

FOUR-1982

\$4.50

THE Audio Amateur

THE JOURNAL FOR AUDIOPHILE CRAFTS



A TANGENTIAL TRACKING TONE ARM

BY ROD COOPER

Some hi-fi enthusiasts may question the usefulness of a refined tracking arm at a time when the digital disc appears imminent. However we can present several arguments against this view. First, the digital disc has been a long time coming and may yet fail to arrive properly—remember what happened to quadraphonics. Second, the equipment for analog records is relatively simple (and therefore affordable) compared to digital equivalents. Third, non-compatibility of digital equipment may not be welcomed by those people who have standardized on, and have large collections of LP records. Fourth, the quality of records using the relatively new techniques of direct-to-disc recording and the 45rpm computerized LP is astonishingly good, and you need no extra equipment to hear it. To complement these improved techniques and also enable improved performance with existing recordings, I offer a design for a tangential tracking arm. This design offers a "package deal" of small advantages, which taken as a whole, achieves a worthwhile improvement over conventional pickup arms. The most obvious advantage is the reduction of tracking error.

A conventional nine inch pickup arm properly designed produces a tracking error of 2.3 degrees and hence a distortion figure of more than 0.7%. Since

this performance is for an arm with optimum parameters, any discrepancy, whether by design or accident, will increase the distortion. Longer arms reduce tracking error but increase inertia and, as Randhawa points out (*Wireless World*, Mar. & April 1978) some manufacturers have ceased long arm production because of this. He also highlights other shortcomings of the conventional arm, namely delay distortion introduced with elliptical styli, as well as the need for antiskating compensation and lateral balance. These factors combine to make the conventional arm a dubious compromise, especially in the context of recent developments in almost every other branch of audio. Looking at it another way, the distortion introduced at this particular program source makes current efforts to produce amplifiers (for example) with vanishingly small harmonic distortion figures seem academic.

By adopting the servo assisted tangential tracking technique, all the undesirable effects of the conventional arm can be resolved at a stroke. This idea has been around for many years, but has remained a pipe dream because of the difficulties involved in manufacturing a reliable control system to keep the tracking arm on station. Pivot head arms as typified by Garrard's Zero 100, while reducing tracking error, do

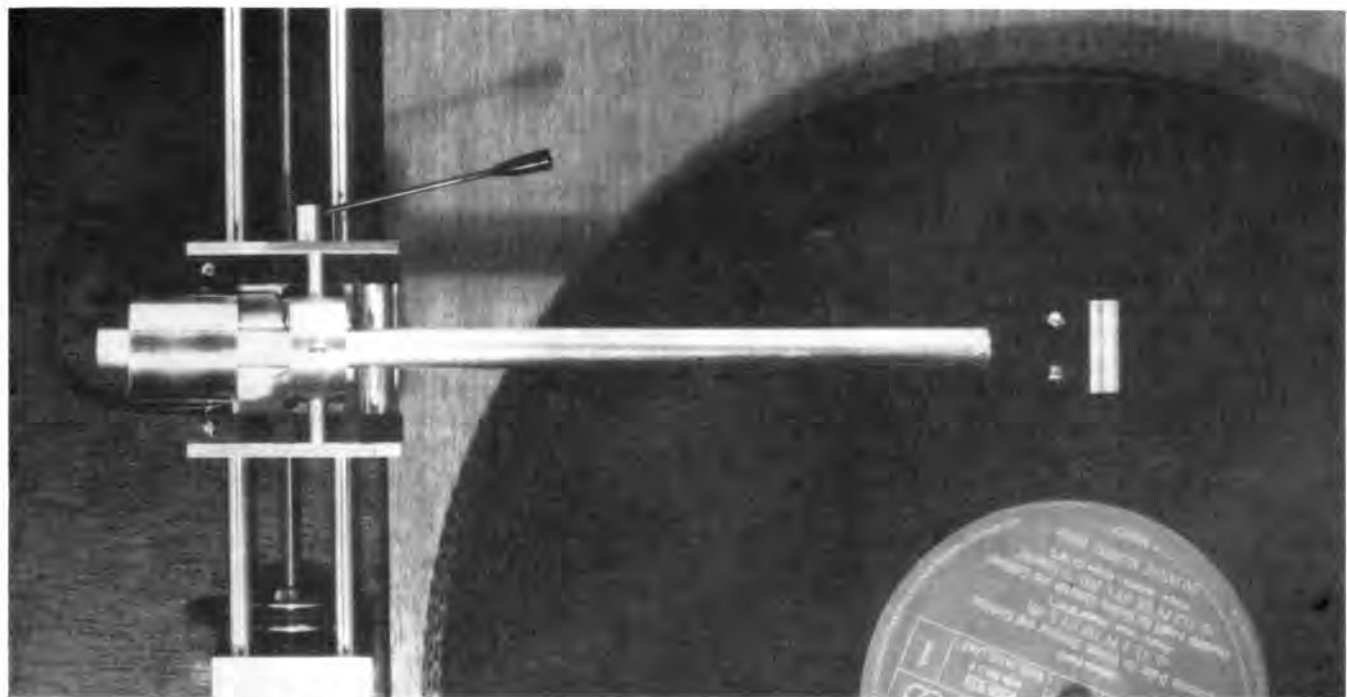


PHOTO 1: The tangential tracking arm improves sound quality by lowering the effective mass and tracking error.

© 1982 Rod Cooper, adapted from articles appearing in *Wireless World* March & April, 1978. Reprinted, with permission.

not solve all the problems and introduce some new ones as well. Antiskating is still needed, and the friction involved in moving the arm across the record increases due to the extra linkages. Also, the mass of the pivot head mechanism increases the inertia of the arm, which goes against the principles laid down by Randhawa.

The energy required to move the arm assembly across the record and thus actuate the pivot head is derived from the record surface, whereas in the tangential tracking system the record is relieved of this duty altogether by the servo motor energy. The tangential tracking arm's much lower effective mass is an important benefit of this design. The arm is shorter, having a pivot to stylus length of 7.25" compared to 9" for a typical conventional arm. The 19% saving in material is only part of the story, because the shorter arm can also be made of thinner wall tubing without loss of stiffness. In addition, a lighter counterweight can be used because the cartridge is nearer the pivot and thus needs less to counterbalance it. This reduces the effective mass still further and puts less demand on the arm's structural strength. Taken all together, the effective mass of a parallel tracking arm can be reduced to about half that of a conventional arm made of the same material.

MASS AND ARM RESONANCE. The advantages of a low effective mass arm are easy to explain. The resonant frequency F_0 of the pickup arm and cartridge combination is given by the formula:

$$F_0 = \frac{1}{2\sqrt{M_e C}}$$

Where M_e is the total effective mass of arm and cartridge, and C is the compliance of the cartridge. For most combinations of M_e and C , F_0 lies at the low end of the audio spectrum. Unfortunately, with today's pickup arms and high compliance cartridges F_0 tends to be around 10Hz. This presents problems as the region 0—10Hz is full of interference frequencies from record warp, eccentricity and, turntable rumble, which are greatly magnified by arm and cartridge resonance. These cause noticeable distortion in the audible range.

As cartridge compliances get higher, the manufacturers of pickup arms make strenuous efforts to reduce the mass and keep resonance above 10Hz, by resorting to exotic materials for construction, and by eliminating all unnecessary fasteners, connectors and other fixtures which add to the effective mass. Making use of exotic materials has good marketing appeal because of the aura surrounding such things as titanium and carbon fibre but it costs a lot to gain a

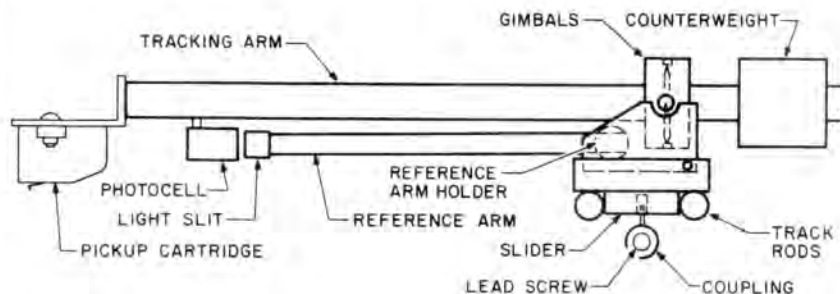


FIGURE 1: Tangency to the groove is maintained by the photocell and servo motor. If the arm is pulled inward by the record faster than the lead screw's preset rate, the photocell sends a correcting current to the servo motor.

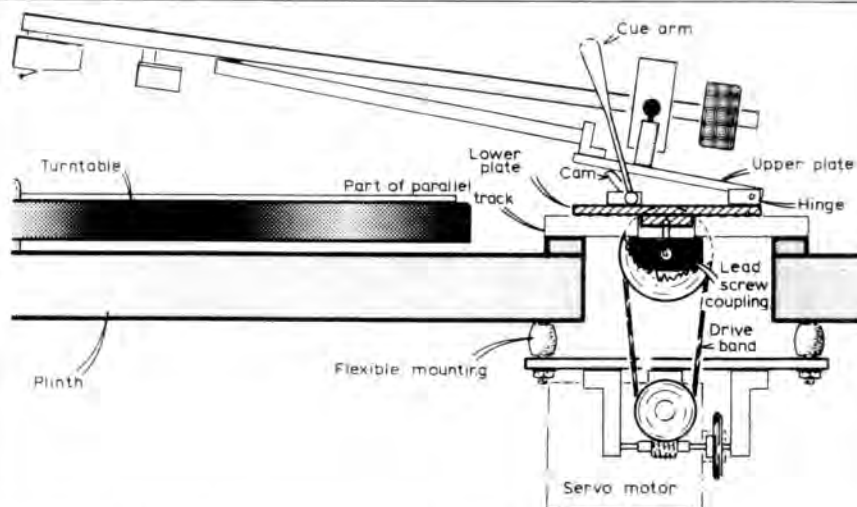


FIGURE 2: A small cam raises the arm assembly off the record for easy cueing.

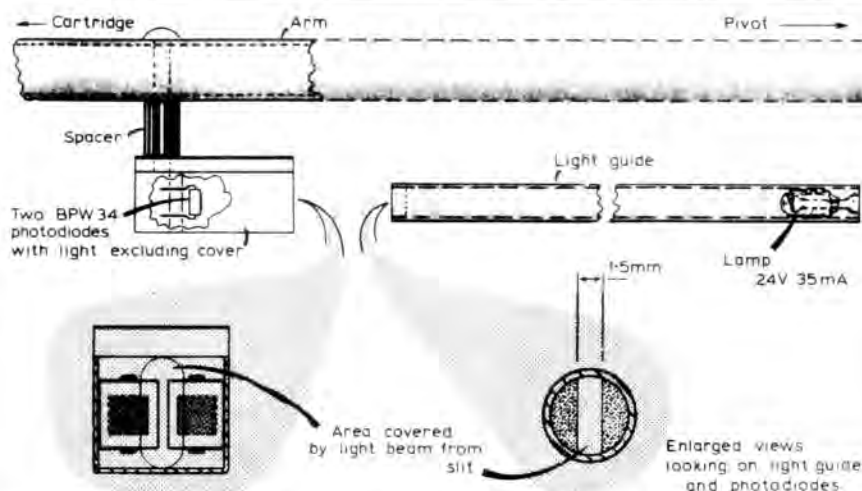


FIGURE 3: A masking slit instead of lenses narrows the light beam so that it falls on both diodes equally when the arms are parallel.

little. The most efficient method is to shorten the arc, but this cannot be done with conventional arms without increasing tracking error.

The effective mass of any arm can be worked out approximately by dividing the mass of the arm by three and adding 20% for the counterweight. To get M_e , add this to the effective mass of the cartridge (the mass as stated by the manufacturer). Reducing the cartridge mass is a good method of reducing M_e . Unfortunately, with the introduction of the moving coil cartridge, the trend seems to be the other way, despite the fact that cartridge manufacturers try to keep the mass within reason.

LIGHT BEAM TRACKING. Recently, with the advent of optoelectronics, a few manufacturers have produced workable tangential tracking arms using a light operated switch mounted on a fixed reference arm alongside the actual tracking arm. Tracking errors are detected by relative movement between the two arms and the error signal relayed to a servo motor. Unfortunately the production of an accurate light beam, the alignment with it of an optical switch, and the integration of the two on a moving platform require precision mechanical and optical engineering far beyond the capability of most amateur constructors. These mechanisms are also very expensive, typically \$500-\$1000 or more.

In this context, for a construction project to be within the bounds of possibility, we must use a different approach, particularly for the switching device. The switch should add little to the mass of the arm, impose no mechanical drag on the tracking arm, have negligible hysteresis between switched states, and be fail safe, to prevent damage to records. I tried several lines of inquiry including capacitive and magnetic proximity devices, but all suffered from one drawback or another. However, I developed a proportional optoelectronic control which is particularly suited to amateur construction as it needs virtually no optical engineering.

A PRACTICAL DESIGN. In my approach, I use a fixed reference arm and movable tracking arm arranged vertically. (Figs. 1 and 2). The lower reference arm is fixed to a sliding platform pushed along a parallel track by a lead screw, details of which appear in Fig. 2. The tracking arm, mounted on gimbals, holds the opto-switch in front of the end of the reference arm, which is a simple light guide using an ordinary T 1 1/4 filament bulb as a light source. A slit at the end of the tube produces a vertical beam of light 0.06" (1.5mm) across and 0.2" (5mm) high which strikes the faces of two BPW34 diodes (cemented side-by-side in a small holder attached to the tracking arm). Extraneous light is shielded from the diodes by a shroud fitted over the holder. Figures 3 and 4 show the general setup. The advantage of using two diodes connected like this is that outside light, if diffuse, produces no error signal. Switching on a room light has no effect on the tracking system. The small physical size and square shape of the BPW34 diode make it perfect for this application.

The two diodes operate in a push-pull mode. When

the light beam covers part of each diode equally, the output sums to zero. When the beam moves to one side, it sends an error current to a simple current-to-voltage converter (the 741 in Fig. 5). The voltage output powers the tracking motor via an emitter-follower, and this voltage is either raised or lowered depending on which side of the two diodes the light beam strikes. Vertical motion of the beam due to record warp has no effect. With no error current, the motor runs at a predetermined speed corresponding to the average tracking speed, pre-set by the 2.2k Ω pot and Tr₆. The 13V Zener diode simply limits the maximum voltage applied to the motor.

Transistors Tr₁ to Tr₄ form an alarm system. When light from the slit falls on both diodes, current flows in Tr₁ to Tr₃, holding off Tr₂ and Tr₄ respectively and the relay remains de-energized as either Tr₂ or Tr₄ will still be fully turned off. If the light beam falls fully on one photodiode, but not the other, Tr₁ holds off Tr₂—and Tr₄ turns on (relay not energized). If the beam falls fully on the other diode, Tr₃ holds off Tr₄—and Tr₂ turns on (relay not energized). However, if the beam moves so far that neither diode receives light, then both Tr₂ and Tr₄ will turn on and close the relay. An alarm could be triggered, the liftoff activated, or the main power supply shut down, (I chose an audible alarm). The relay will de-energize only when the light beam returns to the diode's field of vision.

Normally the relay operates only if a major failure of the tracking motor or the drive to the sliding platform occurs, or if the filament bulb fails, or perhaps if the runout groove at the end of a record is too large for the tracking motor to catch up. However, even if everything stops working, including the warning system, the tracking arm, because of its gimbal mount, will still track the record as a conventional arm, albeit with poorer design parameters. This should give confidence to those who hesitate to trust their records to the mercy of a servo system.

The system avoids the use of lenses, prisms and mirrors, and greatly simplifies construction, but is very sensitive, and can switch the tracking motor from full ahead to full stop within ± 0.2 degrees. The outline of the light beam is rather blurred at the edges and the intensity may not be uniform, but this does not in practice affect accuracy. This is determined by the differential action of the diodes and the voltage output of the 741 current-to-voltage converter which is $V_o = I_{in} R_f$, where R_f is the feedback resistor in Fig. 5. Thus the basic sensitivity can be set by adjusting R_f .

ECCENTRIC CURE. Much greater accuracy than ± 0.2 degrees may be obtained, even with this ill-defined light beam, but to a large extent it is pointless as record eccentricity begins to make itself felt at about this stage. To reduce the tracking error further to compensate for record eccentricity would mean using a fast acting bidirectional servo system with no mechanical play, rather than the simple unidirectional system described, where the mechanical clearances are taken up during forward motion. The law of diminishing returns enters here, and the cost of a complex servo system does not justify itself when a much better method of dealing with ec-

centric records exists. The meter included to monitor the voltage across the servo motor clearly indicates where eccentricity lies. Simply enlarge the center hole and position the disk centrally on the platter. If the eccentricity is the same on both sides, then with a little PVC cement you can make a new permanent center hole to cure the problem once and for all.

SERVO DRIVE. The servo system consists of a motor driven lead screw pushing a sliding platform (with the two arms and gimbal assembly) along a parallel track via a mechanical coupling. Driving the platform directly from the lead screw, dispensing with the track, appears to be an easier approach. In practice a sufficiently straight and accurately threaded lead screw which prevents instability in the platform movement (side to side wobble is difficult to manufacture).

Originally I used a small 6V motor from a cassette deck resiliently mounted to avoid noise transmission to the tracking arm. Also, rubber belt drive from motor to gears and from gears to lead screw (overall reduction of 100:1) helps reduce noise. Nylon worm

gears are ideal because they require no lubrication, are silent in operation, produce the large reduction in a single step, and are easy to assemble. Matched sets of 40:1 are available together with the associated hardware (shafts and bushes).

When tracking a record, the motor drives the platform at the average rate of tracking a typical LP—about 3" in 15 minutes. To achieve this the voltage to the motor is pre-set as already explained. The opto-switch simply raises the voltage to the motor when the tracking arm lags behind the record, and reduces it to zero when the arm leads. The motor must have good self-starting properties for this system to work.

To return the arm to the starting position, a switch reverses the polarity of the supply to the motor via a pre-selected resistor which limits motor speed for a reasonable rate of return. On the prototype this was set at two minutes, which compares favorably with rewinding times for a tape recorder. For general use this might be too long, in which case you could incorporate a gear change on the motor to speed things up. The prototype was used solely for transcribing disk to tape, hence two minutes was no problem.

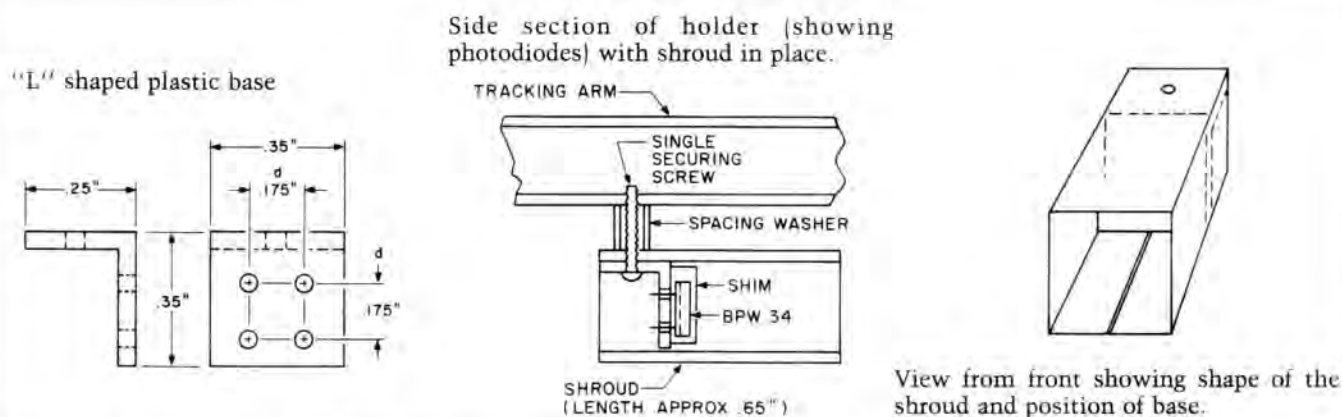


FIGURE 4: The photocells are mounted side by side on the holder, with a light shroud around them and a shield between.

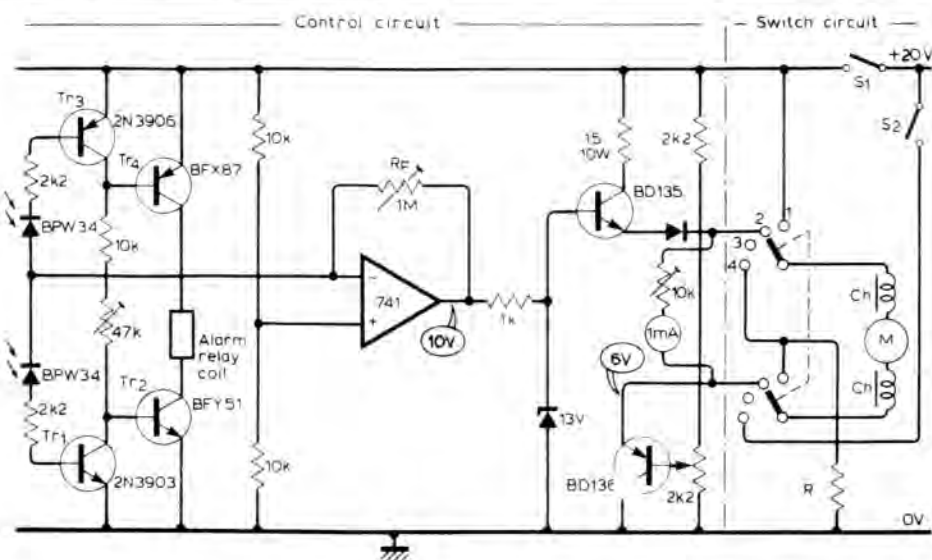


FIGURE 5: The motor runs at an average speed set by 2k2 pot. Variable resistor of 47k allows for spread in transistor H_{FE} and different types of relay. Switches S_1 and S_2 are microswitches; positions on rotary switch are fast forward 1, fast reverse 4 (select R on test), play 2 and stop 3. Chokes are motor interference suppressors.

For fast forward, the motor is fed from the same pre-set resistor with the correct polarity. A micro-switch at each end of the parallel track switches the motor off automatically at precise positions corresponding to the run-in groove at the start of the record and the end of the run-out groove at the finish.

CUEING DEVICE. To cue the arm at any point on a record, the sliding platform is constructed as two platforms hinged together (Figs. 6 and 7). The lower platform follows the parallel track, and the upper platform carries the gimbals and the two arms. Cueing is achieved by tilting the upper platform about 20° by means of a small cam underneath, operated by the cue lever. In this position the tracking arm rests lightly on a small bar on top of the reference arm, and records can be taken off, or put on.

Make the hinged platform as carefully as possible, as the errors introduced by play in the hinge are difficult to correct, and even a little play at this point can produce errors of one degree. A hinge consisting of a short rod pinched between two screwed pivot points can be designed to have no running clearance, but gives stiff operation. A compromise can be reached by screwing in the pivot points until the weight of the upper platform can just close the hinge. Such an arrangement performs very well. Any play can be taken up readily by tightening the pivots. The MKL15 direct drive motor and integral platter chosen for the prototype was very easy to mount on a plinth and has excellent performance.

MECHANICAL DETAILS. Both the tracking arm and reference arm are made from thin-wall dural tube, $\frac{3}{8}$ " (9.5mm) diameter for the tracking arm and $\frac{1}{4}$ " (5.5mm) for the reference arm. Plug the tracking arm with a small piece of dural where the vertical pivot goes through it, to strengthen the tube at this point. Dural tubing used for this project is in the fully-hardened state, and although very stiff it is also fragile due to the thinness of the walls. The tracking arm complete with plug weighs a mere 10gm or so.

Constructors will notice that the positions of horizontal and vertical pivots have been transposed (Fig. 8), compared with the conventional arrangement. Having the vertical pivot on the tracking arm is not good practice on a conventional arm of course, but is permissible here because the tracking arm on a tangential tracking machine does not swing on the pivot more than half a degree, whereas the conventional arm must swing through a wide angle. The change provides a horizontal pivot that allows the tracking arm assembly to be taken off easily for transport or adjustment without dismantling anything, and allows replacement without having to realign it with the reference arm (Fig. 9). This design is much easier to make than the usual spindle type, virtually friction free, needs no lubrication, has no play due to bearing clearances and does not introduce play due to wear.

Avoiding play is important because the control system cannot distinguish between play and tracking error. For this reason too the sliding platform is spring

loaded, so that any running clearance (Figs. 10 and 11) in the track is taken up. The 0.2° accuracy is possible despite the play because it is taken up by the forward motion of the mechanism and never re-introduced, since the servo never reverses. A diode in the motor circuit prevents this. Figure 9 shows the horizontal pivot design. Two adjustable screwed pivot pins (A_3) hold the gimbal ring (A_1) up by means of a short stub attached to the gimbal ring on each side (A_2). Machined into each stub is a 90° conical cup. Since the pivot pins are only 60° a small amount of rotation can take place. This arrangement has proved very satisfactory and is quite stable provided the two pivots are far enough apart.

The vertical pivot consists of a short rod (A_5) with a 60° pivot point at each end, supported inside the gimbal ring (A_1) by means of 90° conical cups (A_6). The cups can be screwed in and out to adjust the amount of play of the vertical pivot, and clearly a little attention will be needed here to get the best compromise between minimum play and minimum friction. Nut-locking compound (such as "Loctite") must be used on the cup bearings to get good results on adjustments, and also to secure them when the adjustment is complete. No locking nuts are used. To reduce wear on all these pivot points, a nonspreading nongumming light grease or oil such as that used on clocks is needed. Unfortunately, the ordinary mineral oils sold for general lubrication tend to gum with age and are not satisfactory.

For the sake of simplicity, I made the counterweight on the prototype from a piece of 1" diameter brass bar drilled through the center and decoupled with a rubber insert. However, you should read the comments by Randhawa on counterweights (*Wireless World*, April 1978 pages 63-8) for a better design. The main requirement for the counterweight is that it should give neutral equilibrium with the chosen cartridge when the tracking arm is positioned about halfway up the vertical pivot.

MAKE THE LIGHT SWITCH. The photocell holder is a piece of lightweight "L" shaped plastic extrusion secured to the tracking arm by a small nut, bolt and spacing washer. Glue the two BPW34 photodiodes side by side to the plastic with epoxy resin as shown in Fig. 3, to form the photocell. An aluminum shim separates the diodes, this being necessary to prevent light from one diode reaching the other by reflections via the transparent sides of the BPW34. The size of the shim is not critical but for good light cut-off between the diodes it should project $\frac{1}{8}$ " or so all around. A shroud made from the same aluminum shim material fits over the holder and is held in place by the attachment bolt. The aluminum shim can be fashioned readily from soft drink cans.

Make the wiring from the photocell (and also from the cartridge and filament bulb) with Litz wire. No readily available alternative to Litz wire is flexible enough for the job. The wiring is carried inside the tubular tracking arm and exits near the vertical pivot. Clamp it firmly to the side supports (A_8) and use sleeving from here to a plug and socket on the plinth. The filament bulb wiring is also clamped to a side

support and carried in sleeving to the same plug and socket. This arrangement gives a neat and symmetrical layout and helps prevent the lead-out wires from fouling the gimbals.

With a little extra attention, you can conduct all the signals in just a couple of Litz wires because all the strands that make up the Litz wire are insulated from each other. However, the soldering technique for these very fine wires is more demanding, and the result is not as robust as using a separate lead-out for each signal.

The T 1 ¼ filament bulb is rated at 24V 35mA and is run directly from the 20V supply. When under run like this it has a very long life but does not emit much white light. This is an added benefit, as the response of the BPW34 diode lies mainly in the infrared and matches the bulb's output quite well. An infrared emitting diode could be used, but is not as simple to drive as the filament bulb. Polish the inside surface of the reference arm to improve its efficiency. Bright aluminum has high reflectivity in the infrared register.

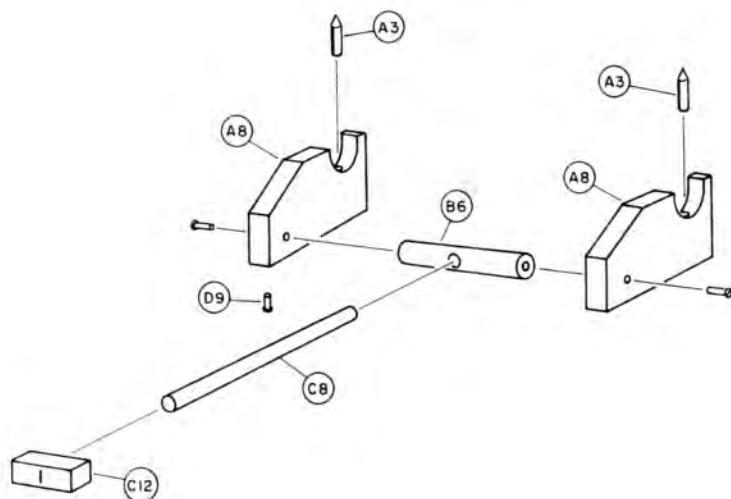


FIGURE 6: The upper platform carries both arms and can be tilted for easy cueing.

SIDE SUPPORT & REFERENCE ARM, UPPER PLATFORM

Parts:

- A³: Side pivot pins
- A⁸: Side supports
- B⁶: Reference arm holder
- C⁸: Reference arm
- C¹²: Light slit
- D⁹: Level screw

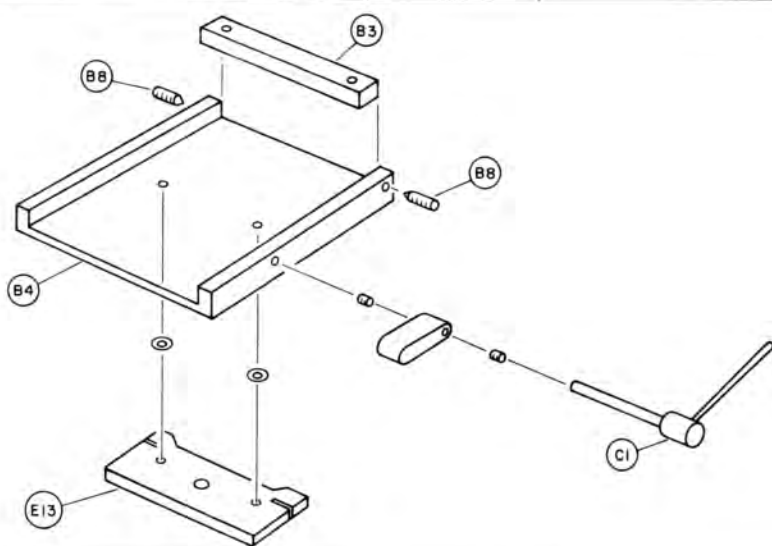


FIGURE 7: The lower platform is connected to the lead screw by a pin and nylon slider.

LOWER PLATE & CUE LEVER.

Parts:

- B³: Hinge bar
- B⁴: Lower plate
- B⁶: Hinge pivot pins
- C¹: Cue lever
- E¹³: Nylon slider

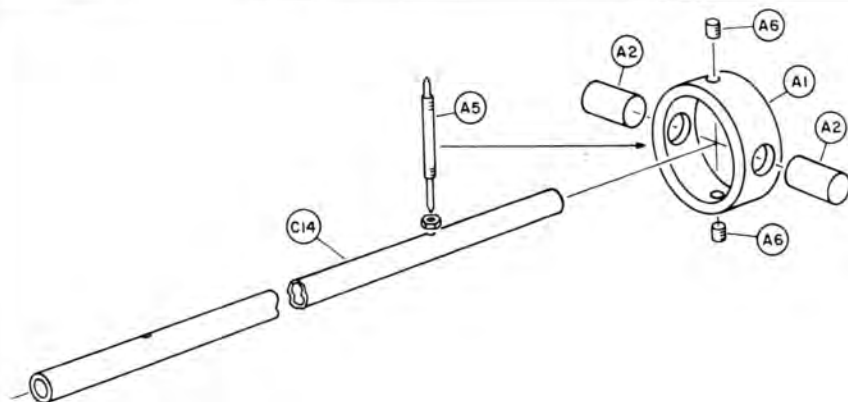


FIGURE 8: Suspending the tracking arm in a gimbal permits it to move freely even if the servo system fails.

TRACKING ARM AND GIMBALS

Parts:

- A¹: Gimbal ring
- A²: Side pivot
- A³: Vertical pivot pin & locknut
- A⁶: Vertical Pivot Bearings
- C¹⁴: Tracking arm assembly

T 1¼ bulb is the only commonly available bulb which fits into the standard ¼" diameter tube. It should not be free to move when in place, and wrapping a small piece of adhesive tape around the plastic body of the bulb makes a firm push fit. Insert so that the filament is vertical.

The cassette motor used in the prototype drew 60mA on normal play, rising only a few milliamps when running on full rated voltage, but drawing 500mA when stalled. The output transistors need to be mounted on heat dissipators to avoid overheating when the motor is stalled; though stalling should never take place in theory, it is not unlikely during testing and setting up. Similarly, the short-circuit protection resistor in the BD135 collector circuit should be generously rated.

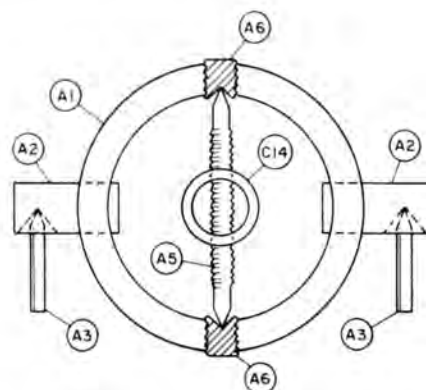


FIGURE 9: The arm rests on pivots A₃ and can be removed easily.

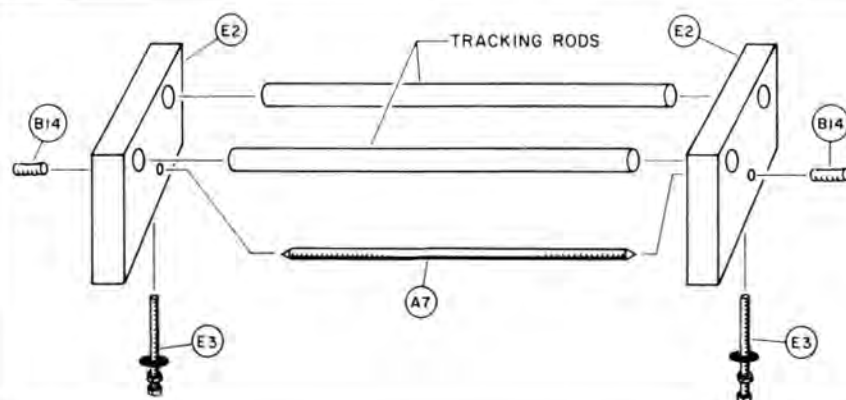


FIGURE 10: Parallel tracking rods guide the carriage.

EXPLODED VIEW OF PARALLEL TRACK.

Parts:

- A⁷: Lead screw
- B¹⁴: Lead screw bearings
- E²: End plates
- E³: Screws to attach end plates to plinth

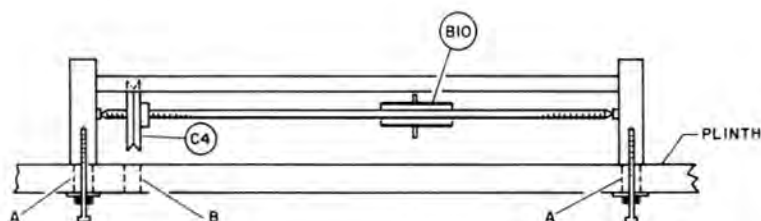


FIGURE 11: Rotation of the pulley wheel drives the coupler and the carriage down the lead screw at a rate determined by the servo loop.

VIEW FROM SIDE FRONT OF TRACK ASSEMBLED ONTO PLINTH

Parts:

- C⁴: Lead screw pulley wheel
- B¹⁰: Lead screw coupling

I used a sensitive reed switch relay with a coil wound specifically for this circuit, but a standard 12V relay could be used in conjunction with a series ballast resistor. Set the 47kΩ adjustment so that in normal ambient light conditions and with the light slit off the face of the photodiodes, the relay will close. High ambient light conditions may swamp the diodes despite the shroud, and prevent the relay from closing. However this is never likely to occur if the unit is used sensibly, for example away from bright sunlight. A heavily tinted or even opaque cover on the record player is recommended.

The power supply for the turntable, servo motor and electronics is a 20V stabilized unit capable of giving 1A (my turntable required 350mA peak). The design of the power supply is not critical and is left to your discretion. On the prototype, which had the mains transformer bolted to the plinth, I found that mechanical vibration was finding its way to the

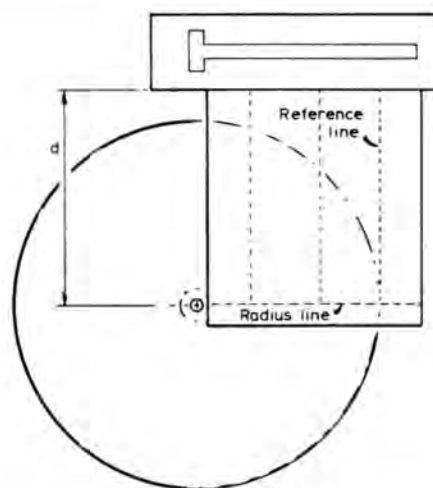


FIGURE 12: Construct this template to help you in the final setup and alignment.

tracking arm at AC hum frequency. Mounting the transformer on rubber grommets cured the problem, but a better solution is to separate the power supply from the plinth. At least one commercial unit adopts this approach.

SETUP PROCEDURE. With the tracking arm fully assembled, complete with cartridge and counterweight, raise or lower the vertical pivot with respect to the tracking arm by means of the screw thread so that neutral equilibrium is produced. If neutral equilibrium cannot be produced it may be necessary, particularly with heavier than usual cartridges, to file some metal from the underside of the counterweight.

With the cartridge resting on a discarded record, adjust the height of the photocell so it is in line with the light guide by means of the spacing washer. The position of the tracking arm with respect to the record surface should also be checked. This can be altered by raising or lowering the side pivot pins (A_3) or by adjusting the height of the turntable (a very easy thing to do if you are using the MKL15 turntable).

A template to check the accuracy of tracking is essential. Cut a sheet of thin aluminum to suit Fig. 12 and check the corners against an engineer's set square. Find distance d , which will depend on cartridge position, with the template resting firmly against the front edge of the parallel track. Scribe a radius line at distance d parallel to the front edge of the template, left to right, and then using the set square scribe several lines for reference purposes at right angles to this radius. Track the arm fast forward and check that the reference arm remains parallel to the various other reference lines. If you see a discrepancy, the parallel track is not straight, and should be adjusted. (Fortunately the eye has very good perception of parallelism). When this is satisfactory, and with the photocell disconnected, play a record, setting the voltage to the servo motor so that the tracking arm keeps pace with the record, very approximately. Note this voltage.

Now connect the photocell and with the record stationary and the sliding platform disconnected from the lead screw, bring the tracking arm parallel to the reference arm. The meter reading should now correspond to that obtained with the photocell disconnected. If it does not, then either the reference arm must be moved sideways to correct this (and then realigned of course), or the photocell must be moved in relation to the tracking arm.

FINAL CHECK. Observe the tracking arm from above as it plays a record properly, and note the changes in meter reading as the servo system corrects tracking errors. Now is the time to adjust the sensitivity by means of R_f and the maximum voltage to the motor (if necessary), by changing the 13V limiting Zener diode for a higher or lower value as required. The prototype was set to correct an error of 0.2 degrees in about 0.5 seconds, which I found to be adequate. The time taken depends not only on the sensitivity but on how hard one is prepared to drive the servo motor. The amount of noise generated by

the small motors used for cassette decks is naturally quite small, and on the original tracking arm I found that the 6V motor could be run at about 5V before noise from this source overtook noise from the turntable motor.

This situation can of course be improved by paying more attention to acoustic decoupling of the servo motor and gearbox. After a series of trials, I found that using soft, resilient round section drive cords made of expanded neoprene instead of the usual solid rubber type gave better results. Also, a synthetic viscoelastic rubber marketed in the UK under the name of "Sorbothane" is an excellent material for mounting the motor/gearbox onto the plinth. Sorbothane is a remarkable substance. It is very lossy to mechanical excitation, typically has 90% absorption, and can recover from deformations of up to 500%. It is already being used for decoupling the counterweight on some commercial turntables. □

SUMMARY OF PERFORMANCE

- * Effective length (pivot to stylus) of tracking arm: 7.25" (8.5cm)
- * Effective mass of tracking arm: ca. 5gm
- * Photo electric control, imposing no load on tracking arm
- * Out of configuration warning alarm to safeguard records
- * Fail safe tracking in the event of system fault. (see below)
- * Limit switches at both ends of track
- * Manual cueing at any point on record
- * Corrects tracking errors of 0.2 deg.

REFERENCES

- Randhawa: "Pickup Arm Design Techniques" *Wireless World*, p. 73, March, 1978
Randhawa: "Pickup Arm Design Techniques—2" *WW*, p. 63, April, 1978

A NOTE ON RECORD SAFETY

Will failure of the servo system damage records? This is a very popular question, for reasons that are obvious. Here are the answers.

1. The tracking arm is equipped with a universal pivot just like a conventional arm, so it will continue to track the record like a conventional arm (although with reduced performance parameters) if the servo fails, until...

2. The out-of-configuration alarm sounds. The alarm is an integral part of the electronic circuit and will operate if any serious tracking error occurs, or if a fault in the opto-electronics occurs, but...

3. Even if a fault does occur in the opto-electronics, the servo motor will still proceed at a steady average predetermined speed to keep track of the record, although obviously this will not be to within the specified high accuracy.

4. Since the servo circuit and the recommended direct drive turntable both work off the same low-voltage DC supply line, failure of the supply will not leave one operating without the other to cause tracking error.

In conclusion, the answer to this question is (at least where this design is concerned) that damage to records is much more likely from other sources, such as a chipped or worn stylus, incorrect cleaning of records, poor storage facilities, and the occasional accident in handling the record.