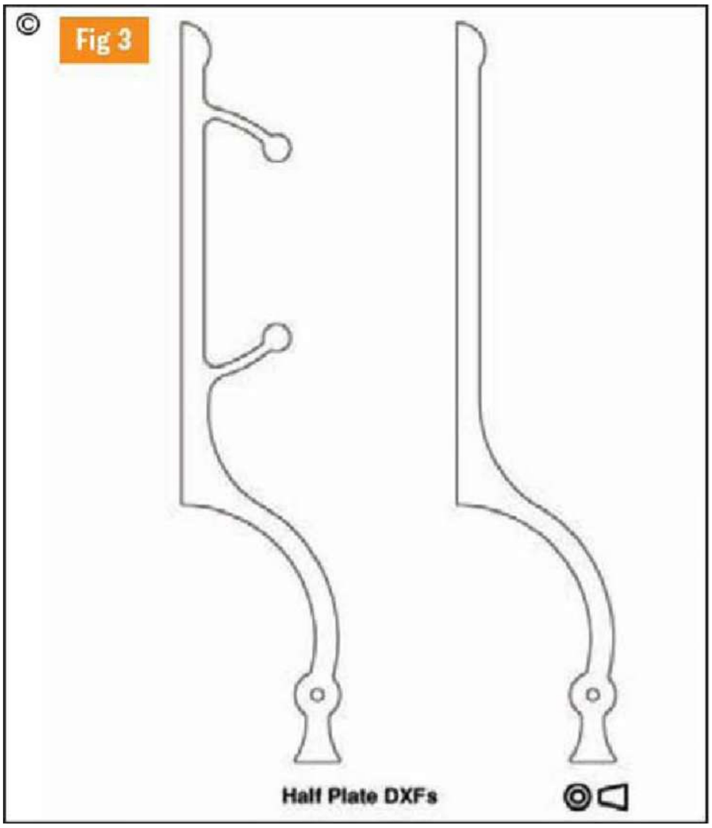
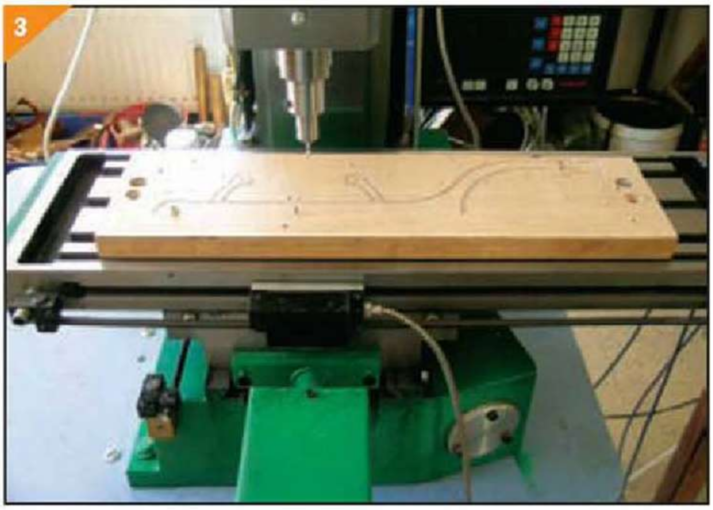




Base for holding me plates.

This clock needs to be carefully constructed in order to reduce the friction in the train to a minimum. Detailed drawings and instructions have been provided for this series along with all measurements.
It must be stressed, that although the dimensions given are precise, these must only be taken as a guide.

As each component of the clock is made its dimensions may need to be tailored to fit with the parts already made. Especially as material sizes may differ from those used in the prototype clocks. Do not attempt to make all the parts, put each aside and when all the parts have been made attempt to assemble the clock. If you do this do not be surprised if nothing fits correctly.

Cutting out the front and back plates

The front and back plates are illustrated in **Figs. 1** and **2.** Full size drawings of the plates will be made available as .dxf or .bmp files. I profiled my plates on my X3 milling machine, which has a maximum travel along the x-axis of 350mm and on the y-axis of 150millimeters. The total length of the plates is 330mm and the width is 140millimeters. The x-axis travel was just adequate provided the work was accurately positioned. The y-axis travel was I felt just a bit marginal to allow the ptate to be profiled in a single operation. To overcome this problem the drawings of the plates were halved along the centre line.

The half plates are illustrated in Fig. 3. Drawings of the half plates will also be made available. Each plate is then profiled in two operations.

Profiling the plates in two operations

To profile the front and back plates in two operations start by cleaning the surfaces of both plates to remove all grease and dirt. J find household cream cleaner works very well as a degreasing agent. Dry the plates and stick them together with double sided adhesive tape. A piece of tape top and bottom will be adequate.

Lightly scribe lengthwise a line in the centre of one plate. This side of the plate will eventually be used for the outside of the front plate of the clock. The rear of the underside plate will be the back of the back plate. It is worth marking these two sides so that you will not make a mistake later. Mark, on the line, the position of the centre arbor on the plate. Put the two plates to one side. Cut a piece of 18mm thick Melamine covered MDF board the same width as the plates and about 60mm longer. Attach the board to the table of the mill with suitable countersunk screws (see **Photo** 3) Clamp the two plates to the MDF board using hold-downs.

Centre the mill exactly on the marked position of the centre arbor The best way of doing this is to use a centring microscope fitted in the spindle of the mill. If you don't possess a centring microscope you should get one or make one using the Hemmingway centring microscope kit. It will soon become an indispensable tool. I use mine continuously for accurate setting up, accurately positioning pivot holes, setting lathe tools at the correct centre height, etc etc.

Drill a 2mm hole at the position of the centre arbor through both plates and 10mm into the melamine board. Remove the two plates and insert a piece of 2mm silver steel 20mm long into the hole in the board. Remember to chamfer both ends of the 2mm peg. Replace the plates using the 2mm peg to position them.

The scribed line must now be orientated precisely along the x-axis of the mill. This is most easily done using a centring microscope. Centre the spindle on the 2mm peg and set the digital readout (assuming you have one) on both x and y to zero. Move the table to x = -80 mm and rotate the two plates until the scribed line intersects the cross hairs. The plates will now be precisely lined up along the x-axis.

Clamp the plates in this position. Move the table a further 5mm to x = -85mm, the position of the top pillar. Drill and ream a 5mm hole through both plates and 10 mm into the board. Make a 5mm brass peg 20mm long, chamfer both ends, and insert it into the hole just drilled. Now move the table to the position of the on the lower pillar i.e. at x = 200mm y = 60mm and drill and ream a second 5mm hole 10mm into the board.

Leave the spindle in this position, remove the plates and turn them over and replace the plates using the top 5mm peg and the centre 2mm one to position the plates. Clamp firmly down and drill and ream the 5mm hole for the second pillar. Remove the two plates and separate them. Double sided tape holds very securely, to make it easier to separate the plates warm the plates to soften the adhesive. Clean off any remaining tape and adhesive using solvent.

Two further 5mm pegs drilled and tapped for 2.5mm metric screws need to be made. These pegs should extend 4.5mm above the surface of the board. The pegs are secured in the two holes in the board using superglue. The length of the 2mm centre peg should also be reduced to 4.5mm above the board.

• *To be continued*

MAGNETIC DRIVE CLOCK

PART 2

Continued from page 202 (M.E 4293, 16 February 2007)

Richard Stephen continues with profiling the plates and moves on to the wheels and pinions.

4. *Back plate ready for profilling.*

5. The *finished plates.*

6. Drill*ing for* the *pins.*

The pegs are secured in the two holes in the board using super glue. The length of the 2mm centre peg should also be reduced to 4.5mm above the board. The back plate can now be profiled. Photograph 4 illustrates the back plate ready for profiling the second half of the plate. The screws securing the plate to the 5mm pegs can be seen. It is essential that before you start profiling that both the plate and all the waste material are very well secured to the board. I find that 20mm panel pins are the best way to secure the waste material. Make sure that the pins will not foul the slot drill.

Returning to the front plate, with the plate and all the waste well secured, check that the 2mm centre hole is still precisely at the origin of the co-ordinates (x = 0, y = 0). Now drill a 1.7mm hole at the position of the two dial pillars x = -42mm, y = 42mm and x = 42mm, y = 42mm. Secure the dial pillar arms to the board with 20mm panel pins. The front plate is now ready for profiling. For a good final finish the following points should be observed.

The finished plates are shown in **photo 5.** The profiling of both pfates after setting up took a morning to complete. Here is some guidance on cutting them out:

The plates are designed for profiling with a 3mm slot drill.

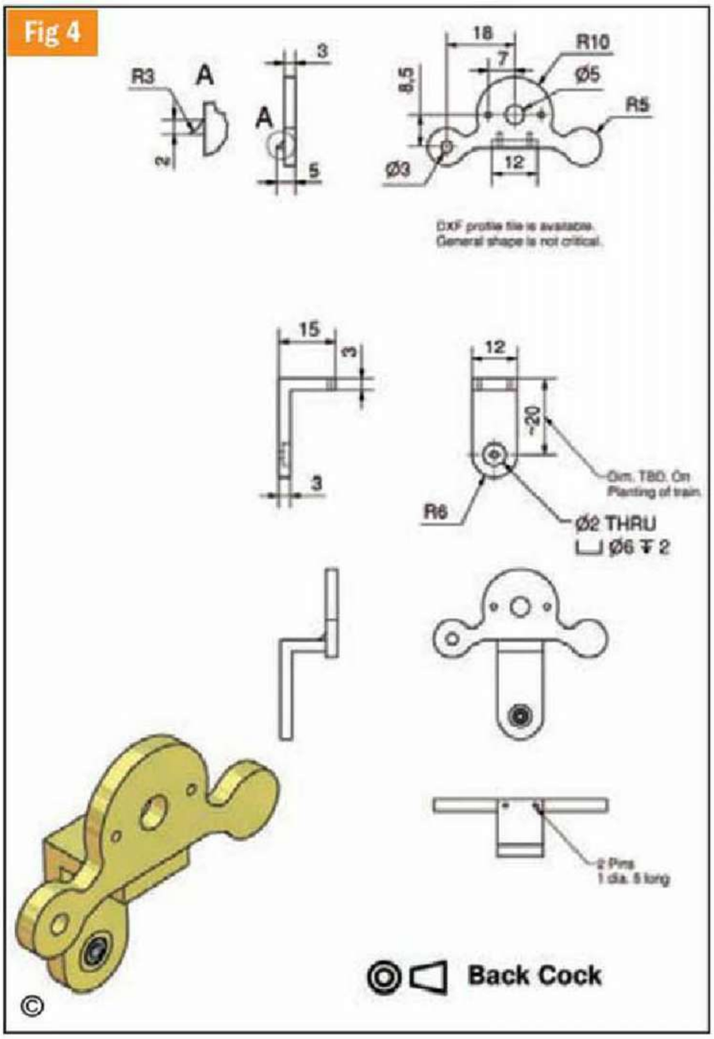
- Use a new slot drill.
- It is necessary to continuously remove the chips that are produced using a vacuum cleaner particularly as the cutting depth increases, if the chips are allowed to accumulate in the cut they will get stuck between the side of the slot drill and the work. This will certainly damage the surface finish and, in extreme circumstances, cause the breakage of the slot drill.

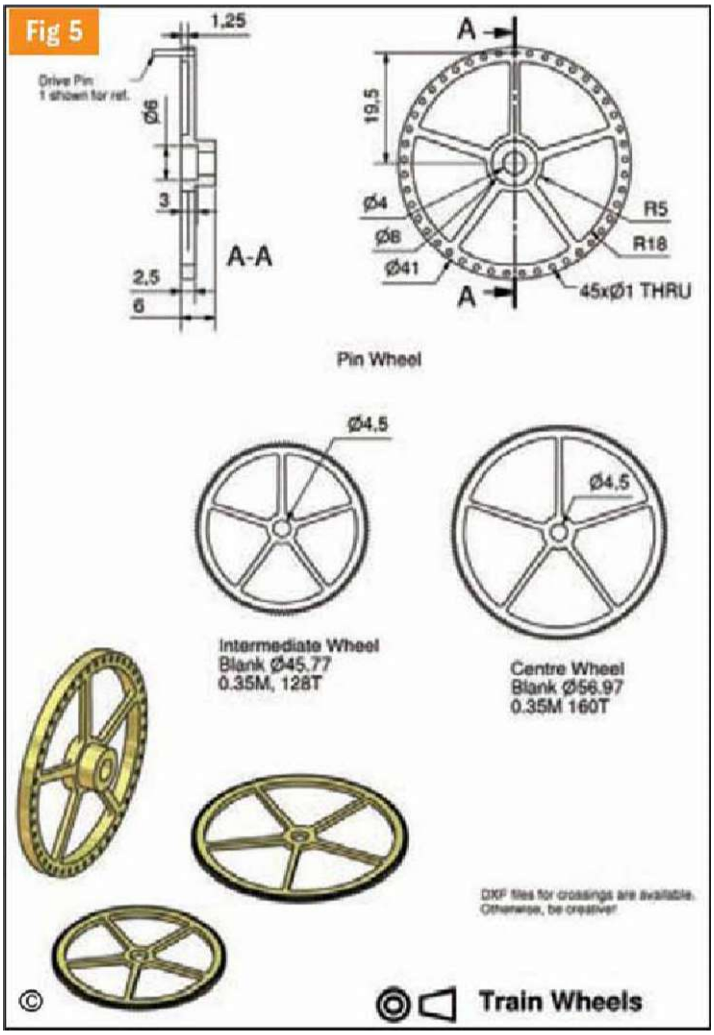
Keep all parts of the work well secured to the baseboard.

- Do not use too high a feed rate 60mm/min is quite fast enough.

A spindle speed of about 2500rpm is ideal if you are cutting dry. The combination of the recommended feed rate and spindle speed will reduce the chip size and make it a lot easier to vacuum chips out of the cut.

If these points are observed you should have almost no





further work to do on the edges of the plates.

Back cock

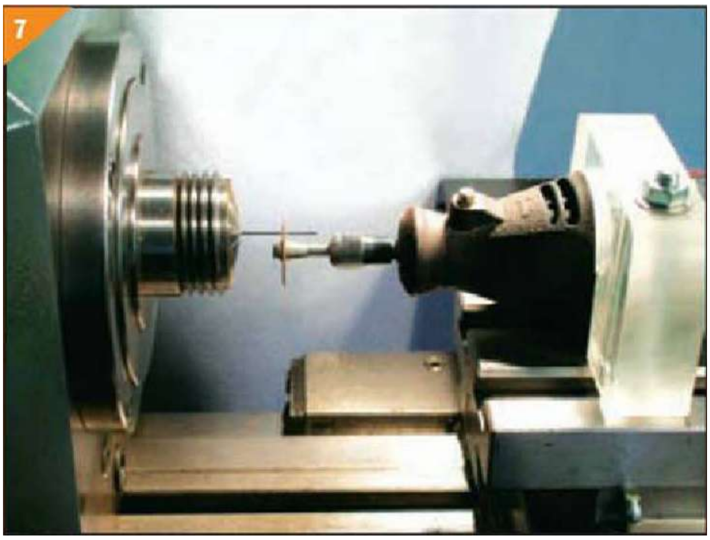
The dimensions and details of the back cock are shown in **fig 4.** The cock is fabricated for ease of construction in two parts. The plate is profiled out of an off-cut of 5mm engraving brass and the L-shaped section cut out of a suitable scrap of 12mm compo brass plate. The plate of the cock is quite small and as a consequence awkward to hold securely for profiling.

I soft-soldered the blank to an off-cut of 3mm brass sheet, which in turn I screwed to a piece of 18mm MDF board which was clamped to the table of the milling machine. The origin of the drawing, and the start point for the profiling is the centre of the 5mm hole that fits on the upper pillar extension. Drill and ream a 5mm hole at the origin. The 3mm hole for attaching the pin wheel non-return ratchet should be drilled and reamed at the co-ordinates shown. Return the spindle to the origin position and profile the back cock plate.

With the profiled plate still in position on the milling machine, reduce the thickness of the

7. Grinding down the pins.

8. Polishing the teeth.



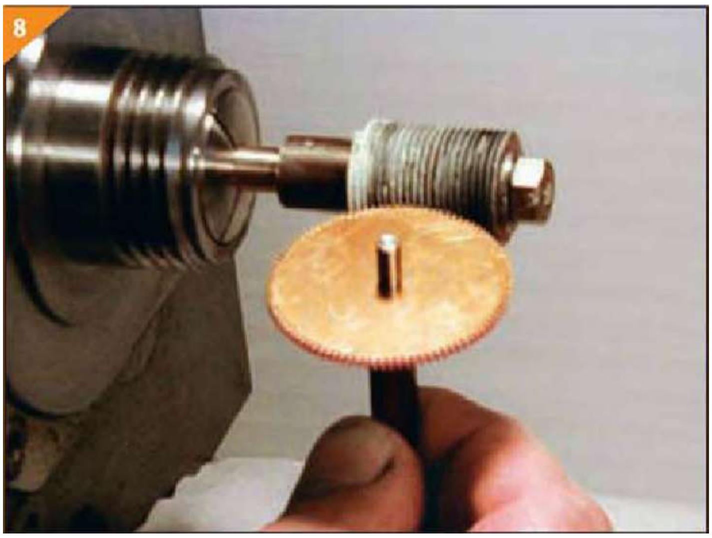


plate to 3mm leaving the section shown the full thickness. Replace the slot drill used for reducing the thickness with a 6mm bail nose cutter and fillet the raised section as shown in fig 4. Remove the plate from its mounting and clean up all the surfaces and edges with wet and dry paper. Now cut the L-shaped section out of a scrap of 12mm thick compo brass plate. Clean up all the edges and surfaces with wet and dry paper. I joined the two sections with Loctite 326 and 1mm brass pins for extra security.

Wheels and pinions

Details of the wheels and pinions are given in fig 5 and fig 6. The pin wheel shown in fig 5 has 45.1mm pins set on the circumferences of a circle 39mm in diameter. The pin wheel forms part of the drive mechanism of the clock.

The pendulum only drives the train as it swings in a clockwise direction The gravity ratchet engages with the pins in the wheel to prevent the pendulum from driving the train as it swings in an anti-clockwise direction (see details of the pinion drive mechanism). The amplitude of swing of the pendulum is determined by the number of pins in the wheel. The pendulum for this clock is designed to have a total amplitude of swing of 8deg. (±4deg.). With this amplitude the pendulum will have to make 45 complete oscillations (i.e. periods) for the pendulum arbor to make a 360deg. rotation. For a half second beating pendulum (period 1 second) this will take exactly 45 seconds. The centre arbor of the clock takes 60x60 = 3600 seconds to make a complete revolution. Dividing 3600 by 45 gives 80 (8 x 10) as the gear ratio required between the pin wheel and the centre arbor. The train uses 0.35 module 16 leaf pinions through out. Suitable wheel counts for the intermediate wheel and centre wheel, using the above factors, are 128 and 160 teeth respectively.

Pin wheel

The pin wheel is made from a disc of free machining brass 6.0mm thick and 45mm in diameter. I cut my disc off a length of 50mm dia. brass bar. If you use brass bar, begin by facing off the end. Turn down the end to form a boss 3.5mm long and 8mm in diameter. Drill and ream a 4mm hole about 8mm deep in the centre. Now part off the blank, 8mm from the end of the boss. This will leave you plenty of material to true up the parted off end and reduce the thickness of the blank to 2.5mm (6.0mm including the boss). Turn the blank down to 45mm in diameter. The 45 holes for the pins should be drilled next. The holes are drilled on the circumference of a circle 39mm in diameter. The wheel will eventually be reduced to 41mm in diameter. This diameter leaves adequate clearance between the wheel and the arbor of the intermediate wheel.

Photograph 6 illustrates the set-up I used to drill the pin holes. The stepper drive dividing head was mounted vertically on the table of the milling machine using an angle plate. My gear cutting programme was configured to drill the 45 pin holes. I used a Sphinx 1mm micro drill.

Grip the 8mm wheel boss in a collet and reduce the diameter to 41 millimetres. The wheel is then recessed to a depth of 1.25mm leaving a rim of width 3mm and a boss 10mm in diameter. Bore the 4mm hole in the centre to 6mm diameter to a depth of 3mm. The wheel can now be crossed out, the dimensions of the crossings are shown in fig 5. Clean and polish the crossings before you insert the pins.

The 1mm pivot steel pins should be cut next. The blue pivot steel must first be polished with fine wet and dry paper to remove all traces of the blue. Unless this is done the Loctite used to secure the pins in the holes will not cure. Loctite requires both surfaces to be clean metal if the adhesive is to cure and grip.

Photograph 7 illustrates the set-up I uses to cut the pins.

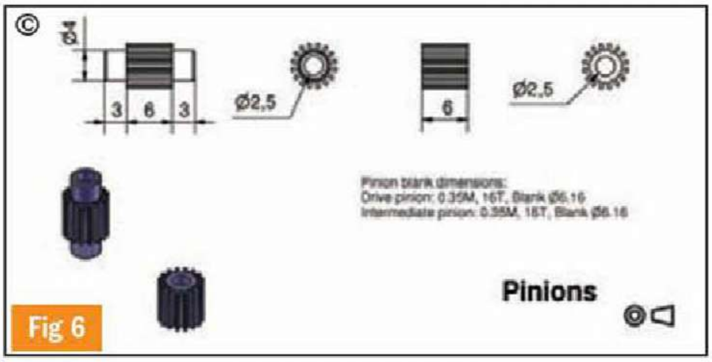


Fig 6

The Dremel, fitted with a 20mm diameter carborundum grinding disc, was clamped to the top slide of the lathe using a home made clamp. Grip a length of pivot steel in the lathe using a collet If you have one. Leave no more than 25mm sticking out. With the lathe turning fast and the Dremel set to maximum speed true off the end of the length of pivot steel. Using a slip stone remove the sharp corner of the end of the pivot steel. Advance the top-slide 9mm and with both the lathe and Dremel running cut off a length of pivot steel. Again remove the sharp comer and cut off a second length. Continue cutting until you have cut off 45 pins and a couple of spares.

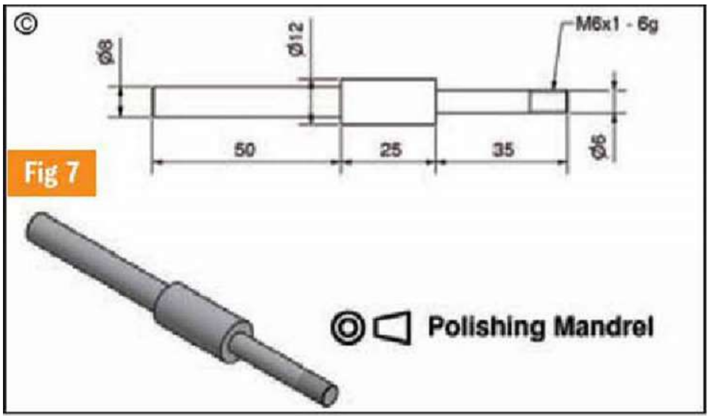
The pins can now be inserted in the holes in the wheel rim and secured with Loctite 603. Press the ends of the pins flush with the back of the wheel rim. Carefully remove all excess Loctite from around the pins as you insert them. If any traces of Loctite remain after all the pins have been inserted this can be removed with a little Xylene solvent (if you can get some). To finish the wheel the pins all need to be ground to the same length (approximately 6.5mm proud of the surface) again using the Dremel grinder and the carborundum grinding discs.

The set-up is illustrated in photo 7 is used to grind down the pins. Grip the wheel by the boss in a collet or chuck. With the lathe turning slowly and the Dremel at maximum speed slowly advance the grinding disc until the pins are all ground to the same length, about 6.5mm from the wheel surface. This completes the pin wheel.

The pinions and wheels are made next. The dimensions of the wheels, pinions and the design of the wheel crossings are shown in fig 5 and fig 6, I make my pinions out of EN1A mild steel as this steel cuts very cleanly and preserves the edge of the very expensive Thornton cutters I use. The drive wheel pinion is made with a 4mm diameter by 3mm long boss at each end. The holes in the pinions are drilled 2.5 millimetres.

Case hardening the pinions

Before hardening the pinions true up and smooth the ends. The safest way to do this is to use the side of a carborundum dental cutting disc in a Dremel mini-drill. Hold the pinion in a collet in the lathe and grind the faces true. Now make a mandrel out of a 60mm long scrap of 3mm steel rod. Using a file taper the end so that it fits tightly into the hole in the pinion. Grip the mandrel in the chuck of a cordless or a hand drill (not mains powered). Check the pinion rotates truly. Heat the pinion with a blowtorch while at the same time rotating it To minimise the formation of scale use the end of the flame not the base. When it is hot (not red) dip it in the case hardening powder and return to the flame. Repeat this process until you have built up a good covering on the pinion. Now heat the pinion up to red heat and maintain it at red for at least two minutes all the time rotating it in the flame. This continuous rotation ensures the pinion is evenly heated. Quench the rotating pinion in cold water. Quenching while rotating will prevent any distortion from occurring. With the wheels cut and the pinions hardened the



teeth on both the pinions and wheels should be polished. Polishing the teeth significantly reduces the engaging friction.

Polishing the teeth of the wheels and pinions

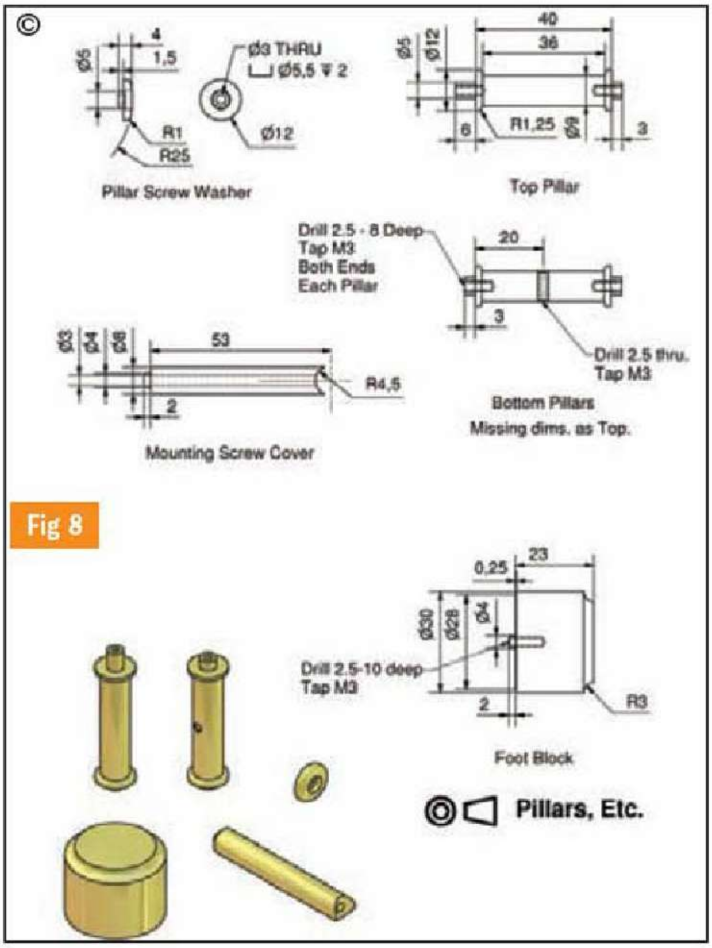
Readers may wonder why I go to the bother of polishing the wheel teeth. If one examines the teeth of a newly cut wheel under a microscope it is clear that the teeth are not smooth. Cutting the teeth even with the sharpest cutter will leave a slight surface roughness. This surface roughness generates a certain amount of friction as the wheel engages with the pinion. The presence of this friction is highlighted by the sound the wheel makes as it engages with the pinion before and after polishing the teeth. The sound generated reduces significantly after polishing indicating a reduction in friction. If polishing the teeth was a time consuming exercise it would possibly not be worth doing. Fortunately it is not.

Making the polishing hobs

To make the hobs you will need a piece of box wood (the best) or any other hard close grained hardwood 70mm long and 30 x 30mm. Centre the block of wood in a 4-jaw chuck and turn a cylinder approximately 30mm in diameter. Drili a 6mm hole through the cylinder and cut it into two pieces about 30mm long. This gives enough to make two hobs one for brass wheels and one for hardened pinions. Make the mandrel shown in **fig 7** and attach one of the hob blanks. Screw-cutting wood is a problem using conventional screw-cutting methods because the wood being rather brittle tends to break up. The easiest way to cut a clean thread in the hob is to use a milling spindle on a vertical slide fitted with the cutter used to cut the wheel you want to polish. Fix the vertical slide so that the axis of the milling spindle is parallel to the bed of the lathe. Running the cutter as fast as possible, cut the thread in the hob blank in the same way as you would any other thread. The pitch of the thread should be the same as that of the wheel you want to polish. For both versions of the clock you will need four hobs two for the 0.35 module wheels and pinions and two for the 0.40 module wheels and pinions. Suitable pitches for the hob threads are **1**.10mm (0.35 mod) and 1.25mm (0.40 mod).

Polishing the teeth

Grip the mandrel in a collet or 3-jaw chuck. The hob first needs to be charged with a polishing compound. If the wheel being polished is made of brass, the polishing compound must be a non-embedding abrasive. The best non-embedding abrasive I have found is Autosol polishing paste for car paint work. This works equally well on hardened pinions. An advantage of non-embedding abrasives is that they will do little damage to the lathe if by chance some gets on the bed. Rather than taking any chances protect the lathe bed and compound slide with paper towel to ensure that the abrasive doesn't go where it shouldn't! To polish the teeth hold the wheel on a hand held



arbor. Engage the wheel in the thread of the hob, as shown in **photo 8** with the plane of the wheel inline with the axis of the hob. Run the lathe at about 500rpm. As the hob rotates the wheel is forced to rotate as well engaging with the abrasive loaded hob thread. As the wheel turns one flank of each tooth is polished. To polish the other flank, simply turn the wheel over on the arbor. The advantage of this method of polishing is that it does not damage the tooth form of the wheel. Polishing the teeth before you cross also avoids any possibility of distorting the wheel. Polishing pinions with a hand held arbor is a bit awkward because of their small size. Instead I use a fixed arbor as illustrated in **photo 9,**

Pillars, feet blocks, screw covers and washers

The details of the piilars, feet blocks and the covers for the mounting screws and washers are illustrated in **fig 8.** The two lower pillars are cross drilled and tapped 3mm precisely in the centre of each pillar.

To be continued.

9. Set-up for polishing pinions.

MAGNETIC DRIVE CLOCK

PART 3

Continued from page 329 (M.E. 4295, 16 March 2007

Richard Stephen continues his instructions with a different type of pinion drive and the various arbors.

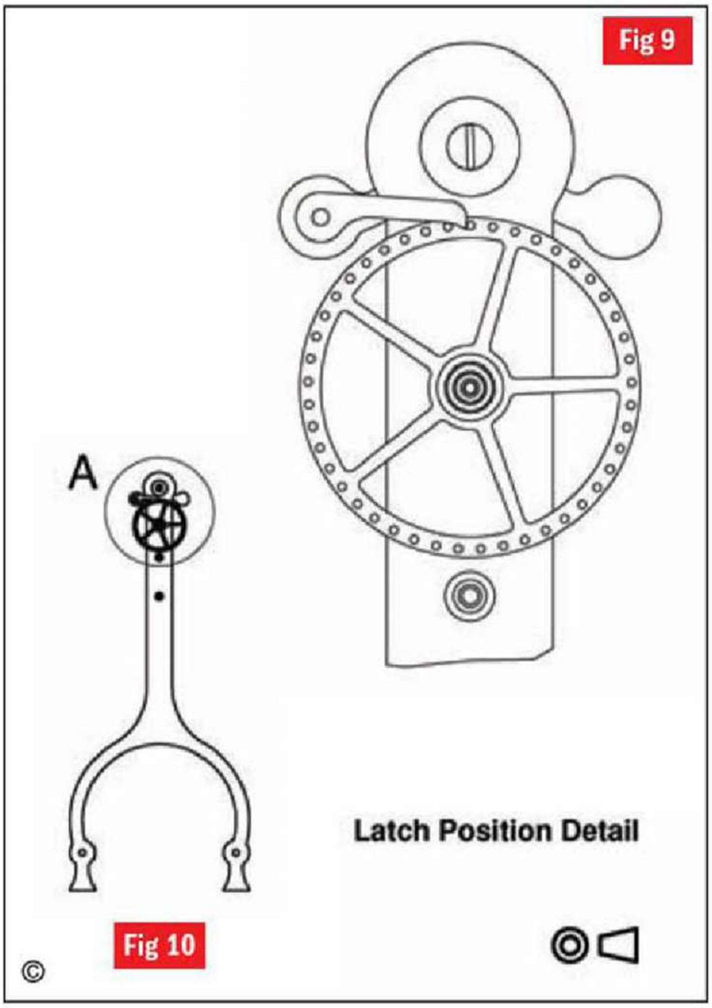
The threaded holes in the two lower pillars are for the screws that secure the movement to the feet blocks and the base. Machining these components should present few problems. The two screw covers still need to have the ends fitted to the two lower pillars. This can be done once the base and the feet blocks are made.

Fitting the back cock

The back cock is fitted to the back plate next. To initially position the cock you will need to make a peg to position and secure the cock to the back plate before you can drill the 1.5mm holes for the two register pins. The peg is made from a scrap of 8mm brass rod about 8mm in length. Face off both ends and turn down one end to 5mm for a length of 6.2 millimetres. Drill a 2.6mm hole and tap it 3 millimetres. Mark a centre fine on the back surface of the L-section of the cock.

Assemble the cock on the back plate. Align the centre line of the back plate along the x-axis of the mill. Position the back cock so that the centre line you have just marked also coincides with the centre line of the back plate. It is very important to precisely align the back cock as the cock carries the non-retum ratchet for the pin wheel.

Figure 9 illustrates the position of the non-return ratchet relative to the pin wheel. The arbor of the ratchet must be precisely at the position indicated if the ratchet is to function correctly. This in turn requires the back cock to be correctly positioned. With the back cock correctly positioned the holes for the 1.5mm register pins can now be drilled at the positions indicated on **fig 10.** The two register pins are secured in the back cock with Loctite 326. The cock is reassembled on the back plate and the register pins cut off flush with the inner surface of the plate.



The pinion drive mechanism

The pinion drive mechanism is illustrated in fig 11a. As mentioned earlier, the train of this clock is different to the train of all conventional clocks that are wheel driven. Energy to maintain the pendulum motion is derived from a falling weight or tensioned spring and transmitted to the pendulum by a train of wheels and pinions. In the majority of magnetically driven clocks the motion of the pendulum is maintained by applying energy directly from an external source.

A magnet attached to the pendulum is either attracted to or repulsed by a magnetic field induced in a solenoid by an electric current applied to the solenoid as the pendulum swings. A portion of the pendulums energy is used to drive a train to move the hands of the clock. The basic problem with this system is that the swinging pendulum rotates both clockwise and anti-clockwise, where as the train that moves the hands must only rotate in one direction i.e. the centre arbor must rotate clockwise.

A variety of mechanisms have been developed for this purpose in magnetically driven clocks usually involving some form of ratchet and pawl type mechanism. In these movements the pendulum is suspended in the conventional way using a suspension spring. The ratchet and pawl mechanism has to be attached at some point on the pendulum rod. The closer to the point of suspension this mechanism is attached the greater will be the torque the pendulum can apply to the train.

To maximise the available torque the pendulum of this clock is suspended on ball races and attached to an arbor that forms part of the train. As the pendulum swings the pendulum arbor rotates both clockwise and anti-clockwise. A roller clutch incorporated in the drive mechanism and attached to the drive pinion allows the pendulum arbor to rotate freely anti-clockwise but locks to the arbor when the pendulum rotates clockwise and so drives the train. Since the centre wheel rotates 80 times slower than the drive pinion there is more than adequate torque available at the centre wheel, to drive the motion work and the hands without significantly compromising the motion of the pendulum.

The details of the drive mechanism are illustrated in fig 11a, Begin by making the housing for the roller clutch. This is made from a 12mm length of 10mm diameter EN1A mild steel. Face both ends of the piece of steel and reduce the length to 9mm and just clean up the outer diameter.

The hole for the roller clutch needs to be made next. The diameter of the roller clutch is 6,5mm, the diameter of the hole in the housing is just slightly less than this as the clutch is a press fit into the housing. The hole in the housing needs to be 6.4985mm exactly. To facilitate boring the hole to this size you will need to make a test bar 6.498mm in diameter. Drill a hole in the housing 6.3mm in diameter. Using a small very sharp boring bar gradually bore the hole until you can just insert the test bar. The diameter of the hole should now be just right.

Check that the roller clutch will just not slip into the hole. Using some fine wet and dry paper wrapped around a length of 5mm dowel rod, taper the front of the hole for about 2mm until you can just insert the end of the clutch. Do not insert the clutch at this time. Cut off a piece of 8mm diameter EN1A about 8mm long. Face both ends; reduce the diameter to 7mm and the length to 5mm. Now turn down one end for 3mm to make an easy fit (not loose) into the end of the housing {not the tapered end). You may need to slightly chamfer the edge of the hole in the housing to get the insert to but snugly.

Attach the piece into the end of the housing using Loctite 326 adhesive. Holding the housing in a collet turn down the insert to 6mm and drill a 4mm hole in the end. Fit the housing and the pinion into the pin wheel and check that they line up accurately. The pinion bearing housing is made next. This is made from a piece of EN1A mild steel 6mm diameter and 5mm long. Face both ends and drill and ream a 4mm hole. I used an aluminium bronze bush for the drive bearing.

Turn a piece of aluminium bronze to 4mm diameter and cut off a 3mm length. Fit the piece into the end of the housing to a depth of 2mm and secure with Loctite 326 adhesive. Turn down the end flush with the end of the housing. Drill and ream a 2mm hole through the aluminium bronze insert. Reverse the housing in the lathe and drill the insert to a depth of 1mm with a 3mm drill to reduce the length of the bearing to just under 1 millimetre. The drive mechanism can now be assembled and fitted to the pin wheel. Do not insert the roller clutch at this time.

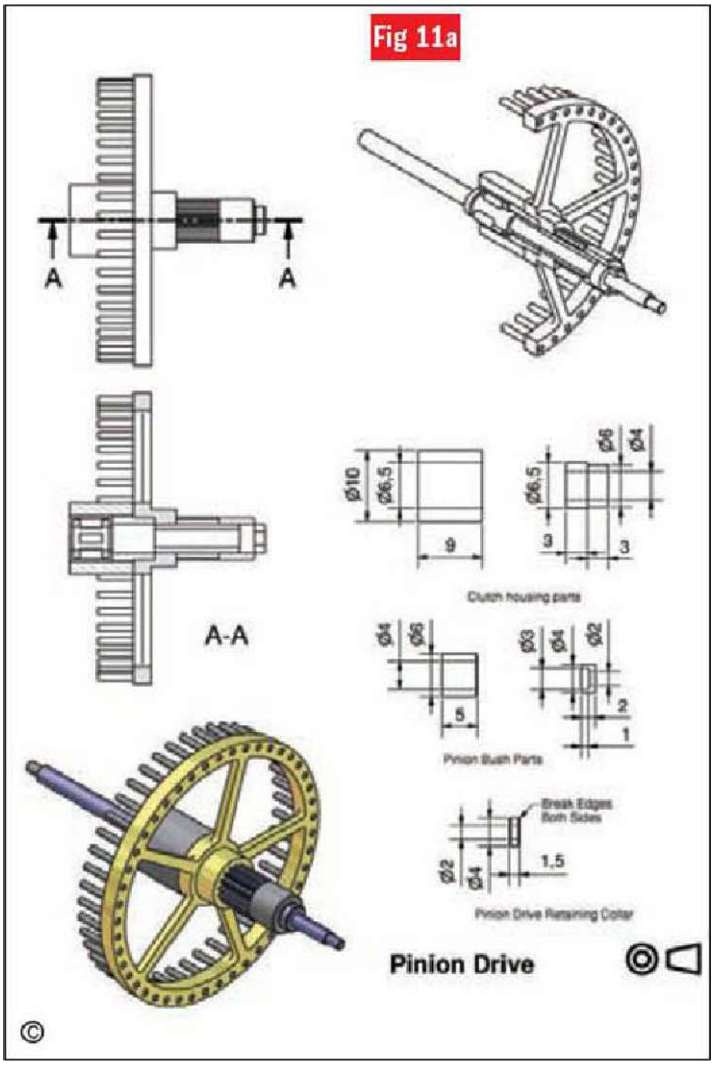
The arbors

The details and dimensions of the arbors are shown in fig lib. All the pivots except one on the pendulum arbor and the front of the centre arbor are made from 1.5mm pivot steel rod inserted into the ends of the arbors and secured with Loctite 326 adhesive.

The intermediate and centre arbors

The intermediate and centre arbors are illustrated in fig lib The intermediate arbor is made from a length of 2.5mm silver steel. Measure the spacing between the plates and make the arbor 0.5mm less than the measured length. Drill a 1.5mm hole in each end to a depth of 4mm. Loctite lengths of 1.5mm pivot steel (blue removed) into the holes and reduce the length of each pivot to 2.5 millimetres.

The centre arbor is fabricated out of a length of 4mm silver steel and a length of 2mm silver steel for the motion work arbor. Again measure the spacing between the two plates and note this value. Cut off a length of 4mm silver steel 7mm longer than the spacing you have measured. Face off one end and drill and ream a 2mm diameter hole in the end to a depth of 12mm for the 2mm motion work arbor. Turn down the end to 3mm diameter for a length of 6mm to fit the front 3mm ball race.



Square off the shoulder and check the 3mm race is an easy fit right up to the shoulder. Face off the other end and reduce the length from the shoulder to 0.5mm Jess than the measured spacing. Drill a 1.5mm hole for the pivot to a depth of 4 millimetres. Fit the pivot and reduce the length to 2.5mm. Now turn down the end to 2.5mm for a length of 9 millimetres.

I gently tapered my centre arbor as can be seen in fig lib. This looks a bit more elegant than leaving it plain. The 2mm front section for the motion work will be made and glued in position later when the dial is in place and the motion work is completed. This will allow the correct arbor length and position of the retaining groove to be determined.

Pendulum arbor

The pendulum arbor is fabricated in two parts from a length of 2.5mm diameter silver steel rod and a length of 4mm diameter silver steel rod. The constructional details of the arbor and the drive assembly are illustrated in figs 11a and 11b. Assemble the plates, pillars and the back cock.

Measure the distance between the inner surface of the back cock and the inner surface of the front plate. The pivot that fits into the front plate bearing is integral with the arbor. Add 2.5mm to the measured length to allow for the pivot. Turn a 1.5mm pivot on the end of the piece of rod. Carefully square off the shoulder of the pivot and check that the pivot is an easy fit in the 1.5mm ball race. Now turn down the arbor for a length of 35mm to 2mm diameter. Drill a 1.5mm hole in the other end of the arbor to a depth of 4mm for the second 1.5mm pivot. Set a piece of 1.5mm pivot steel (remove the blue with fine wet and dry) into the hole with »

Loctite 326. Cut off and reduce the pivot length to 2.5mm and chamfer the end.

Make the hardened sleeve from a length of 4mm silver steel about 12mm long, Face both ends. A 2mm hole is now drilled and reamed through the full length. Check after you have drilled the hole that it is central. Turn down to 3.0mm diameter for a length of 7mm, remove all tool marks and finish the surface with fine wet and dry paper Now reduce the length to 8mm leaving a collar 1mm long. Again remove all tool marks and finish with fine wet and dry leaving a fine polished surface. Now insert the sleeve into the roller clutch. The clutch will grip the sleeve when turned one way and rotate when turned the other way. You will feel a small amount of resistance when the sleeve turns 'freely'. If required, carefully reduce the diameter in small increments until the sleeve turns freely in the clutch one way but still grips when turned the other way.

The sleeve now needs to be hardened. To hold the sleeve taper the end of a 100mm length of 3mm mild steel rod to fit into the end of the sleeve. Grip the rod in a cordless drill and fit the sleeve onto the end. Check that the sleeve runs true. With the drill running heat the sleeve cherry red and with the drill still running, quench the sleeve in cold water.

Return it to the lathe and re-polish the end. Grip it again in the drill and heat to a pale straw and quench in water. Polish the surface again. The 2mm bore will have oxidised as a result of the hardening and will have to be cleaned before it can be fitted with Loctite to the arbor. Loctite will not cure properly if the surfaces are oxidised.

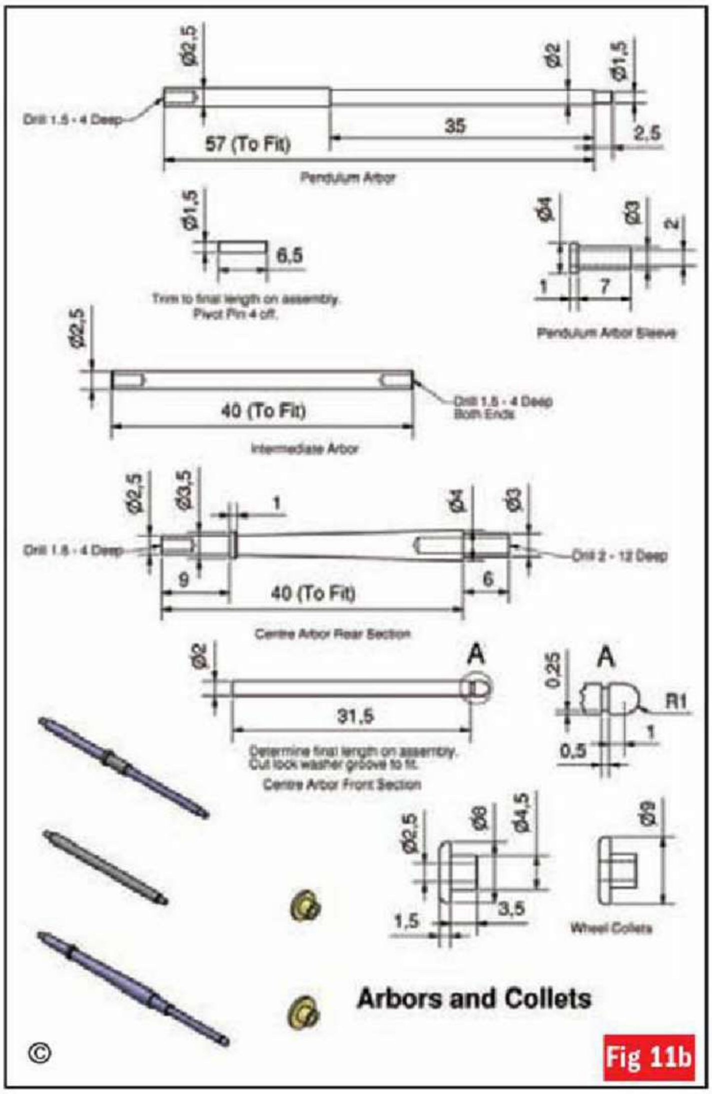
The easiest way to clean the bore is to use a wooden toothpick covered with Autosol paste. Grip the long end in the lathe and with the spindle running quite fast run the toothpick in the bore until all scale is removed. Clean off all traces of the paste. Fit the hardened and tempered sleeve in place on the arbor using Loctite 603.

Inserting the roller clutch into the drive housing

The roller clutch can now be fitted into the housing of the drive mechanism. Before fitting the roller clutch into the housing it is necessary to check that it is being inserted correctly. Once you have pressed the clutch into the housing it will be very difficult to remove it again.

The roller clutch must grip the arbor when it is turned clockwise i.e. the pin wheel must turn clockwise when viewed from the front of the clock and remain stationary when the arbor is rotated in the opposite direction, Once you have determined the correct orientation of the crutch it can be pressed firmly in place in the housing.

•To *be continued.*



Arbors and Collets

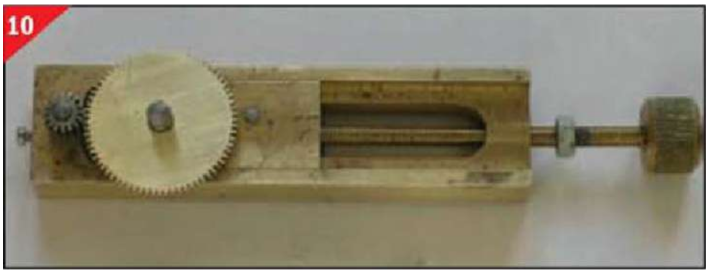
Fig 11b

PART 4

Continued from page 448 (M.E. 4297, 13 April 2007)

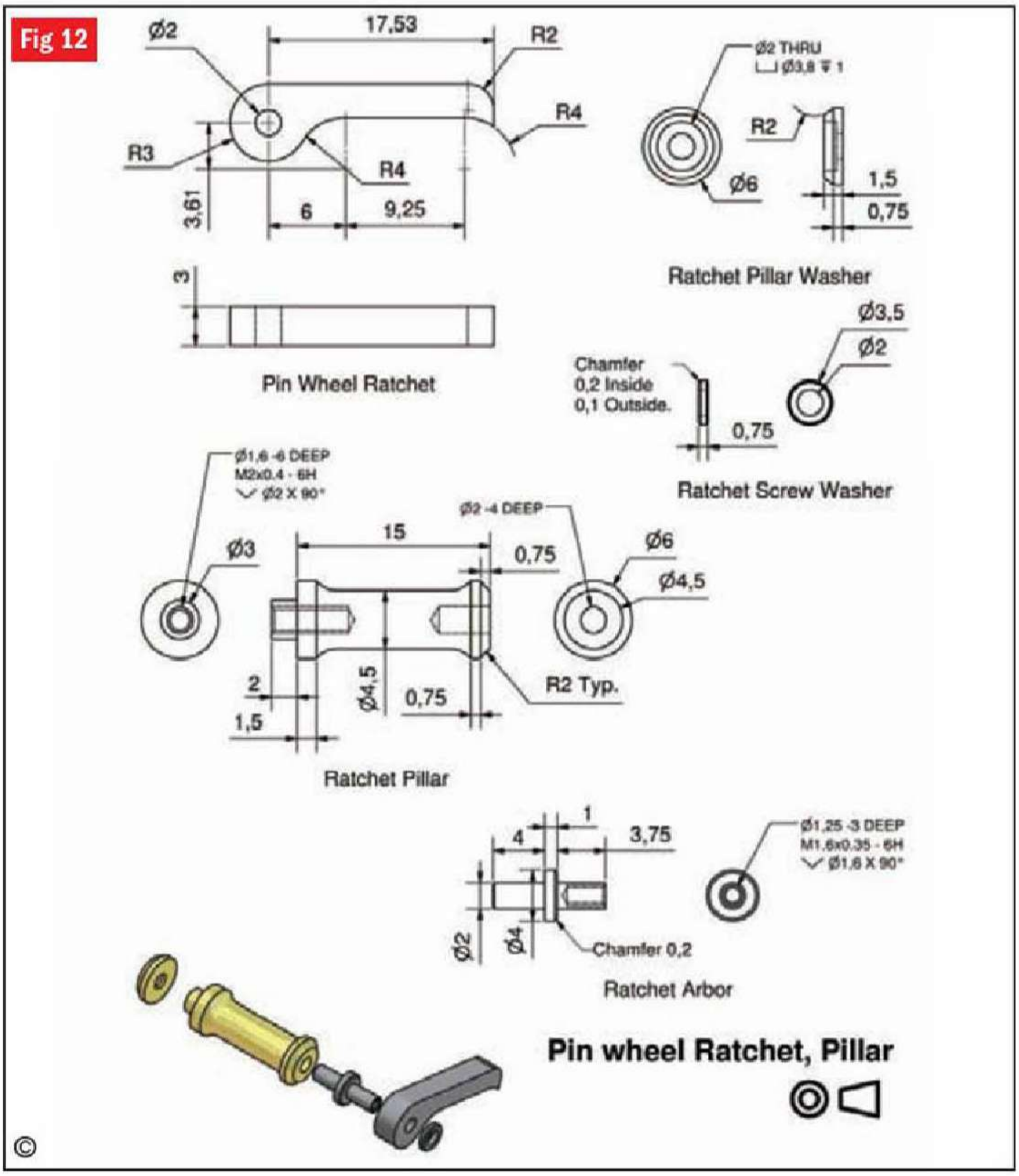
Richard Stephen continues the construction of this fascinating clock by depthing the wheels.

MAGNETIC DRIVE CLOCK



10. Depthing tool.

Fig. 12. Pin wheel ratchet



I use the depthing tool shown in **photo 10** for depthing my wheels. The advantage of this tool is that it allows very precise adjustment of the arbor spacing, as well as allowing the engaging of the wheel and pinion to be examined either with a hand lens or a binocular microscope.

It is worth taking some trouble with the depthing to minimise the engaging friction between the teeth. A special runner will have to be made to depth the drive pinion and the Intermediate wheel because of the roller clutch.

The train can now be planted. All the bearings used in the clock are precision ball races. For minimum friction, the ball races must not be a tight fit in the plates or this will increase the friction in the bearings. The bearings should be a light push fit just tight enough not to fall out.

I have found that it is very difficult to bore blind holes in the plates for the ball races with this precision of fit. Instead I find it a lot easier to counter bore oversize holes and to make sleeves for the ball races.

Most readers will not have suitable counter bores available. A slot drill of a suitable size will work just as well provided the work is securely held in a milling machine,

The plate must be precisely centred and firmly clamped down. To centre the plate you can either use a centring microscope or you can use the method shown in **photo** 11. A 2mm drill rod was held in the drill chuck and passed through the 2mm hole in the brass plate. I have a set of HSS metric drill blanks in 0.1mm increments, I find these invaluable for all sorts of jobs as these blanks are absolutely true as well as being hard. Fit the 2mm rod into the hole in the plate and lower the spindle until the plate can be clamped firmly down. Raise the spindle and remove the rod. Rotate the spindle by hand, and re-insert the 2mm rod. It should enter the hole without any resistance. If it does the plate will be precisely centred.

To counter bore the recess for the 3mm ball race you will need an 8mm slot drill. Centre the spindle of the mill on the hole in the plate. Fit an 8mm slot drill into the spindle and bore a recess 2.5mm deep. Finally drill a 3.2mm hole through the front plate to give adequate clearance for the centre arbor. Repeat the above procedure to counter bore the recess in the back plate for the 1.5mm race. Use a 6mm slot drill and drill the recess which is 1.6mm deep. The existing 2mm hole will give more than adequate clearance for the end of the pivot.

The remaining two wheels can now be planted. Fit the two plates together using the three 5mm register pegs. A peg for centring is made next. Turn down a piece of 6mm brass rod, face off the end and turn down to 3.2mm diameter for a length of 6 millimetres. Drill and ream a 2mm hole to a depth of about 9 millimetres. Part off the peg 8mm from the end. Fit this peg into the hole in the front plate.

Now repeat the procedure using a 2mm dia. rod to centre the spindle on the centre arbor. Check that the rod will pass through both plates without any resistance. Clamp the plates to a piece of 18mm MDF board. Now drill a 2mm hole into the MDF board using the 2mm hole in the plates as a guide. Replace the 2mm drill with the 2mm rod and pass the rod through both plates and into the MDF. Zero the digital readout on the mill.

Remove the drill chuck and fit the centring microscope into the spindle. Move the table about +50mm along the X-axis. Focus the microscope on the front plate and rotate the two plates about the 2mm rod until the crosshairs of the microscope are on the centre line marked on the front plate. The plates will now be precisely orientated along the X-axis. Clamp the plates in this position. Return the digital readout to the zero position.

The remaining two pivot holes can now be drilled. Drill a 2mm hole through both plates for the intermediate wheel and for the pendulum arbor. Separate the two plates and, following the description above, bore the 6mm diameter recesses for the front and back plates for the intermediate arbor and in the front plate for the pendulum arbor.

The pivot hole for the rear pendulum arbor bearing in the back cock must be drilled next. Place the back plate on a suitable piece of MDF board. Centre the mill spindle on the 2mm hole in the back plate for the pendulum arbor as described above. Clamp the plate to the board. Fit the back cock onto the back plate and secure with a 3mm screw and washer as described above. Drill a 2mm hole through the cock. »

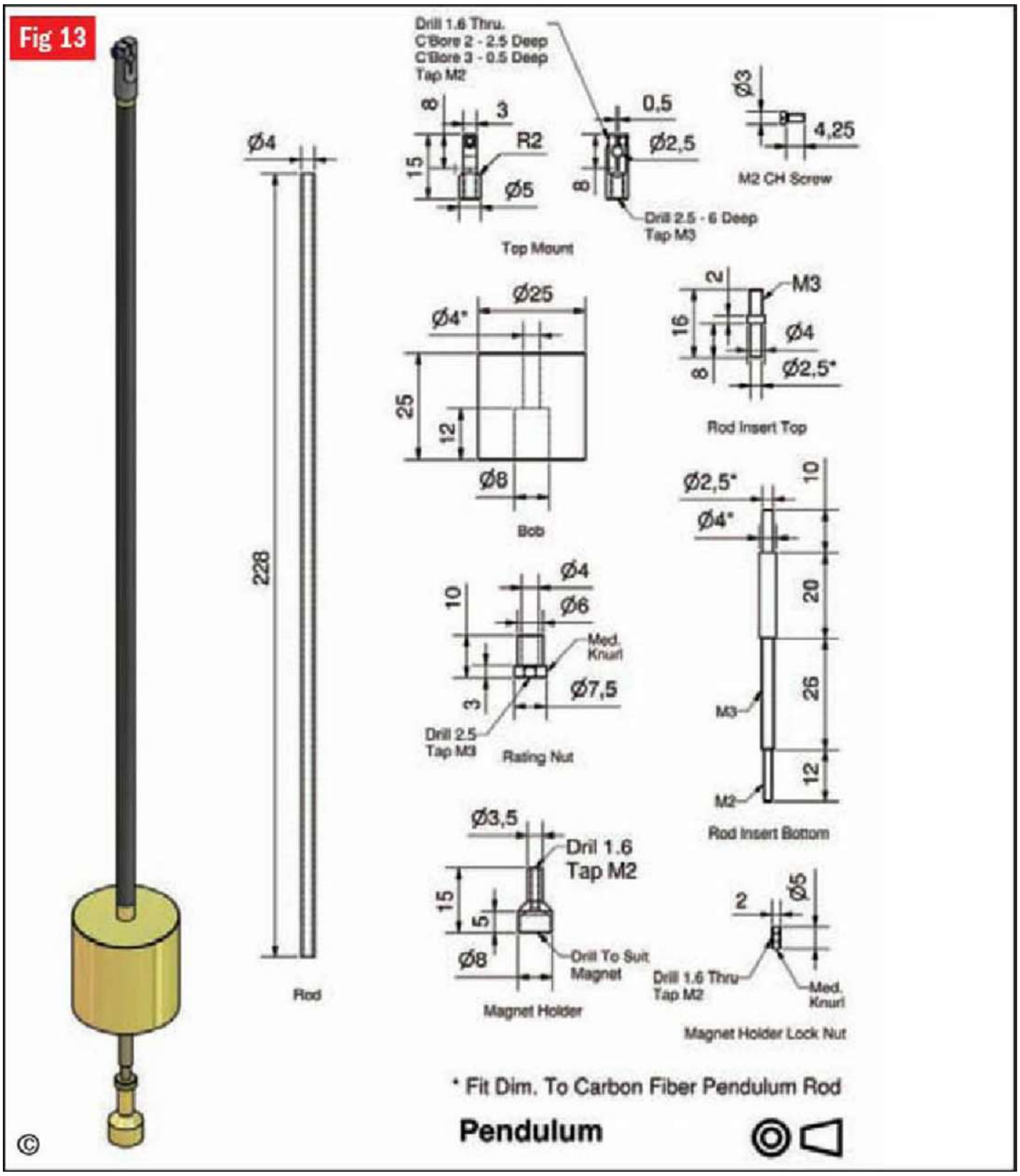
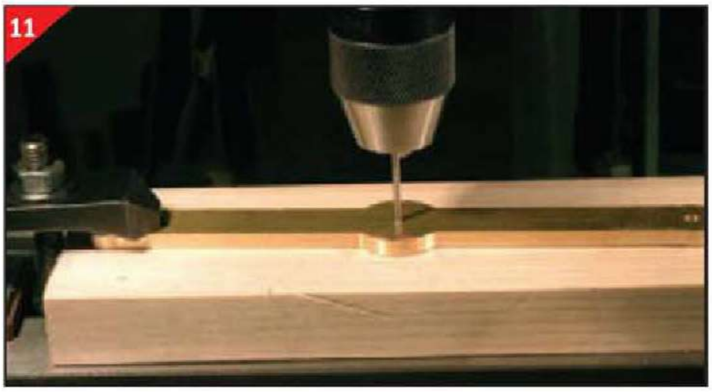
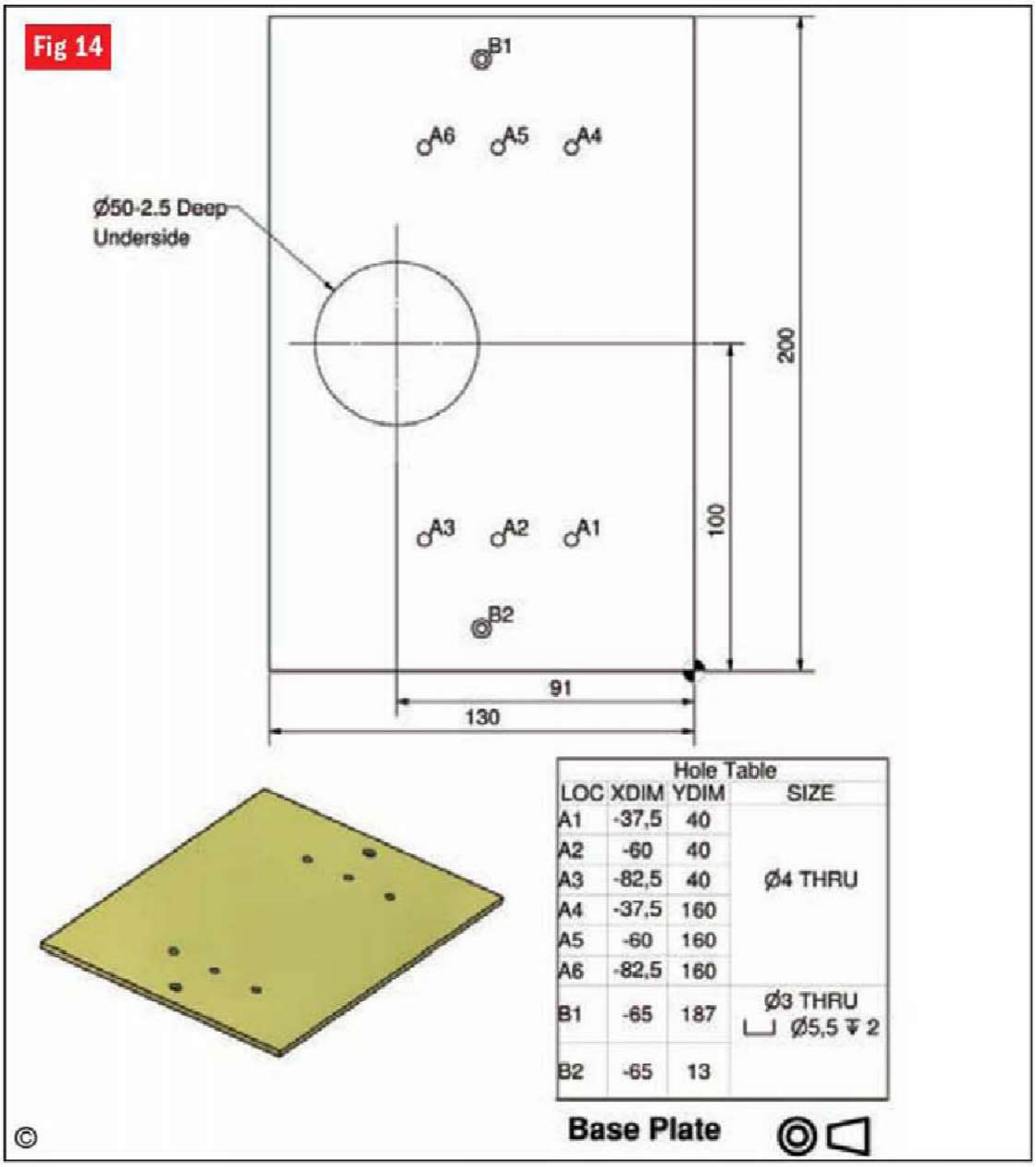


Fig. 13. Pendulum.



11. Centring the plate.



Hole Table			
LOC	XDIM	YDIM	SIZE
A1	-37,5	40	Ø4 THRU
A2	-60	40	
A3	-82,5	40	
A4	-37,5	160	
A5	-60	160	
A6	-82,5	160	
B1	-65	187	Ø3 THRU ⌴ Ø5,5 ↧ 2
B2	-65	13	

Fig. 14. Base plate.

Leave the plate clamped to the board. With the back cock attached to the back plate a 2mm rod should pass easily through the hole in the cock and the hole in the plate. Remove the back cock and then drill a 4mm hole through the back plate centred on the 2mm hole. This will give adequate clearance for the pendulum arbor. Drill the 6mm recess in the back cock for the rear pendulum arbor bearing.

Bearing sleeves

The bearing sleeves are made from scraps of brass rod. For the 3mm bearing sleeve you want about 12mm of 10mm diameter brass rod. Grip the rod in a collet and face off the end. Drill and ream a 6mm hole through the length of rod. Turn down the end of the rod for about 6mm to fit in the recess in the front plate. The fit must not be tight an easy fit is what is required. Before, part off a piece about 2.8mm long and lightly chamfer the end of the sleeve.

The sleeve can now be fitted into the recess and secured with Loctite 326. Carefully clean out any excess adhesive from inside the sleeve. File the sleeve flush with the surface of the plate. Using a hand countersink chamfer the inside of the sleeve. The bearing will be a snug fit and should not fall out easily. Follow the above procedure to make the sleeves for the 1.5mm ball races.

Pin wheel ratchet

The details of the pin wheel ratchet, pillar and arbor are illustrated in **fig 12.** The length of the pillar is given in fig 12. However, the length is best determined with the pendulum arbor and drive wheel in position between the plates. The ratchet wants to rest midway along the length of the pins. The ratchet must be exactly to the dimensions shown in fig 12 for it to operate correctly.

I used CNC to profile my ratchet, which I made from a piece of 3mm thick EN1A mild steel, I always use this grade of steel for small components simply because I get a perfect surface finish. I then case harden the part and polish it. I have used gauge plate but find the work required to produce an acceptable finish is not worth the dubious advantage of having a material that is slightly easier to harden.

Pendulum

The details of the pendulum are shown in **fig 13,** 4mm diameter carbon fibre tube is used for the pendulum rod. There are two reasons for using carbon fibre for the rod, firstly it is non magnetic and secondly it is light as well as being very stiff.

A brass insert threaded 3mm is glued with super glue into the top of the rod. This insert screws into a clamping piece, which attaches the rod to the pendulum arbor. A length of 4mm brass threaded rod is glued into lower end of the rod that carries the rating nut. The lower end of the threaded rod is threaded 3mm for a length of 12mm to attach the brass drive magnet housing shown in Fig 13 to the end of the pendulum. This allows the height of the drive magnet above the coil to be adjusted to regulate the pendulum amplitude. The magnitude of the impulse delivered by the drive coil to the pendulum depends on the distance between the coil and the drive magnet.

The pendulum bob is made out of a length of 25mm brass bar. The bob should be no longer than about 25 millimetres. Do not make the bob too heavy. As will be explained later the accuracy and temporal stability of the clock is not controlled entirely by the pendulum as in a normal mechanical clock. The reason for reducing the mass of the bob is related to the coupling of the pendulum to the electronic drive.

Base plate

The dimensions of the base plate are shown in **fig 14,** The underside of the base is recessed to a depth of 2.7 millimetres. The diameter of the recess is 50mm. slightly greater than the diameter of the drive coil. The reason for recessing the base is to reduce the distance between the drive coil and the pendulum drive magnet. Hiding the drive coil beneath the base makes it difficult for the casual observer of the clock to see how the clock is being powered. This sense of mystery adds, I feel, to the attraction of the clock.

Dial

The dial on this clock is quite large partly for visibility and partly for aesthetic reasons. The clock only has three wheels and as a consequence there is nothing below the centre wheel apart from the pendulum rod. I tried a small dial when I was designing the clock, it didn't look 'right' as the movement looked unbalanced. The larger dial seemed to 'balance' the movement rather better.

The dial is illustrated in **fig 15** and shows the blank dimensions, location of mounting holes and the details of the pillars and screws. A dxf file is available for the engraving. I engraved my dial on my X3 CNC mill. I could have engraved the dial in one single operation, but decided not to for the following reason. The dial is possibly the one part of the clock that is looked at more than any other part. As a result minor imperfections, such as uneven depth of cut in the engraving, will stick out like a sore thumb. To overcome this problem each numeral, the fine minute division on either side and the 5min. division were engraved separately.

A piece of 18mm Melamine covered MDF was secured to the table of the mill. The board is screwed down to the mill table with two 6mm countersunk screws. If necessary mill the surface of the MDF with a sharp fly cutter to ensure that the surface is perfectly flat and the same height above the table. I checked the board I used with a dial gauge and found it to be perfectly fiat and the same height all over. Drill a 3mm hole 10mm deep at the centre of the circular arc and fit a 3mm peg into the hole extending about 2mm above the surface. Zero the co-ordinates of the digital readout at this centre point. Cut out a circular disc for the dial out of 16 gauge engraving brass sheet. Make the diameter of the disc at least 10mm larger than the overall diameter of the dial. Drill a 3mm hole in the centre of the disc. Fit the disc onto the 3mm peg and clamp the disc as shown in **photo 12.**

Drill a 3mm hole at (X= 40mm Y = 0) through the brass and 12mm deep in the MDF board. Leave the spindle at this position and remove the disc, Expand the hole in the MDF to 6mm and insert a piece of 6mm brass rod drilled and tapped in the centre 3 millimetres. Make a 3mm knurled head screw. Replace the disc and hold it down with the knurled screw. Now drill a 3mm hole through the disc and 10mm into the MDF at the co-ordinates (X = 34.64, Y = 20) millimetres. Undo the knurled screw and rotate the disc 30deg. which will place the hole just drilled over the brass insert. Hold the disc down with the knurled screw and drill a second hole at the set co-ordinates. Drill in all 12 holes. These holes will serve as division plate for engraving the numerals. **Photograph 13** shows the disc in position ready for engraving. Note the 3mm peg is inserted in to the hole at the above co-ordinates.

•To *be continued.*

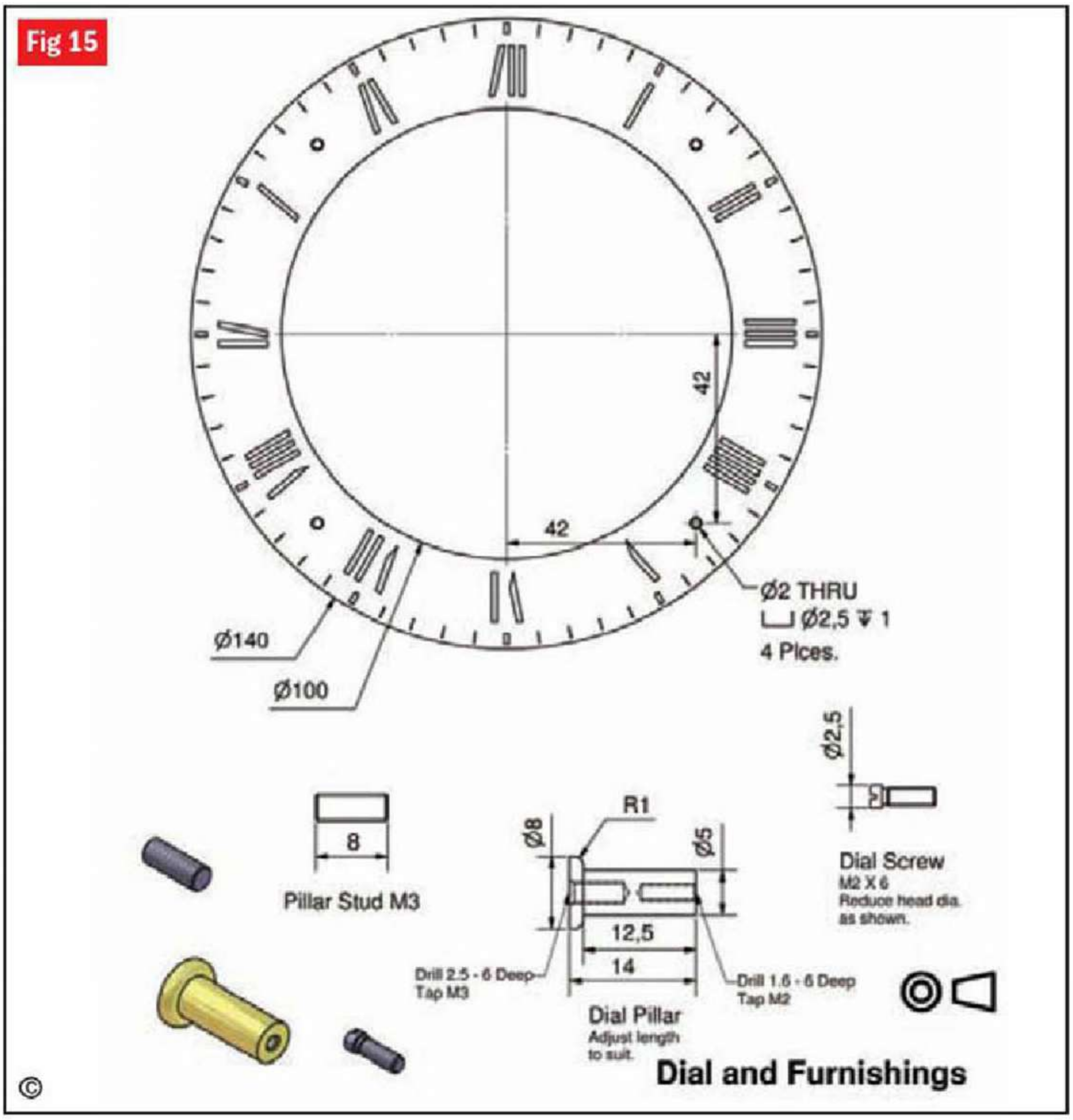
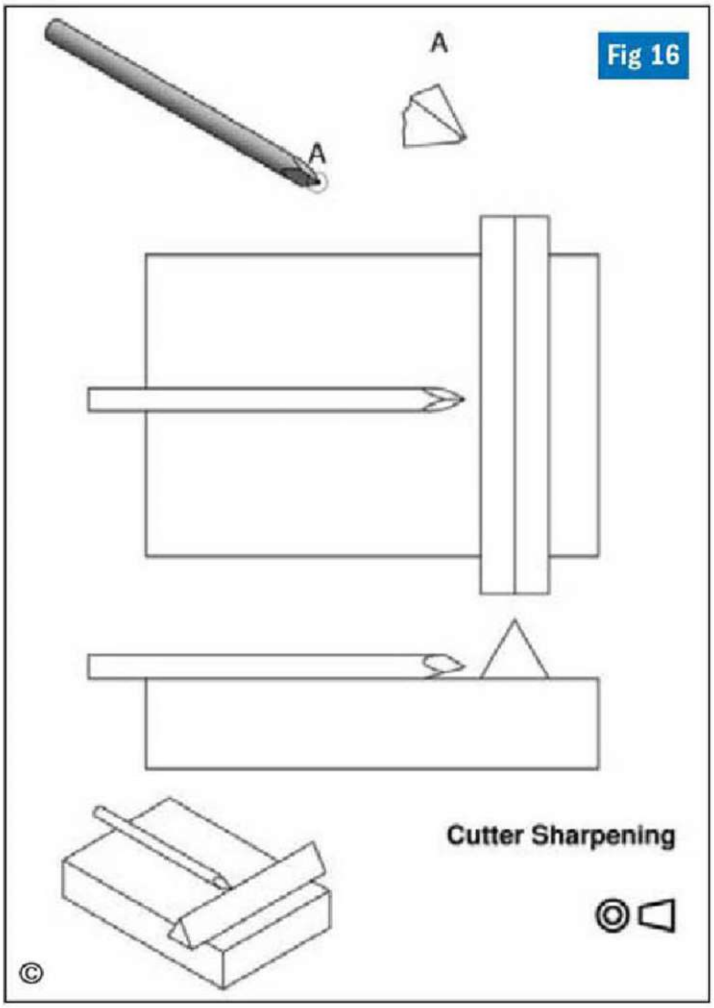


Fig. 15. Dial and furnishings.

12. Drilling Index holes.

13. Ready to start engraving.



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 Hie 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-comered 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 finaE 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 Diall.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 »

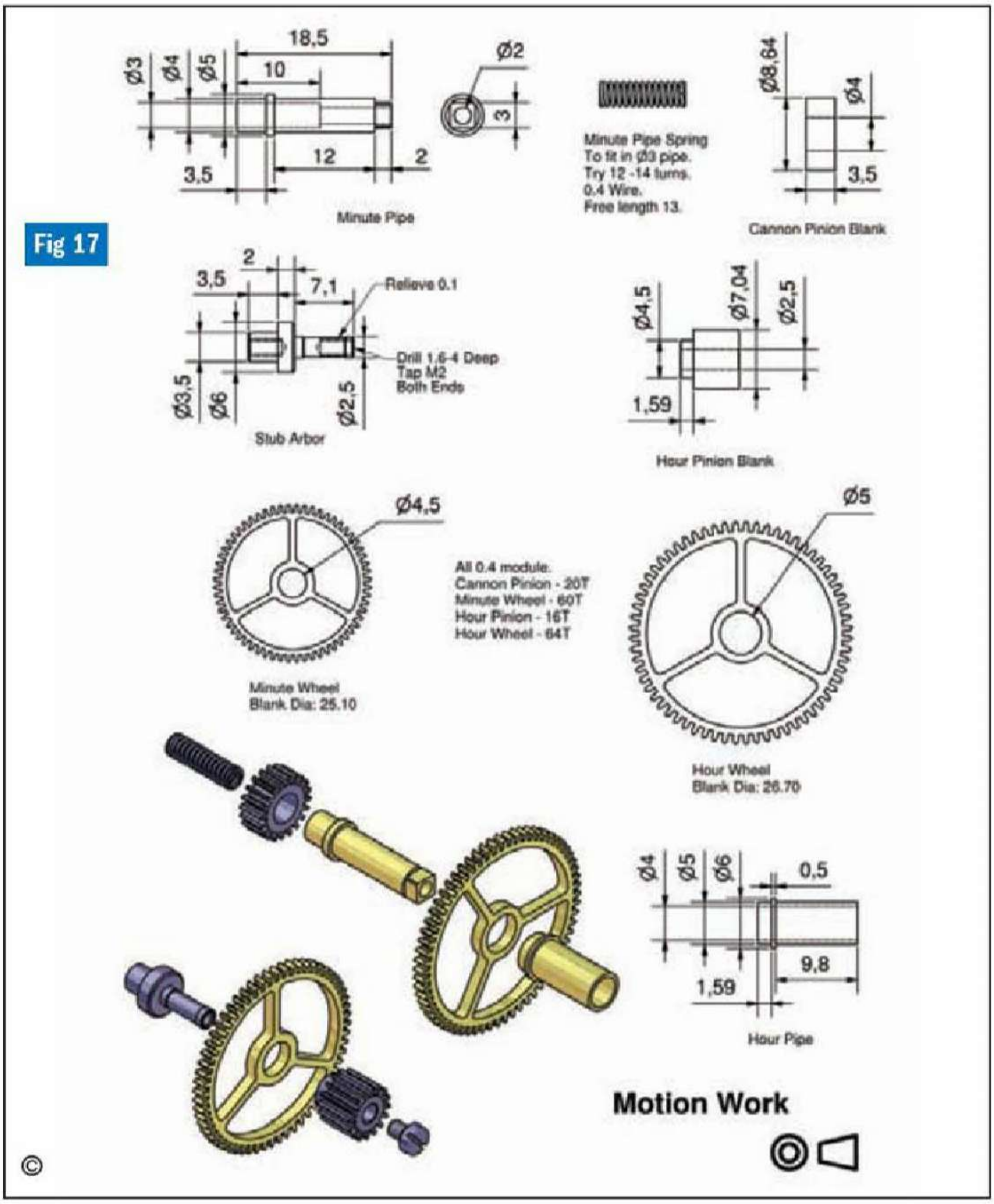


Fig 17

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 4Ldxf. 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 3Pdxf (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 2 mm 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

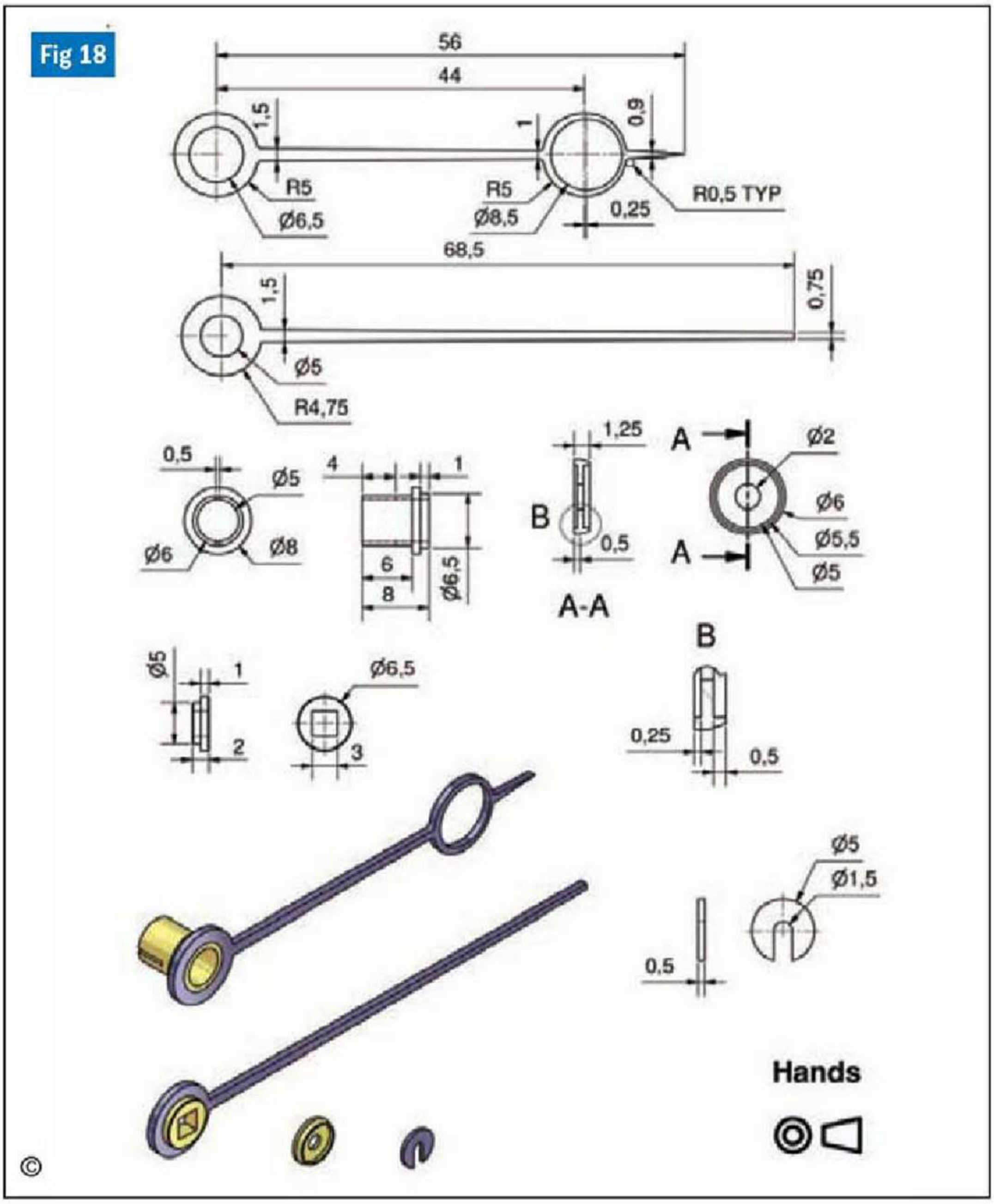


Fig 18

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 l i b (*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.

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 »

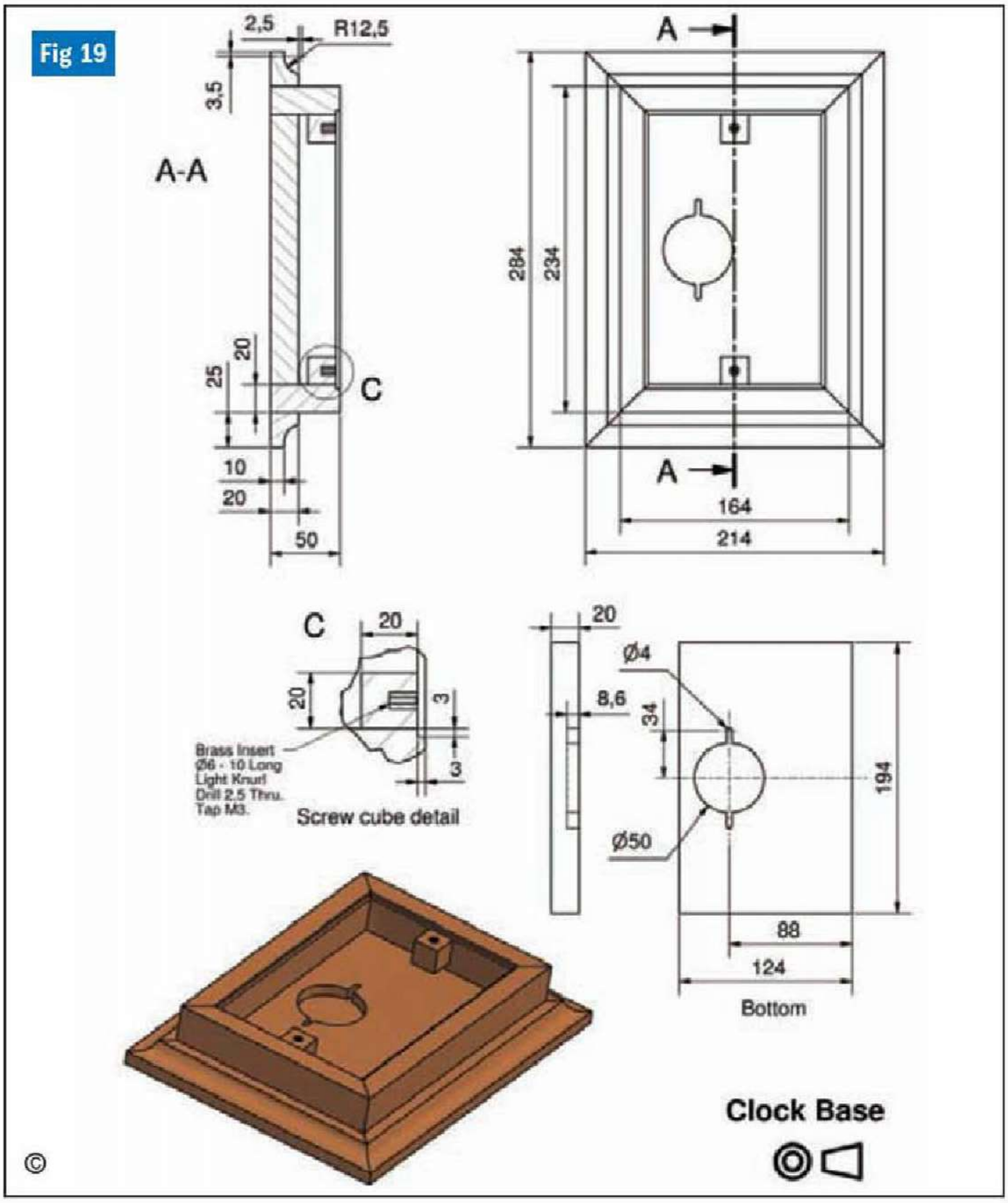


Fig 19

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 coi! 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 fitl 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 V3 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 V2 second pendulum 500 ms. At the end of this delay period the second 555 timer is triggered by the falling edge of the pufse. The second 555 timer then generates a pulse whose duration is set by the variable

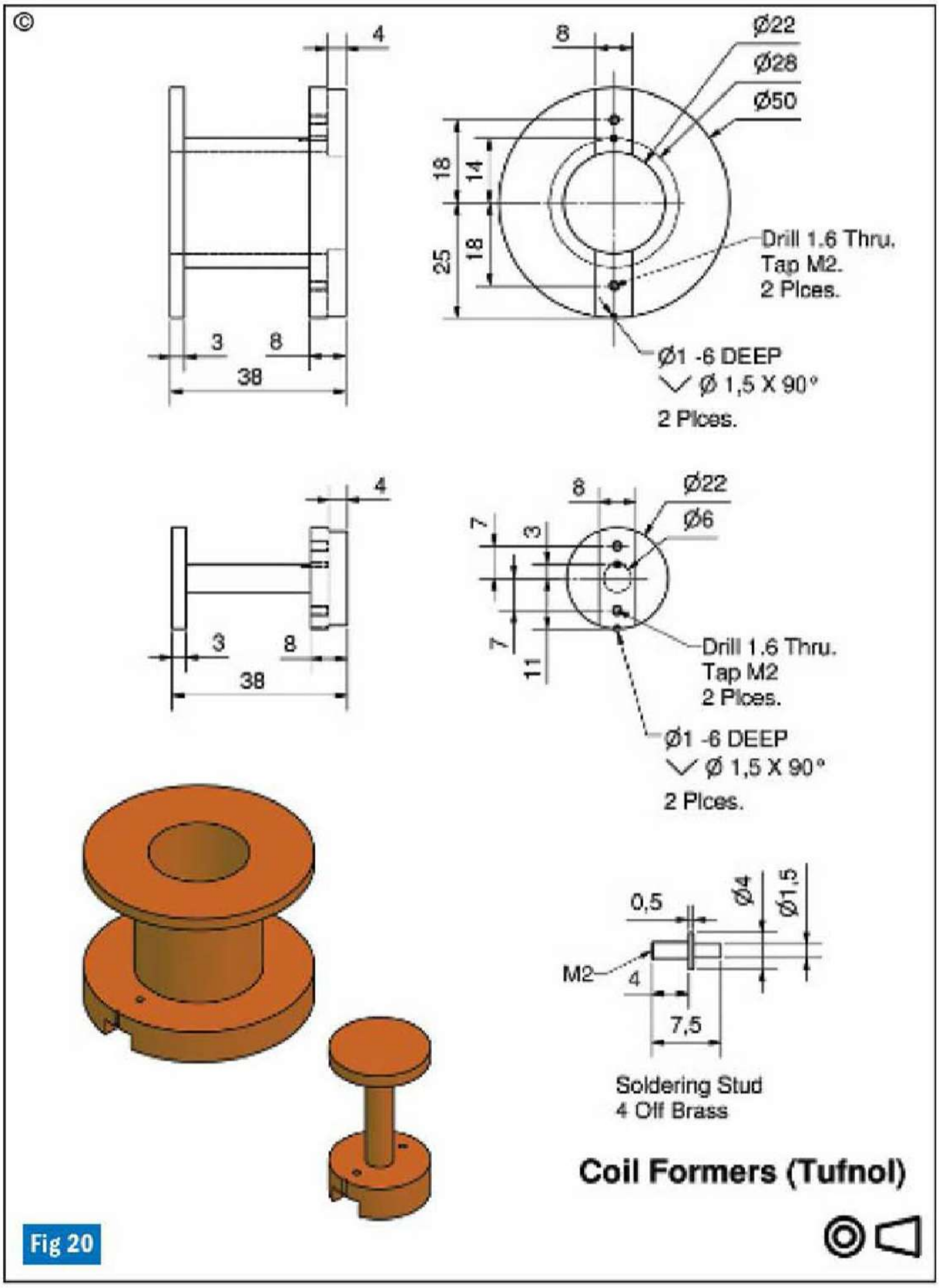


Fig 20. Drive coil formers - best made from Tufnol rod.

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 »

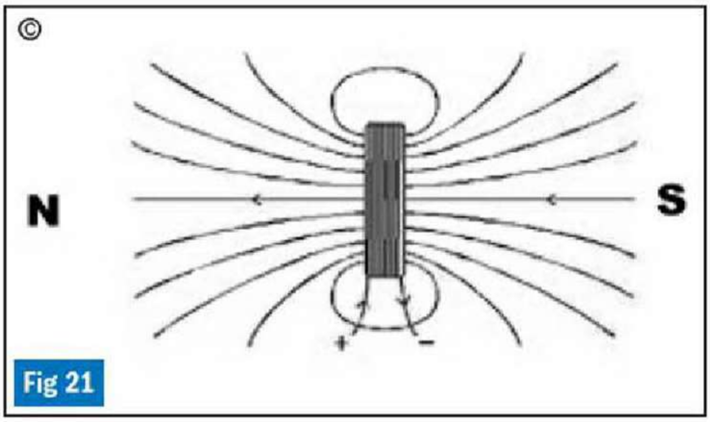


Fig 21

Fig 21. Magnetic field generated by the coll.

14. Suitable setup to regulate Me 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 11OkW 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 ME 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 materiai 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}/i6 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 »

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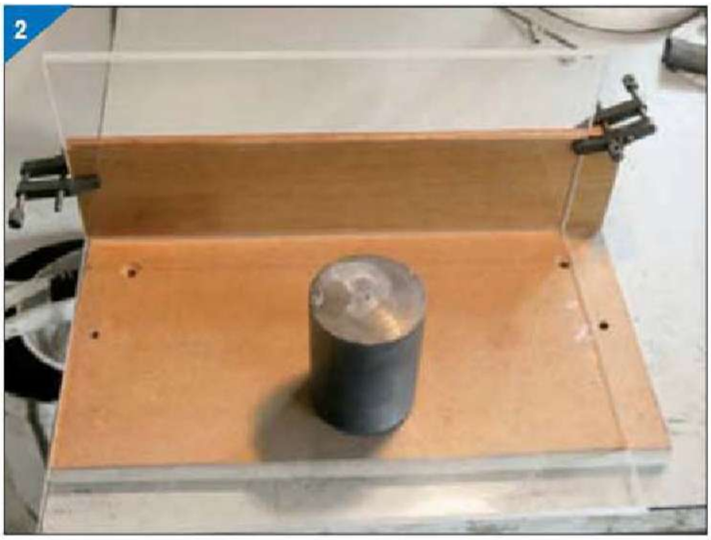
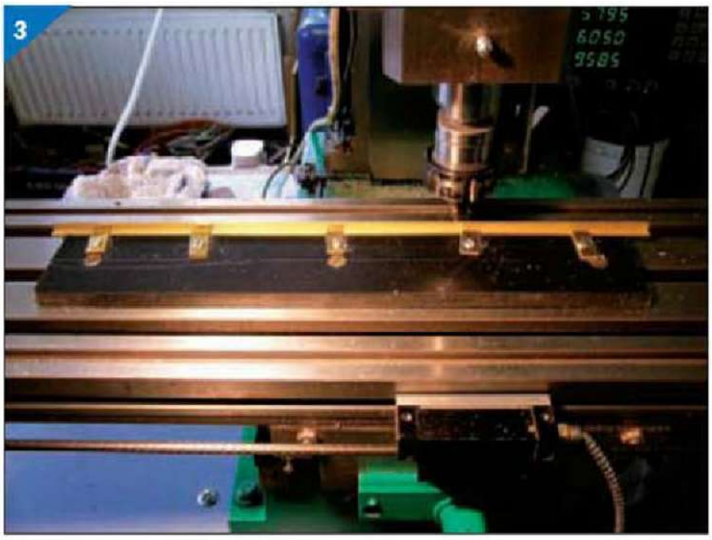
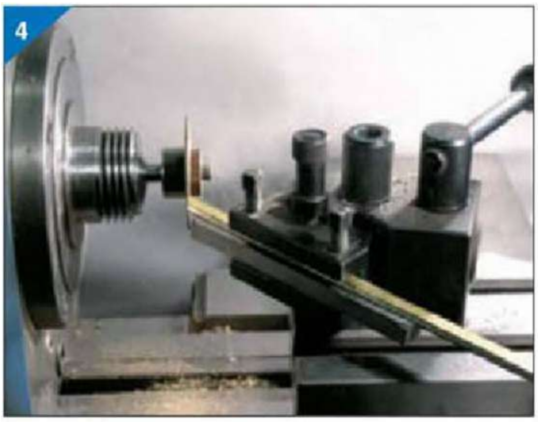




chloroform, I have tried some of the proprietary adhesives but have found them not as good as chloroform. The only problem with chloroform is obtaining some as the COSHH regulations mean that you cannot buy a small amount. I still have a small amount that I obtained many years ago. When you have glued 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 ail 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 1/4in. slot was milled 1/16in. 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 mil! 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.

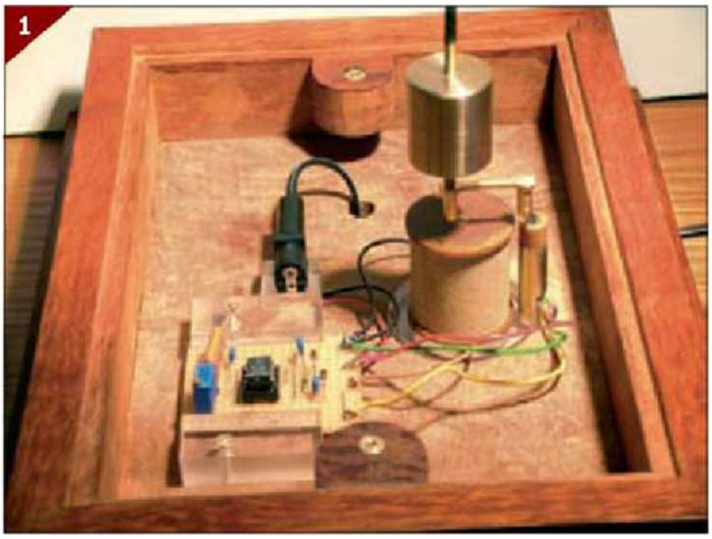
Any scratches can be removed with Perspex polish. I used some scrap Perspex for the cover I made which unfortunately was slightly scratched. It was a tedious job removing these scratches and finally polishing the cover. The final result shown in **photo 6** is okay but not as perfect as 1 would have liked. I guess I will probably make another and use new Perspex this time! ME



Clock gremlin *1*
Unfortunately an error appeared In the last part of the series on Dick Stephen's new clock. Computers aren't as clever as we sometime Imagine, and have difficulty In moving Greek symbols from one application to another. As a result the nomenclature for Ohms appeared as 'W' Instead of a capital omega,

Clock gremlin 2
Dick has recently moved house, and changed his email. In the process he has lost some requests for the CAD files readers have sent In. If you are still waiting to receive these from him, or would like a set, please contact him at **rstephen38@cwgsy.net**

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.

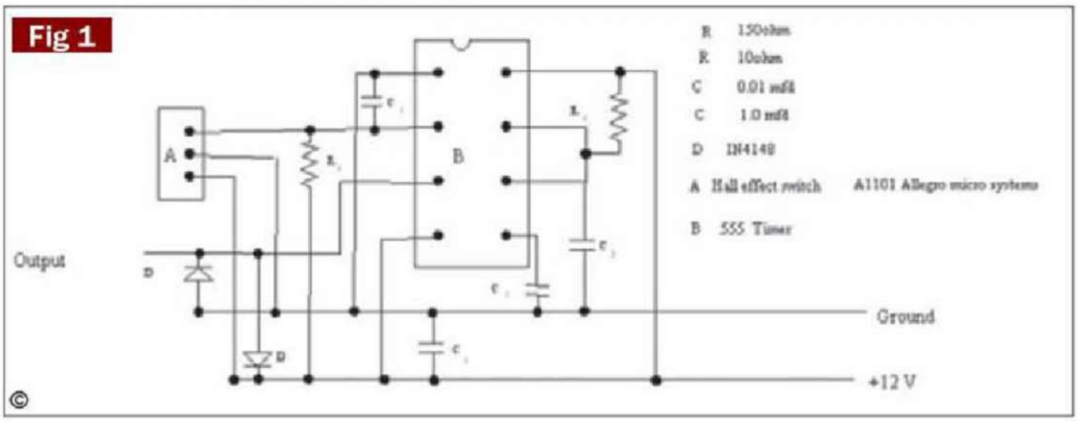
Fig 1. New drive circuit.

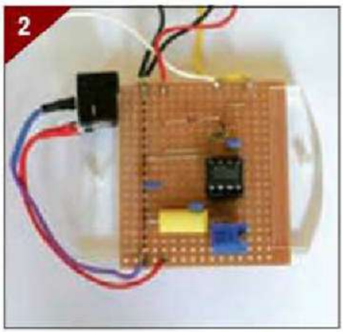
Since completing the writing up of the clock described in the recent series I have been developing a new drive system for the pendulum, This has required quite a lot of experimentation to sort out all the minor problems associated with the new drive circuit. The circuit originally described works very 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 CI, energises the drive coil and impulses the pendulum.

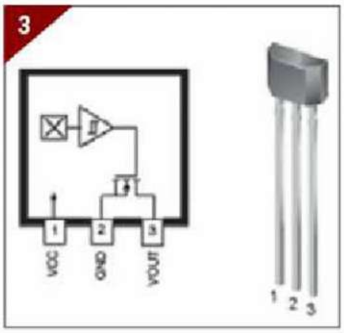
When I was experimenting with the above circuit I experienced the following unexpected problem. As the pendulum swings across the brass base plate of the clock as illustrated in the series, the drive and switching magnets induce in the surface of the plate circulating electric currents, referred to as 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.

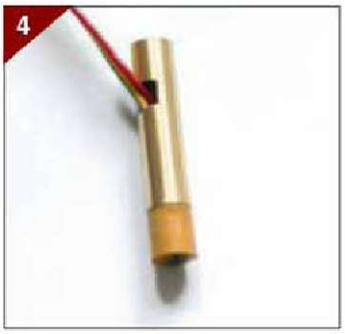
I have since been experimenting with the overall design of the clock and have made a slightly smaller version »

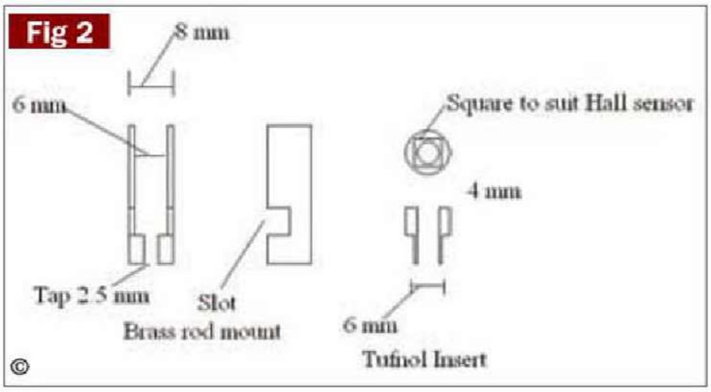
Fig 1











2.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. Overtime the amplitude would slowly increase until it was so large that the pin (or ratchet) wheei 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.

Adjusting the pendulum amplitude

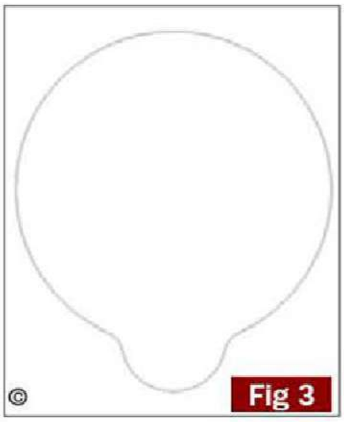
The amplitude of swing of the pendulum depends on the size of the impulse delivered to the pendulum. As the switching magnet swings over the Hall effect device the 555 timer is turned on. The voltage pulse generated is applied to the drive coil and a magnetic field is generated by the electric current 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.

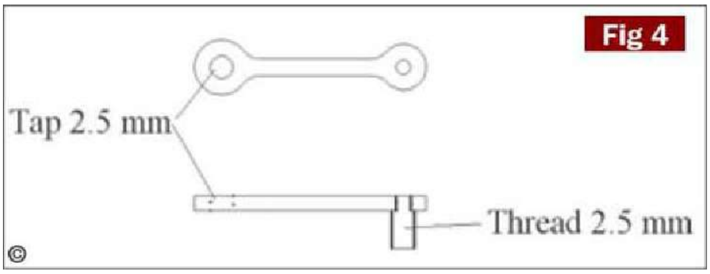
The magnitude of the pendulum impulse depends on four basic factors, the size and strength of the drive magnet, the size, number of turns in the drive coil and the circuit line voltage, the 555 timer pulse duration and lastly the distance between the drive magnet and the surface of the coil. The last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

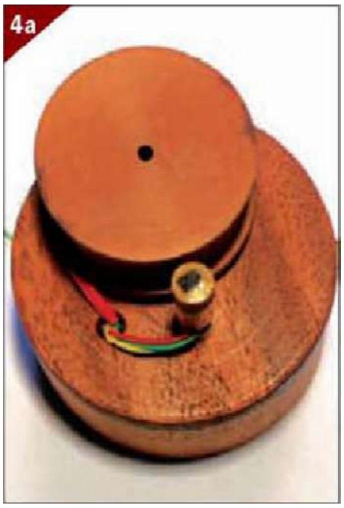
Constructing the Hall effect drive system

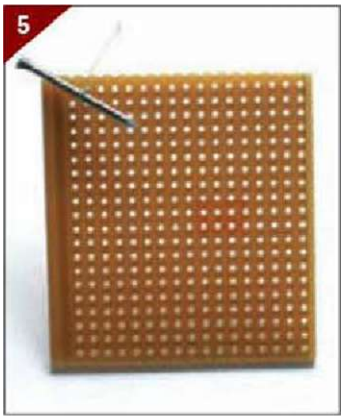
The circuit diagram for the drive system is illustrated in fig 1. It is a relatively simple circuit to construct. If you have not used a 555 timer before it wouid be worth consulting the wealth of information on 555 timers available on the Internet. I made up my circuit on a piece of strip board (Vero 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 (OV) 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 Smm 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 Hail 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 Smm 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 Hail 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 3.1** 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 ciock 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 lm 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 OV 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 OV 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 lOnf capacitor between pin 5 and 0 Volt. Connect the Inf 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 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. Tum 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

Neodymium 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 neodymium 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 neodymium 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. Neodymium 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**