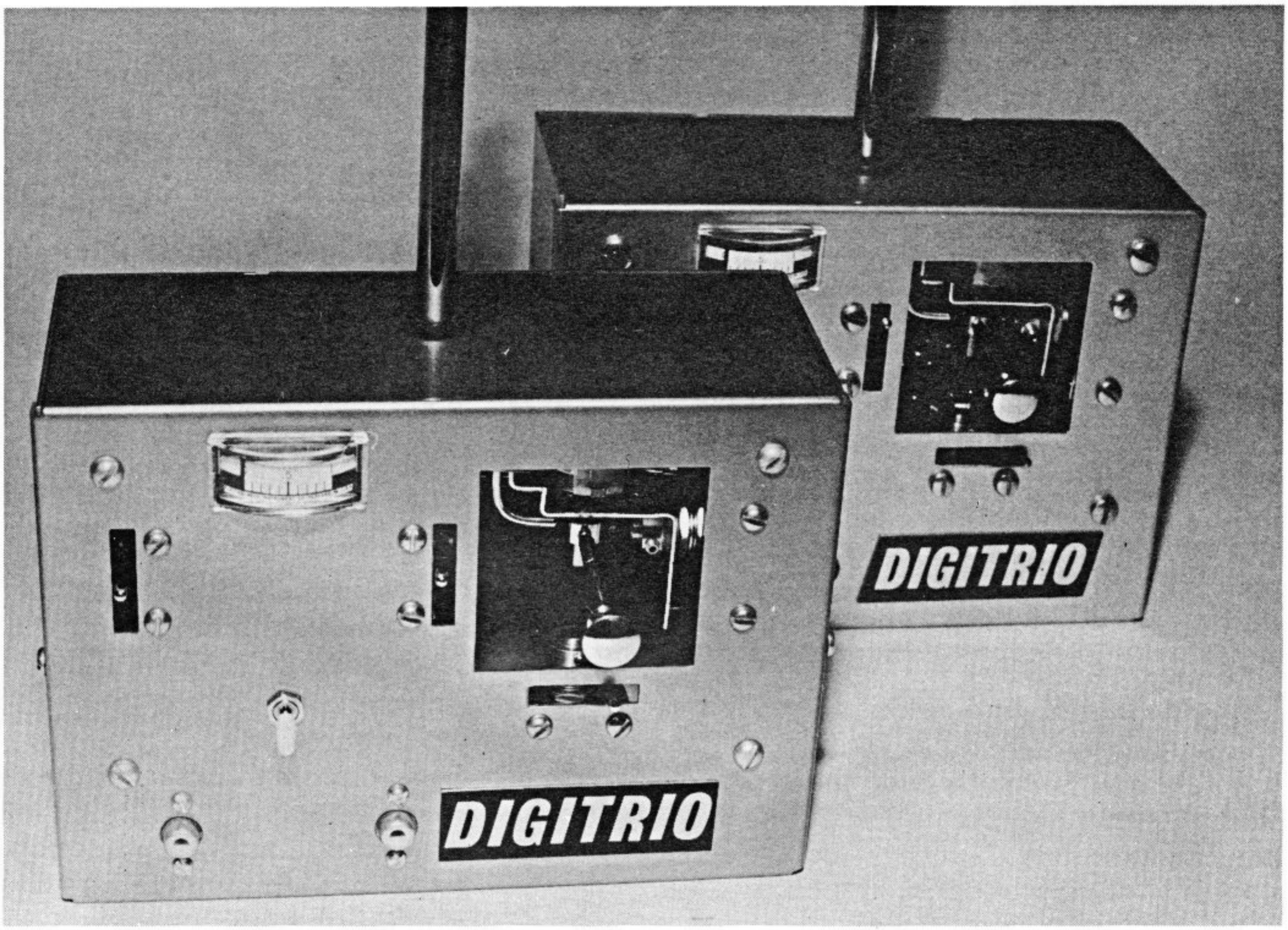
$4.00

RCM DIGITRIO



By Ed Thompson

RADIO CONTROL MODELER MAGAZINE

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*** NOTE**

Due to popular request R/C Modeler Magazine has reprinted the "Digitrio" exactly as it appeared when first published as a series in 1966. Because this is an exact reprint of the original RCM Digitrio, many prices, stock numbers, firm names and addresses, coupons, etc., are obsolete or have changed since the first printing. We want to emphasize that this reprint has been made available strictly as a service to RCM readers and not as an updated or currently edited book.

Editor's Preface

The RCM Digitrio Proportional System, designed and developed by Ed Thompson, Technical Editor, was originally presented as a series of seven articles in Radio Control Modeler Magazine. We feel privileged to present this complete basic series to you with the knowledge that it represents one of the finest individual design and engineering accomplishments in the field of radio control — providing RCM readers with the most thorough and complete construction series ever published in any model aviation magazine.

No attempt has been made to condense, or otherwise shorten, the series, for Ed Thompson will take you from the basic theory straight through to the final installation of this digital proportional system. If you can use a soldering iron and ordinary model shop tools, you can build the Digitrio. No elaborate tools or electronic test equipment is necessary, due to the author's method of presentation. Although access to an oscilloscope would be convenient, even it is not mandatory for alignment.

Individual components for this system are available from most major electronic parts distributors. Complete kits for the transmitter, receiver-decoder, and servos are available from World Engines, Inc., 8206 Blue Ash Road, Cincinnati, Ohio 45236. In addition, other RCM advertisers have made available such items as printed circuit boards, transmitter cases, stick assemblies, transmitter and airborne battery packs, simplified mounting boards, compatible servos, etc., for the convenience of scratch builders. The editors of RCM have built five of these systems from the article, and from the kits, in order to insure that all phases of this system were thoroughly bench and field tested. In addition, many individual modeler-technicians have cooperated in the testing of the system prior to its initial publication. To the latter individuals, we are deeply indebted.

To date, more than two thousand Digitrio systems have been built, and at the time of this writing, have established several first places in national competition as well as a new world's speed record for an R/C hydroplane.

If you follow these instructions to the letter, you will have a proportional system that will provide you with maximum reliability and performance for many years to come. If, for any reason, you should encounter any difficulty that cannot be corrected locally, simply drop a note to The Editor, R/C Modeler Magazine, P. O. Box 487, Sierra Madre, California.

We think you'll enjoy the RCM Digitrio Proportional System. Good flying!

Don Dewey, Editor

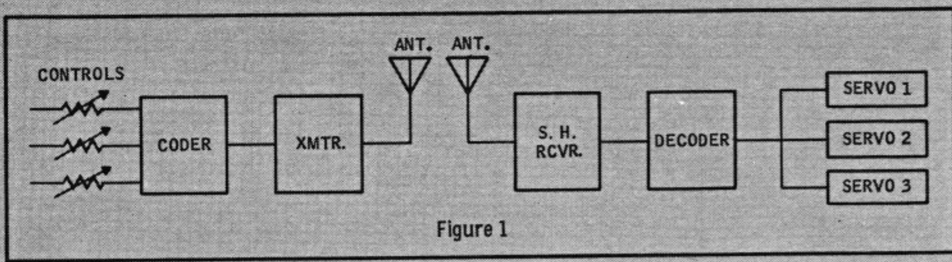


Figure 1

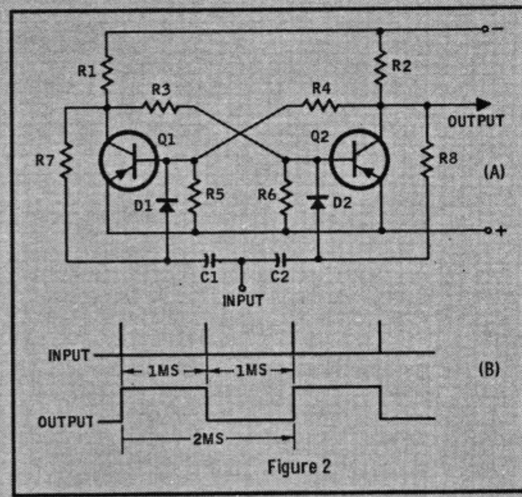


Figure 2

How to obtain Digital Proportional Control using basic computer circuits along with a brief description of the basic circuits that will be used in the RCM Digitrio is the subject of Part I and will enable you to better understand how your system will work.

Preface

THERE is little doubt in anyone's mind that the proportional age has descended upon us. I suspect most of us are a little confused by all the ballyhoo we read and hear about the different systems, no longer having a familiar yardstick to use when evaluating these various systems. In the past, we picked equipment on the basis of dependability, mainly because the equipment was almost identical in makeup – even to the point of looking alike except for the color of the cases! Proportional systems, on the other hand, may look alike, but the internal makeup is limited only by the manufacturers' imagination and ingenuity. Some of it is vastly complex, and if programmed properly, could solve mathematical problems and perform minor computing tasks!

The system presented here will not offer serious competition to Univac nor will it revolutionalize the proportional industry. It will, however, provide a proven three channel, so-called "digital" system. I say "so-called" digital system, because it is not truly digital, nor are the other systems currently on the market. Doug Spreng covered this in a previous article so I won't expound on it.

It appears that a lot of the equipment on the market gets homesick and has a nervous breakdown occasionally. The result is quite dramatic at times – especially when the aircraft tries to do a loop, barrel roll, Immelmann and half ganor at the same time. The usual result is that the hi-strung system is sent home to Papa for corrective action. We then twiddle our thumbs waiting for its return and mutter purple phrases about the manufacturer. We used to be able to spot impending trouble when a reed needed cleaning or tones needed adjustments etc. Now we are faced with sudden malfunctions which leave us baffled, disgruntled, frustrated and unsure (oh yes, reeds will be around for a long time yet). This is mainly due to the lack of knowledge about this new breed of cat.

The manufacturers are apparently not too concerned about this and are doing a good job of keeping their brain children a secret. I don't think this system will unlock any magic door of knowledge on the subject but it will give you an insight to some of the basics used. I sincerely hope that it will stir the imagination of some to experiment and improve the present state of the art.

How To Obtain Digital Proportional Using Basic Computer Circuits

The heart of the system presented here and in subsequent articles will consist of simple computer circuits. These are common circuits that are neither mysterious nor hard to comprehend. Figure 1 shows how we will accomplish this by means of a simple block diagram.

By adjustment of the controls we program the system. The coder senses the position of the controls and modulates the transmitter with this information. The receiver processes the information and passes it on to the decoder which, in turn, separates it into individual channels. This information is compared in the individual servos with information supplied by the servo itself relating to its present position. If the information received differs with that of the servo it senses in what direction to move in order to correct itself. When the servo moves far enough to agree with the incoming information it stops at its new position. The servo now has a new reference position and keeps comparing for further instructions. Old Hat, so far, and not too sensational.

The main departure from norm is that we are going to do it with computer circuits and pulses measured in milliseconds or MS (1/1000 of a second) and micro-seconds (1000 micro-seconds equal 1 milli-second). We are also going to eliminate tones and use the carrier to convey this intelligence (shades of the RK-61 era!). We will pulse the carrier at precise variable rates and intervals. The receiving end will shape these pulses, sort them out, and precisely analyze each one for any change in program at the transmitter. Let's go on to the circuits we will use to accomplish this feat.

Brief Description Of Basic Circuits That Will Be Used

For the following discussions the term ground will be synonymous with emitter potential.

Figure 2A shows a bi-stable or flip-flop circuit. Although it is used only one time in this system it is used extensively in, and is the heart of, some of the decoders on the market. Inspection of the circuit will reveal a sort of suicide circuit. R1 and R2 are the collector loads for their respective transistors. R3 and R6 provide forward bias for Q2. R4 and R5 provide forward bias for Q1. Disregarding the other components for the time being let's look at the operation.

The conduction of either side depends on the other side being cut off, and vice versa. Due to this relationship, one side will be cut off and the other side will be conducting. To make it work let's assume that Q1 has a little higher gain than Q2. When we first apply power it conducts a little heavier. Its collector voltage going to ground reduces the forward bias on Q2 thereby helping its collector voltage go more

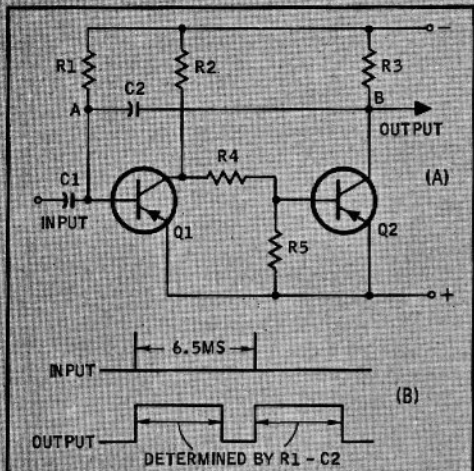


Figure 3

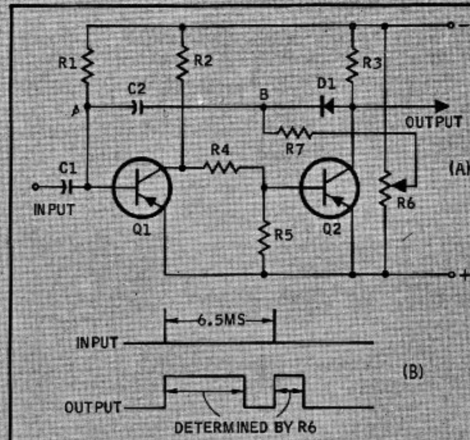


Figure 4

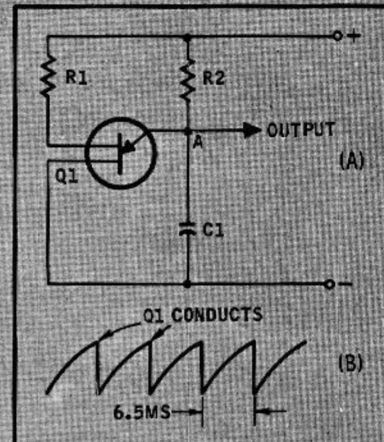


Figure 5

negative. Q2's collector voltage going negative provides more forward bias for Q1 assisting it even further in its race to conduction. This of course assists Q2 to cut off even more. This mutual assistance bond between the two always ends up with one holding the other into conduction.

This then, means that one collector will be negative and one at ground with no in-between conditions allowed. Actually, this takes place instantly, and the state of the two transistors is determined by which one gets a head start. We provide this head start with C1, C2, R7, R8, D1, and D2. If we apply a short positive pulse at the input terminal it will be transferred to Q1's base via C1 and D1.

Simultaneously it will appear at Q2's base via C2 and D2. We left Q2 cut off so the positive pulse will have no effect on it. However, since Q1 was conducting, the positive pulse will cut it off for the duration of the pulse. This causes Q1's collector to go negative briefly and provides forward bias for Q2 which takes advantage of the situation and, armed with a head start, reverses the condition of the circuit. Every time a positive pulse appears at the input the circuit will alternate its state. R7 and R8 are used to assist the action by biasing the diode capacitor junctions. If Q1 is cut off, R7 will apply the negative collector voltage to the D1-C1 junction minimizing the effect of the positive trigger pulse to Q1, conversely R8 will apply Q2's collector ground potential to the D2-C2 junction enhancing, or at least not detracting from the effect of the positive pulse to Q2. This, in effect is trigger gating and allows large trigger-pulse amplitude variations while retaining high trigger sensitivity. There are other ways to trigger the circuit but this is the way we will use it in the system. Actually all I have said so far is that each positive pulse applied to the circuit will change its state. This means that two pulses are required for a complete cycle. Now let's put it to work.

If we send short pulses spaced at 1MS intervals (that's 1/1000 of a second), we will change its state at that same rate. A bit faster than the kicking duck, eh? The output will be square pulses with 1MS widths or 2MS for a complete cycle (See Figure 2B).

We now have to go through another explanation, this time a monostable multivibrator or simply a one shot. (Figure 3A shows this circuit.) R2 and R3 are the collector loads for their respective transistors. R1 provides forward bias for Q1, R4 and R5 provide forward bias for Q2. Q1 is biased more heavily than Q2 and will be conducting in its steady state. Conduction of Q2 depends on the collector voltage of Q1 being negative (which it is not since it is now conducting) so Q2 will be cut off. This places a charge across C2 that is positive at Point A (because the forward biased base emitter junction of Q1 is a very low resistance to ground) and negative by the amount of supply voltage at Point B. If a short positive pulse is applied to the input it will briefly cut off Q1 causing its collector to go negative. This forward biases Q2 which instantly conducts. Q2's collector goes to ground and instantly causes a polarity reversal across C2. Point A now goes positive equal to the negative supply voltage with respect to Point B. This cuts off Q1 which now holds Q2 in conduction. C2 starts discharging through R1 and will keep Q1 cut off until it discharges its positive charge and Point A goes negative enough to cause Q1 to conduct again. This of course causes Q2 to cut off and the circuit is back in its stable state. (See Figure 3B.) At this time we can apply another positive pulse and start all over again. We can also apply a negative pulse to the base of Q2 and obtain the same results by forcing Q2 into conduction. We will in fact do this in the system. As you can see the time it takes to complete a cycle depends on how long it takes C2, discharging through R1, to return Point A to a slightly negative voltage to forward bias Q1. There are two easy ways to control this. We can either vary C2's capacity (larger capacity/longer cycle) or R2's resistance (larger resistance/longer cycle). How do you think we will do it? You guessed it, a third way. (See Figure 4A.) As you can see we have added three components. Now we can vary the voltage at Point B. When Q2 conducts now, Point A will go positive equal to the amount of negative voltage preset at Point B by the setting of R6. This means that for a given time constant of R1-C2 the cycle now depends on the voltage at Point B. The more voltage applied the longer it takes C2 to discharge and vice versa. Diode D1 isolates C2 from Q2. In the circuit's steady state Q2's collector is negative and D1 is reverse biased. When Q2 conducts, it grounds the preset voltage at Point B through D1 which is now forward biased. R7 is a current limiting resistor so we do not damage D1 or load Q2. By adjusting R6 we can vary the cycle time of the circuit. So now we have a **variable** one shot. (See Figure 4B for wave forms.)

One more time, fellas! An easy one this time and then we will put the circuits together. Figure 5A shows a unijunction transistor in a relaxation oscillator configuration. Simply and briefly R2 charges C1 until the voltage at Point A is positive enough to cause Q1

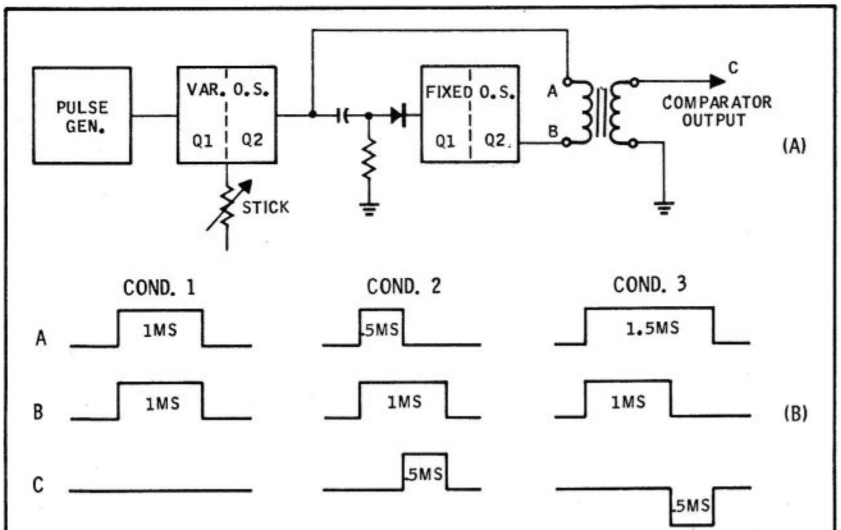


Figure 6

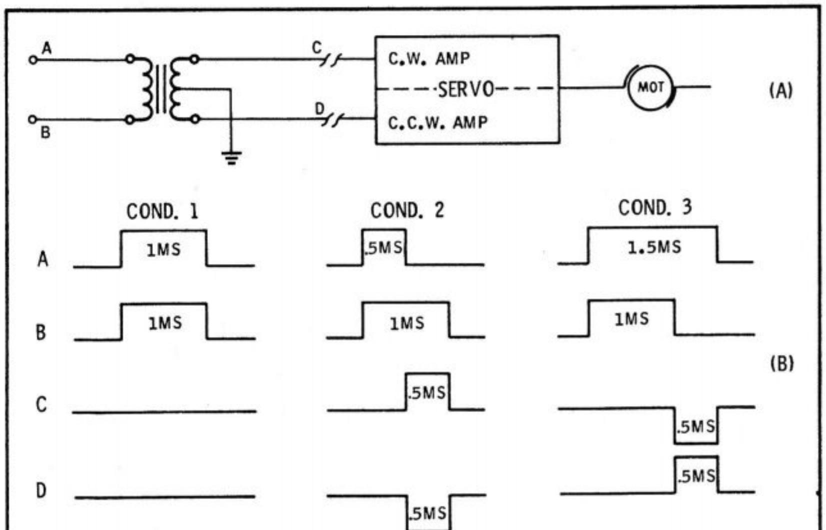


Figure 7

to conduct. When it does the forward biased junction effectively shorts C1's charge quickly cutting off Q1. It then starts over. R1 is similar to a collector load resistor and provides current limiting and temperature compensation. (Figure 5B shows the output wave form.) We will use the downward transitions as a trigger. If we replace R2 with a pot we can vary the repetition rate of the circuit. This circuit appears inverted in the transmitter schematic but inspection will show it is the same as described.

Connecting Basic Circuits To Give Desired Results

Let's assemble a simple circuit now, and see how we detect a change in pulse width. Figure 6A shows a variable one shot coupled to a fixed one shot of 1MS duration. Assume that the variable resistor of the variable one shot is connected to a control stick. We can now vary the pulse width of the variable one shot from .5MS to 1.5MS by movement of the stick to its extremes with 1MS being neutral. Let's run through the operation with the control stick in the neutral position. The pulse generator triggers the variable one shot every 6.5MS and is used to initiate and repeat the action at this rate. Although we will use the downward transitions of the pulse generator coupled to Q2, it is shown here coupled to Q1 to simplify the drawing. The leading edge of the pulse created by the variable one shot will instantly trigger the fixed one shot. The output of the variable one shot is also applied to Terminal A of the transformer. The pulse of the fixed one shot is applied to Point B of the transformer.

Looking at the waveforms (Figure 6B) for Condition 1 we can see that Point A and B of the transformer will have a positive pulse of 1MS duration applied simultaneously. This will not cause an output because the pulses are identical and cancel each other's effect. It's evident at this point that the transformer is used to compare the pulses and it will be referred to as a "comparator." Condition 2 shows the variable one shot with a .5MS pulse duration. Since the fixed one shot always produces a 1MS pulse, Point B will remain positive .5MS after Point A returns to negative. For the first .5MS the pulses cancel each other. When Point A goes negative we have a resultant .5MS pulse due to the remaining pulse length of the fixed one shot holding Point B positive. There is a 180 degree shift of polarity across the transformer so the output of the comparator is a positive .5MS pulse. Condition 3 shows the variable one shot with a 1.5MS pulse width. This will hold Point A positive for .5MS after the 1MS fixed one shot returns to negative. The 180 degree shift of polarity across the transformer will now cause the comparator output to be a .5MS negative pulse.

Let's go to Figure 7A, now, and see how to run a servo with this type of circuit. As you can see the comparator now has a center tapped secondary. An inspection of the waveforms (Figure 7B) will show that we can now get a positive output from either Point C or Point D depending on which way we move the stick. We also get negative outputs but the servo will only respond to positive pulses and will ignore these negative pulses.

Condition 1 shows neutral position and no output at either Point C or D. Condition 2 shows positive output at Point C and negative at Point D (which is ignored by the servo). The servo amplifies this positive pulse at Point C and runs in a clockwise direction. Condition 3 shows a negative pulse at Point C and a positive pulse at Point D. The servo will now run in a counterclockwise direction. This action is repeated every 6.5MS by the pulse generator so we keep pulsing the servo at this rate and can change its direction by movement of the stick.

We're almost home now, and if you're still with me the rest is a snap! If you're not, I suggest you reread those portions you're hazy about or get the local Einstein to help you. A little effort will be rewarded and once you get the hang of it you'll be saying things like, "how simple can you get" and "I knew it all the time."

Well, so far we have a quasi "bang bang" system. Now let's make it proportional. Figure 8 shows that we have replaced the fixed one shot with a variable one shot which we'll call the reference generator, and mechanically coupled the variable resistor to the

For your convenience, the following is a listing of various sources of supply for Digitrio kits and accessories as previously advertised in the regular monthly issues of R/C Modeler Magazine. For additional information, please correspond directly with the manufacturers concerned:

Complete Digitrio Kits

World Engines, Inc., 8206 Blue Ash Road, Cincinnati, Ohio 45236.

These are the designer approved kits, each available separately, e.g., transmitter, receiver, decoder, and servos. Batteries, stick assembly, etc., not included. Tested and approved by RCM.

Compatible Servos

Spar Electronics, 15302 Oak Canyon Road, Poway, California 92064.

Designed for use with the Digitrio system, these servos have not been tested by RCM, but were used with a Digitrio system that recently set a world's hydroplane record.

Orbit Electronics, Inc., 11601 Anabel Avenue, Garden Grove, California.

Orbit has produced a digital servo that is compatible with the RCM Digitrio. These have not been tested by RCM, to date.

Hardware and Stick Assemblies

Justin Inc., 418 Agostino Road, San Gabriel, California.

A completely drilled and ready-to-use transmitter case with all stick assembly and pot mounting brackets for the Digitrio. Tested and approved by RCM.

Stanton R/C, Inc., 4734 North Milwaukee Ave., Chicago, Illinois 60630.

A Digitrio stick assembly kit and pot bracket hardware. Tested and approved by RCM.

Printed Circuit Boards

West Coast Slides, Box 788, San Pedro, California.

Printed circuit boards for the transmitter, receiver, decoder, and servos. These units have not been tested by RCM, to date.

Stanton R/C, Inc., 4734 North Milwaukee Ave., Chicago, Illinois 60630.

Printed circuit boards for the RCM Digitrio transmitter were tested and approved by RCM. It is assumed that the other printed circuit boards are also available.

Transmitter Stick Assemblies

World Engines, Inc., 8206 Blue Ash Road, Cincinnati, Ohio 45236.

The popular Bonner stick assembly, used on the Bonner Digimite, PCS, Kraft, Controlaire, and F&M proportional systems, is available from World Engines for use with the Digitrio. Tested and approved by RCM.

Micro-Avionics, Inc., 346 E. Foothill Blvd., Arcadia, California.

The Micro-Avionics stick assembly, used on the Micro-Avionics and Orbit proportional systems is available for Digitrio builders. Some transmitter case modification is necessary to fit this unit. Tested and approved by RCM.

Power Supplies

P & D Manufacturing Company, P. O. Box 34, Chino, California.

Complete power packs, or power pack kits, are available from this manufacturer. Designed exclusively for the Digitrio system, they have been tested and approved by RCM.

Mounting Boards

Fly-Tronics Engineering, 3010 Brook Drive, Muncie, Indiana 47304.

The Fly-Tronics Circuit Master is a printed circuit board on which the Digitrio servos mount, as well as a 15-pin Cannon plug for the receiver-decoder and power supply, thus eliminating many of the wires and most of the plugs in the system. Tested and approved by RCM.

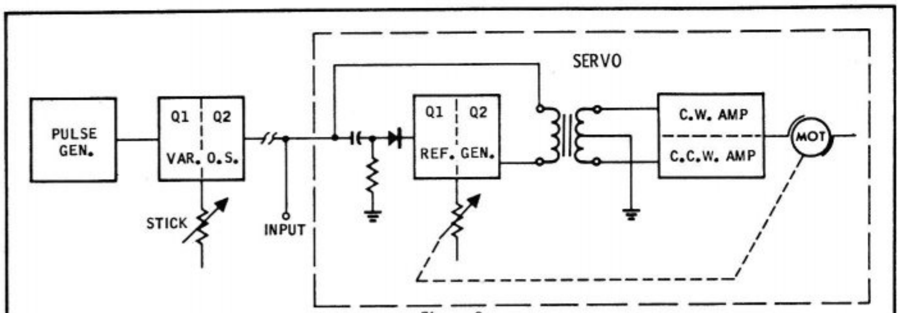


Figure 8

motor. All of this, including the comparator, is now contained in the servo case. When the motor runs it also turns the variable resistor. We now control the pulse duration of the reference generator and lengthen or shorten the pulse depending on which direction the motor turns. If the incoming pulse duration is longer than the reference generator, assume that the comparator will cause the servo to run in a counter clockwise direction. If the variable resistor turns in a direction so as to lengthen the reference generator pulse it will eventually match the incoming pulse length and the comparator output will go to zero stopping the motor. As long as we hold the control stick in this position the servo will remain where it is. Any slight movement of the stick however will cause comparator output and the servo will correct itself. It works the same way only opposite if the incoming pulse duration is shorter than the reference generator pulse. Here is the main departure from analog servo operation. Since any slight movement of the stick will cause comparator output of the same voltage (only the pulse duration varies) we get full power for the smallest incremental movements of the servo.

Figure 9A shows how we do this via radio control. The coder pulses are variable and for Condition 1 (Figure 9B) modulates the transmitter with a pair of pulses spaced 1MS apart. Point B shows the carrier being "spiked" off by these pulses. The receiver receives and processes these pulses and a replica of Point A appears at Point C. The flip flop we discussed earlier converts these pulses to a pulse with a 1MS duration. We can apply this pulse to the input of Figure 8 and by varying the spacing of the pulses transmitted, by stick movement, we can vary the position of the servo. Figure 9B waveforms show how the decoder follows stick movement.

There you have a basic single channel digital proportional system. This has been a simple explanation without frills and the confusion factor has been held to a minimum. As we progress we will replace the transformer comparator with transistors, add two more channels and provide a means for the extremely short comparator pulses to run the servos smoothly.

(END PART I)

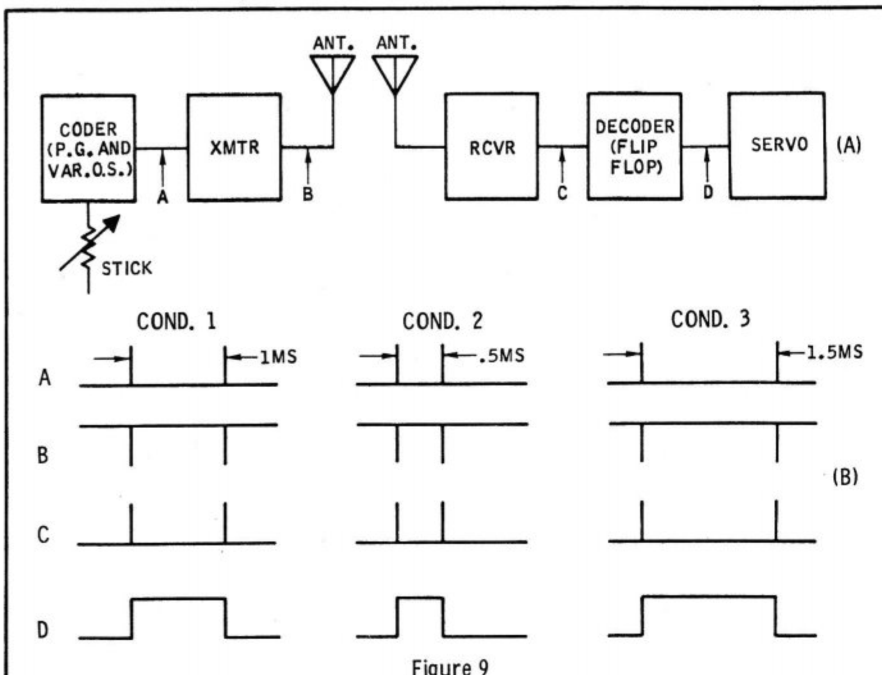


Figure 9

Preface

If the first article in this series stirred your interest and imagination, this and succeeding installments, will answer any questions you might have concerning the RCM Digitrio. Since Don has assigned me the position of Contributing Technical Editor and placed no restriction on the content or length of this series, I think you'll find the articles quite complete – even to the point of boredom for those with a "better-than-average" technical background. This attempt at completeness, however, will allow the average RC'er to "keep up" with the various stages of construction, and what otherwise might be an advanced project for the technician alone. Also, unlike a "quickie" article, this series can be used as a reference by experimenters who would rather "roll their own."

The theory that prefaces each segment of this series will be written somewhere above Ohm's Law and below complicated discussions requiring specialized knowledge or math for understanding. You will not have to be an engineer to understand the language used – I am writing for your understanding and not to impress anyone with technical terminology. The RCM Digitrio was not born from an Einstein-type inspiration, nor was it copied from any other system. Rather, it came from several years of staring at a scope and asking a myriad questions of people with advanced technical backgrounds. Although this system is designed to be duplicated without an oscilloscope, I would suggest that you buddy up with a friend who can assist you if you should run into difficulty.

Throughout the series, reference to ground will be synonymous with emitter potential of the stage under discussion. Let's get started with the transmitter-coder.

Theory of Transmitter

Figures 1, 2, 3 and 4 and the schematic will be used for the following theory discussion. Study these for familiarization before proceeding. All action starts with the pulse generator Q5. The waveform for Point A, Figure 2 shows how C14 charges positive until the firing point of Q5 is reached. When Q5 fires, the rapid downward transition couples a negative-going pulse to Q7's base via C16. R13 and R30 provide a means of varying the time lapse between negative transitions. If the resistance of either R13 or R30 is increased it will increase the time required for C14 to charge to the firing point. The opposite is true if the resistance is decreased. R29 is used to decrease the effect of R30's movement. R13 is used as a coarse setting of Channel 1 and R30 is used for the motor stick control. By selection of R29 we can adjust the servo movement extremes. So far then, we have a negative pulse going to Q7's base with control of the repitition rate.

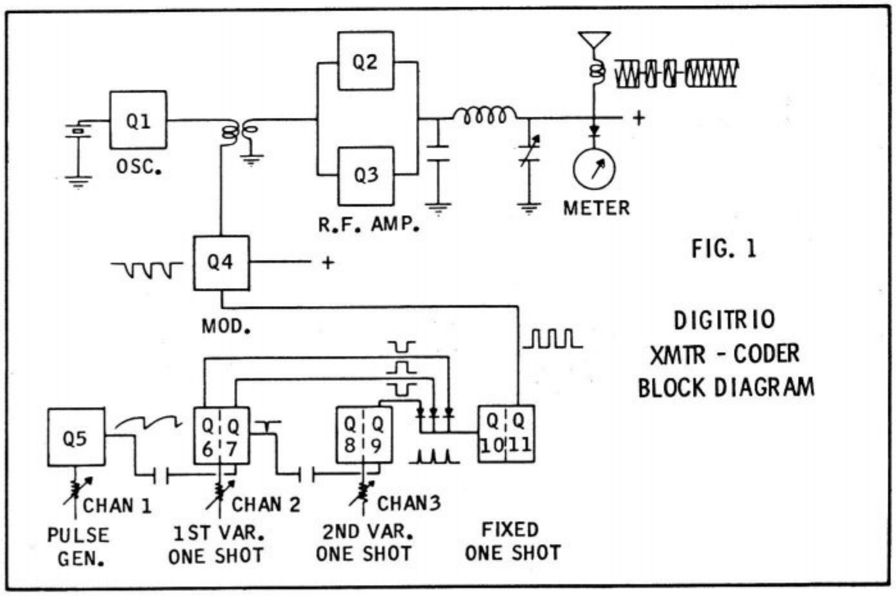


FIG. 1

DIGITRIO XMTR - CODER BLOCK DIAGRAM

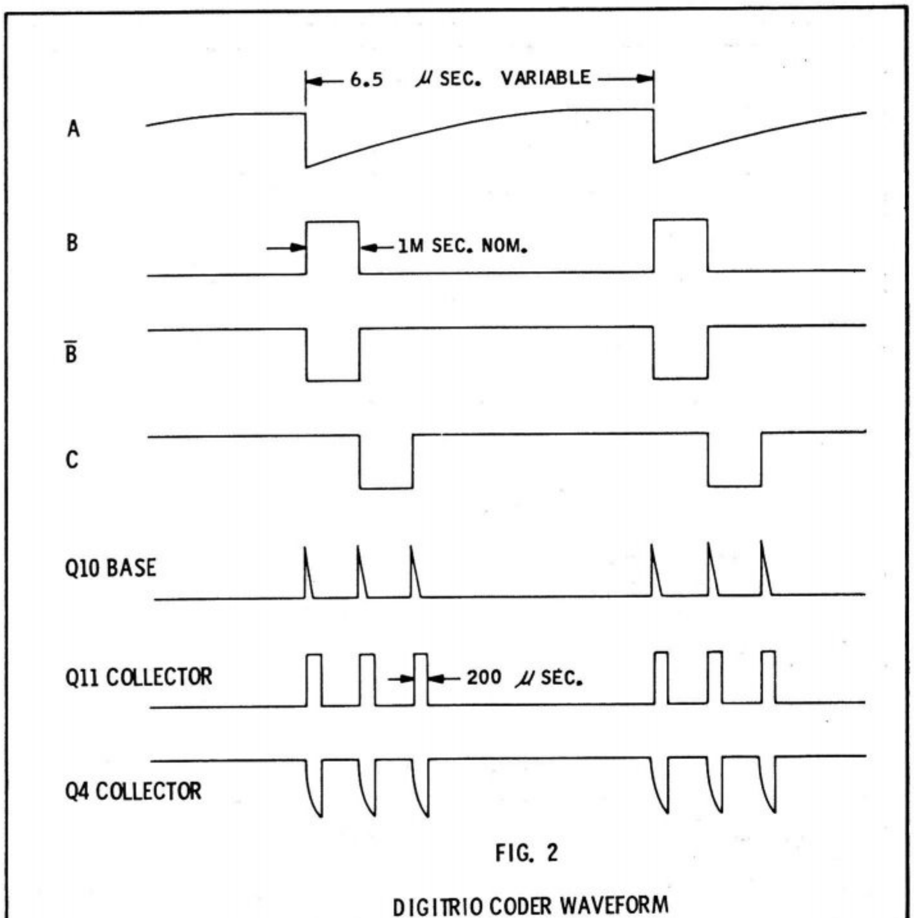


FIG. 2

DIGITRIO CODER WAVEFORM

When this negative pulse is applied to Q7's base the first variable one shot (Q6 & Q7) triggers (See Points B and B of Figure 2 waveforms). The cycle time of this one shot is determined by R31 and/or R34. R34 is the stick control and R31 the trim. R32 decreases the effect of R31's movement. The instant this one shot triggers, Q7 conducts, coupling a positive pulse across C20. When the one shot cycle is completed Q6 conducts (returning to its normal state) coupling a positive pulse across C21.

Q8 and Q9 form another variable one shot identical to Q6 and Q7. It is triggered by a negative pulse coupled across C17 when Q7's collector goes negative at the completion of its cycle. When this second one shot has completed its cycle Q8 conducting, couples a positive pulse across C19. C19, C20 and C21 are tied to ground with R21, R22 and R23. The short time constant of these resistor-capacitor combinations result in short positive pulses applied to Q10's base (See Figure 2). D4, D5 and D6 form an "OR" gate and prevent the negative transitions of the one shots

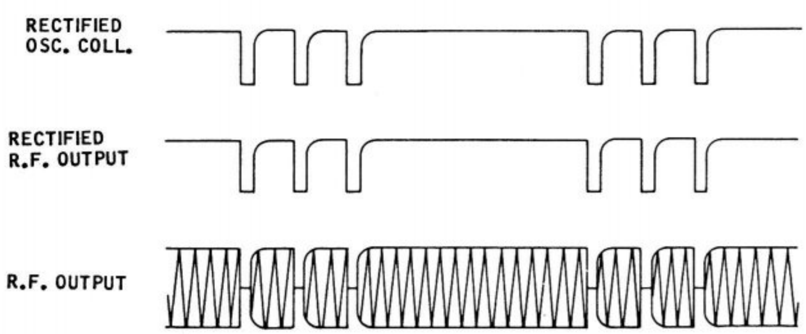


FIG. 3

DIGITRIO XMTR WAVEFORMS

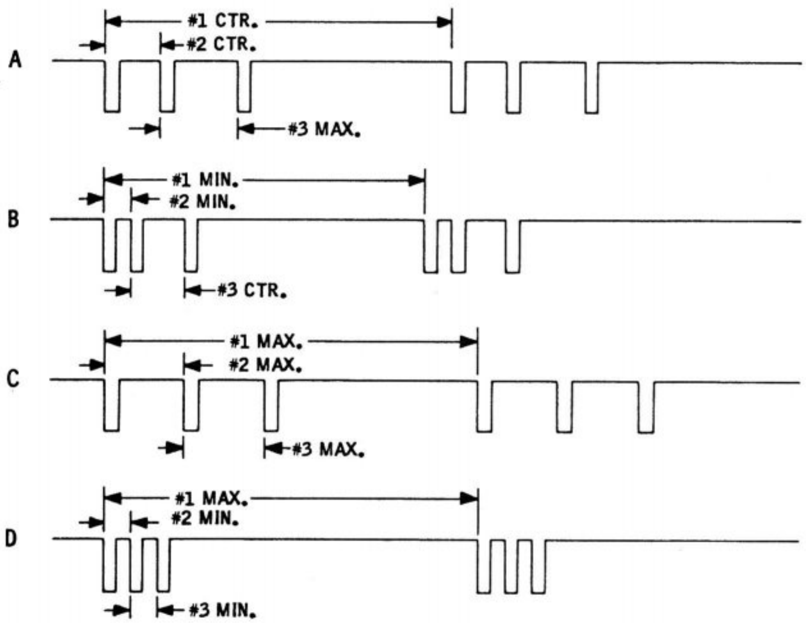


FIG. 4

DIGITRIO PULSE TRAIN WAVEFORMS

from appearing at Q10's base as well. as isolating the different sources from each other. Let's review what we have so far.

The pulse generator initiates the action. When it triggers the first variable one shot, we produce Pulse 1 at Q10's base. We can vary the time between the #1 pulses with R13 (coarse) or R30 (motor control stick). When the first variable one shot completes its cycle we produce Pulse 2 at Q10's base. We can vary the time between Pulses 1 and 2 with R34 (control stick) or R31 (trim).

At the same time Pulse 2 is produced, we trigger the second variable one shot. When it completes its cycle we produce Pulse 3 at Q10's base. We can vary the time between Pulses 2 and 3 with R38 (control stick) or R35 (trim). The time between #1 pulses will be Channel 1. The time between Pulses 1 and 2 will be Channel 2. The time between Pulses 2 and 3 will be Channel 3. Since all channels are initiated at the completion of its preceding channel there is no interaction.

The pause between "sets" of three pulses is called the "sync" pause. The receiving decoder uses this pause to reset, or sync, itself as we'll see later. So far we have three independently controllable positive pulses at the base of Q10. These positive pulses are used to trigger the fixed one shot described below.

Q10 and Q11 form a fixed one shot that will produce a positive pulse at Q11's collector (See Figure 2) of approximately 200us duration each time it is triggered. These positive pulses are directly coupled to Q4's base and will cause this stage to cutoff for the duration of each pulse (See Figure 2). We will call Q4 the modulator as it is used to control the transmitter output. That's it for the decoder, now for the transmitter.

Q1 is the oscillator and gets regenerative feedback across L1 to sustain oscillation. The frequency of oscillation is determined by the crystal. R1 and R2 provide forward bias for this stage. L2's primary and C2 form a tuned circuit for the collector and is tuned to the operating frequency. L2's secondary couples the RF energy to the RF amplifier. The oscillator operates on the fundamental frequency desired and the crystal is a commonly available third overtone type.

Q2 and Q3 form the RF amplifier. Although sufficient power would be available with a one-transistor circuit, two are used in parallel to share the load and heat dissipation. R4-C4 and R5-C5 are used to insure that one transistor doesn't "hog" all the driving power and provide the DC bias voltage return to ground. The RF amplifier operates in Class C and derives forward bias voltage from the RF voltage rectified at the base emitter diode. C6, C7, C8 and L5 form the RF amplifier tuned circuit and is tuned to the operating frequency by C7-C8.

C9, C10, R6, R7 and D1 sample and rectify the RF voltage at the antenna which is applied to M1. R7 allows adjustment to suit the meter used. Positive voltage is applied to the amplifier through L6 which isolates the RF from the rest of the circuit. C3, C11, C12, C13, L3 and L4 are all used to provide RF feedback immunity.

Q4 modulates the transmitter by turning off the oscillator each time a positive pulse is produced at Q11's collector (See Figure 2). By using this method, oscillator leak-through is eliminated when operating the transmitter in close proximity to the receiver when testing etc. This method also produces extremely clean transmitter pulses from the standpoint of rise time and modulation depth.

The emitter of Q4 is tied to the positive side of the battery supply. Its collector goes directly to the oscillator. Q11's collector is normally negative with respect to Q4's emitter, forward-biasing Q4. This applies positive voltage to the oscillator's collector and bias resistors allowing it to operate. R8 and R9 are the bias resistors for Q4. Whenever Q11 conducts, its collector goes to ground potential and this removes forward bias from Q4. The result is that Q4 cuts off, removing the positive voltage going to the oscillator and the oscillator stops. This occurs each time one of the 200us positive pulses, which we generated earlier in the coder, appears at Q11's collector. The RF at the antenna therefore is a carrier that is spiked off in a train of three 200us pulses with controllable recurrent rate and independent control of pulse separation. Figure 3 shows waveforms for the transmitter. The gentle curve at the top of each output pulse trailing edge helps prevent ringing in the receiver IF stages. When we get to the receiver you will note how clean the signal is. Figure 4 shows variations of the pulse trains as control pot settings are changed. Pulses are shown at center or extremes for simplicity but pulse separation is continuously adjustable throughout the control pot ranges.

Z1 is a zener diode wired in the circuit in a reverse bias configuration. It has the property to conduct when its reverse breakdown voltage is applied. It will maintain this voltage as the applied voltage is increased (current increases of course) up to its dissipation limits. R28 (2 ea. 180 Ohm ¼w in parallel) sets the current in a middle range to provide a stable voltage (5.1v) for the coder regardless of normal battery voltage fluctuations. This prevents trim drift due to varying voltage. Figure 1 can be used as a visual aid to tie all the foregoing theory together.

The battery pack is eight 600 M.A. Pencell nicads wired in series. This gives about four-five hours operating time. I doubt if a 9v dry battery will fit in the case shown and do not recommend their use. C23 and C24 are used to filter the circuit DC-wise. J1 and J2 are used as charging jacks for both the transmitter and receiver. They are wired to the off side of the switch. The antenna is center-loaded and contrary to many proponents of the unloaded or base-loaded types I have yet to encounter dead spots while using it. If you are of the "rather fight than switch" group, a base loading coil can be added and a "stick" used, at the expense of lowered "radiated" power.

Parts List and Procurement

By far one of your biggest problems in constructing the Digitrio will be procuring the parts. To make it as easy as possible for you I have included the manufacturer and manufacturer's part number. An unfortunate aspect of our hobby is that most electronic parts dealers handle only parts by certain manufacturers and we electronic builders bounce back and forth between distributors trying to come up with our total requirements. The two largest catalog dealers are very fast and efficient, as long as they have the part on hand and you give them **their** catalog number for the part. The sad part comes when they don't have a part and instead of sending it when they do get it in stock, they send you a "sorry we're temporarily out of the part you requested – reorder in 30 days" type reply. Also I have yet to receive a reply to inquiries about the availability of parts for which I didn't have their catalog number!

Of course, I think we all understand that any purchases **we** make will hardly make a dent in their profits, and in some cases, their handling costs will even exceed their profits – **costing** them money! So it's a sad lot for us "scratch builders." On the brighter side, we are fortunate to have a couple of hobby distributors who will go out of their way to help us when we need parts. Their assortment of parts, however, is limited to selected items used in their own equipment or carried by popular demand. One of these distributors is kitting this system and by buying in large lots they may save you money over buying individual parts – plus a lot of leg work.

For you scratch builders my parts list shows the parts I used in the original "Digitrio" which I obtained from ordinary sources. To give you the best possible chance of duplication I'll comment on the "odd ball," critical ones and give some substitutes.

1. C15, C18 and C22 are "Cal Rad"

RCM DIGITRIO TRANSMITTER PARTS LIST

REFERENCE NUMBER	DESCRIPTION	MANUFACTURER	MANUFACTURER NUMBER
Ant.	C. L. Ant.	World Engines	(Controlaire)
C1	100 PF	Erie	831X5R101K
C2	15 PF	"	831U2M150K
C3	.1	Centralab	UK10-104
C4	.005	"	CK502
C5	.005	"	"
C6	50 PF	Erie	831U2M500K
C7	50 PF	"	"
C8	7-100 PF	Arco	423
C9	27 PF	Erie	831U2M270K
C10	.001	"	CK60AW102M
C11	.05	Centralab	UK10-503
C12	.05	"	"
C13	.05	Centralab	UK10-503
C14	1.0 Tantalum	Mallory	TAS105KO35POA
C15	.1	Cal Rad	.1 Mylar
C16	.01	Centralab	CK-103
C17	.001	Erie	CK60AW102M
C18	.1	Cal Rad	.1 Mylar
C19	.001	Erie	CK60AW102M
C20	.001	"	"
C21	.001	"	"
C22	.01	Cal Rad	.01 Mylar
C23	100 Electrolytic	Mallory	TT15X100
C24	15 MFD @ 15V	World Engines	————
D1	Ger. Diode	Ohmite	IN56A, IN 34 etc.
D2	Sil. Diode	"	IN457
D3	"	"	"
D4	"	"	"
D5	"	"	"
D6	"	"	"
J1	Phono Jack	Switchcraft	3501F
J2	"	"	"
L1	47 uh choke	Miller	74F475A1
L2	OSC Coil Hand Wound on C.T.C. Coil Form No. 2173-3-3		
L3	47 uh choke	Miller	74F475A1
L4	"	"	"
L5	RF amp coil	B & W	No. 3007
L6	47 uh choke	Miller	74F475A1
M1	1 M.A. meter	Ace	22B3
Q1	2N706	Motorola	2N706
Q2	2N706	Motorola	2N706
Q3	"	"	"
Q4	2N3638	Fairchild	2N3638
Q5	2N2160	G.E.	2N2160
Q6	2N3638	Fairchild	2N3638
Q7	"	"	"
Q8	"	"	"
Q9	"	"	"
Q10	"	"	"
Q11	"	"	"
R1	1K ¼W	Ohmite	LIDSM
R2	4.7K ¼W	"	"
R3	47 ¼W	"	"
R4	330 ¼W	"	"
R5	330 ¼W	"	"
R6	1K ¼W	"	"
R7	50K var.	Mallory	MTC54L1
R8	4.7K ¼W	Ohmite	LIDSM
R9	4.7K "	"	"
R10	Deleted	————	————
R11	1K ¼W	Ohmite	LIDSM
R12	27K "	"	"
R13	10K var.	Mallory	MTC14L1

(PARTS LIST CONTINUED ON PAGE 26)

DIGITRIO TRANSMITTER PARTS LIST (Cont.)

R14	1K ¼W	Ohmite	LIDSM
R15	10K "	"	"
R16	1K "	"	"
R17	27K "	"	"
R18	1K "	"	"
R19	10K "	"	"
R20	1K "	"	"
R21	10K "	"	"
R22	10K "	"	"
R23	10K "	"	"
R24	27K "	"	"
R25	1K "	"	"
R26	1K "	"	"
R27	10K "	"	"
R28	90 ½W — 2 ea. 180's ¼W in parallel	"	"
R29	10K ¼W	"	"
R30	10K var.	"	CU1031
R31	10K var.	"	"
R32	22K ¼W	"	LIDSM
R33	4.7K "	"	"
R34	10K var.	"	CU1031
R35	10K var.	"	"
R36	22K ¼W	"	LIDSM
R37	4.7K "	"	"
R38	10K var.	"	CU1031
S1	DPDT Switch	World Engines	W. E. DPDT
XTAL	— — — —	" "	— — — —
Z1	5.1V Zener Diode	IR	1N751A
— —	Ant. Grommet	World Engines	— — — —
— —	1N34 for F.S. MTR.	Ohmite	1N34 etc.
— —	P.C. Board	World Engines	— — — —
— —	Hook-Up Wire	" "	— — — —
— —	Case	LMB	#145
— —	Hook-Up Wire	World Engines	— — — —
— —	Heat Shrink Tubing	" "	— — — —
Misc.	Nuts, Bolts, Washers, etc.		

parts. These should be +-10% mylar, paper or tantalum. The first two are cheaper. An alternate is "Goodall" although I don't have a part number and couldn't find them myself through normal channels. Tantalums are more expensive but should be readily available from a number of different sources. I have a "Cal Rad" catalog but they apparently only sell to dealers and don't show an address. So try your local dealer, or World Engines. Don't substitute run-of-the-mill miniature capacitors with wide capacitor and temperature tolerances or low leakage resistance.

2. D2 through D6 — You're on your own here but any **good** silicon diode should work. I wouldn't recommend the so-many-for-a-dollar-in-a-package type.
3. L5 — Try "Airdux" #516T as a substitute. I would recommend that you use the coil stock rather than hand winding. It will look a lot neater and chances of exact duplication are much greater!
4. I used a 50 ua meter in my original which I purchased from the Lafayette store in town. They later closed down and I wrote to Lafayette about availability along with a complete description. I have yet to receive a reply. The Ace meter looks better anyway. The main thing is that you can use what you have from 50 ua to 1M.A. — that's why R7 is in the circuit.
5. I don't recommend substitution for any of the transistors used except the manufacturer of the 2N706's. Several manufacturers make this item. If you have trouble finding the 2N3638's, try World Engines.
6. R7 and R13 — I ordered these from the Mallory catalog. If necessary, substitute "Centralabs." The 10K is Ace #29A14. Substitute the 50K with Ace #29A15. (25K)
7. R30, R31, R34, R35 and R38. Don't substitute these with cheaper pots. These are sealed and as linear as you'll find. They should last the life of the system without trouble.
8. Crystal — Specify frequency when ordering. Ask for fundamental, third overtone, parallel mode type.
9. Z1 — This should be available from several other manufacturers, T.I. and Motorola are two.
10. R10 — This was a 47 Ohm resistor originally used in the pulse generator circuit in series with B1 (top lead of Q5 on schematic), for temperature stabilization. Tests proved it to be unnecessary and it was deleted.
11. R12, R17 and R24 — Here I would recommend 5% resistors. Although shown on parts list as 10% by the Ohmite number (LIDSM). This will insure more accuracy in your one shot cycle times. If you use Ohmites, the number is (LIDED). In any case, the resistance value and wattage must precede the type number when ordering. If you don't have these, and will be delayed in obtaining them, don't worry about it — it's not that important.
12. C14 — Although a normal electrolytic can be used here the tantalum shown will make adjustment of this circuit much easier and more stable.

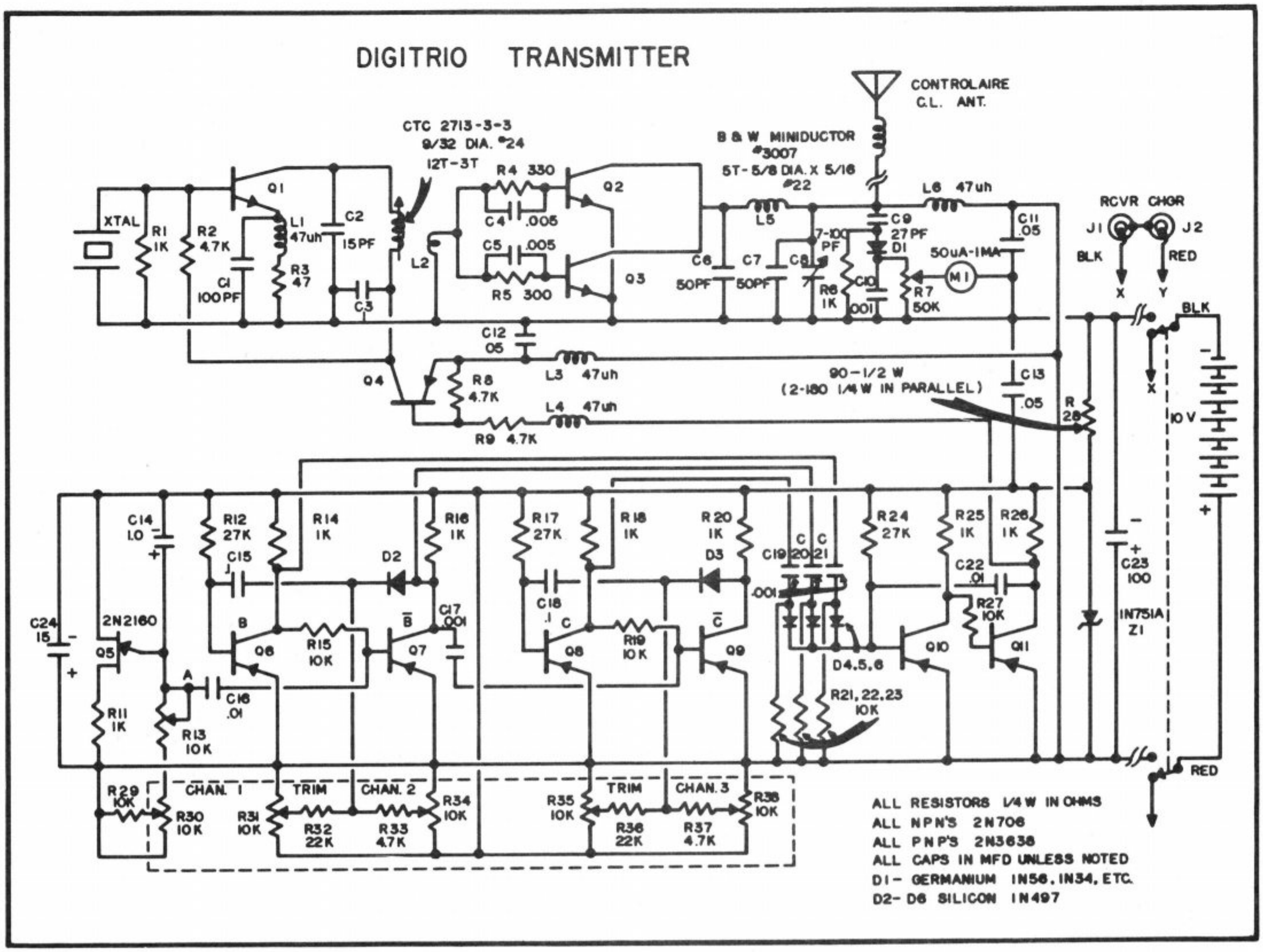
Since this system is being kitted, all parts are also available individually from WORLD ENGINES. I have personally built a transmitter using only parts supplied by them and approve of every one.

Making the P.C. Board

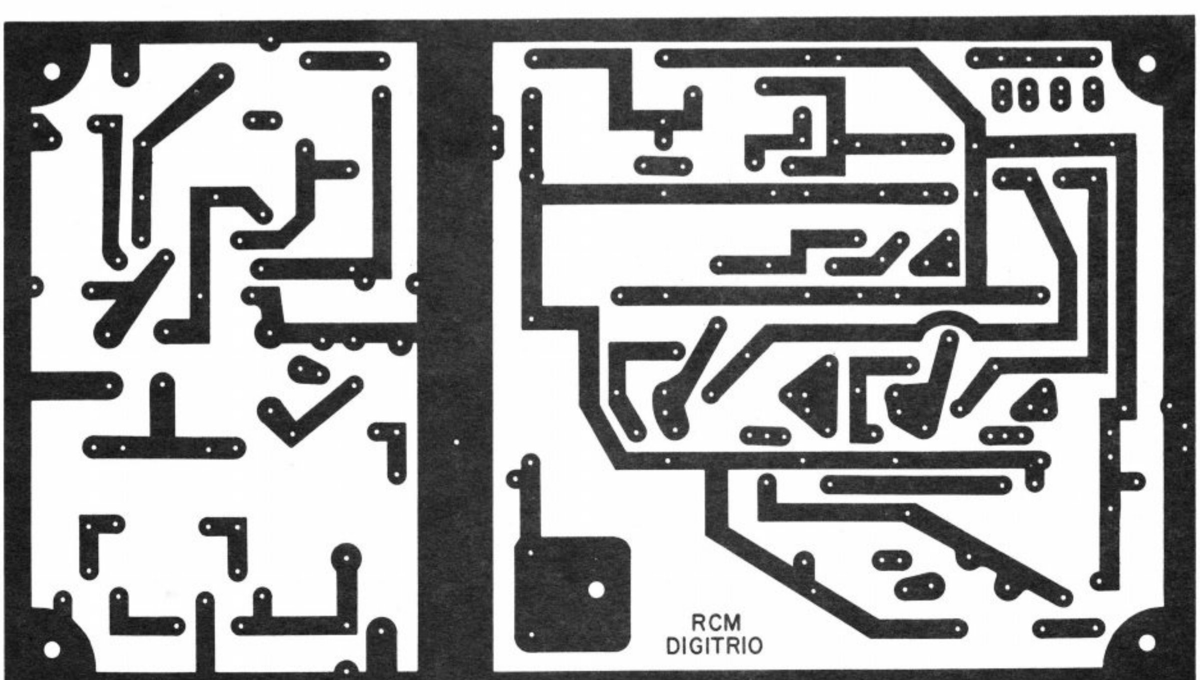
There are numerous methods for making a printed circuit board, although the photographic method is by far the most efficient and produces the highest quality results — albeit more expensive. If you decide to produce your boards photographically, obtain the following materials; available from your local electronics supply house: Kepro Photo-Sensitized Copper Clad glass epoxy board, 12" x 12" Catalog #S1-1212G ($10.20); Kepro Developer #D1-PT ($1.15); and Kepro Etching Solution #E-1PT ($.85). The foot square piece of photo-sensitized copper clad board will be enough for all of the printed circuit boards used in the RCM Digitrio. If the Kepro items are not available locally, write Kepro System, Inc., Tree Court Industrial Park, St. Louis, Missouri 63122. In addition to the above, you will need to round up a #2 photoflood bulb from your local photo dealer, a sheet of plate glass 12" x 12" or larger, and two pyrex trays.

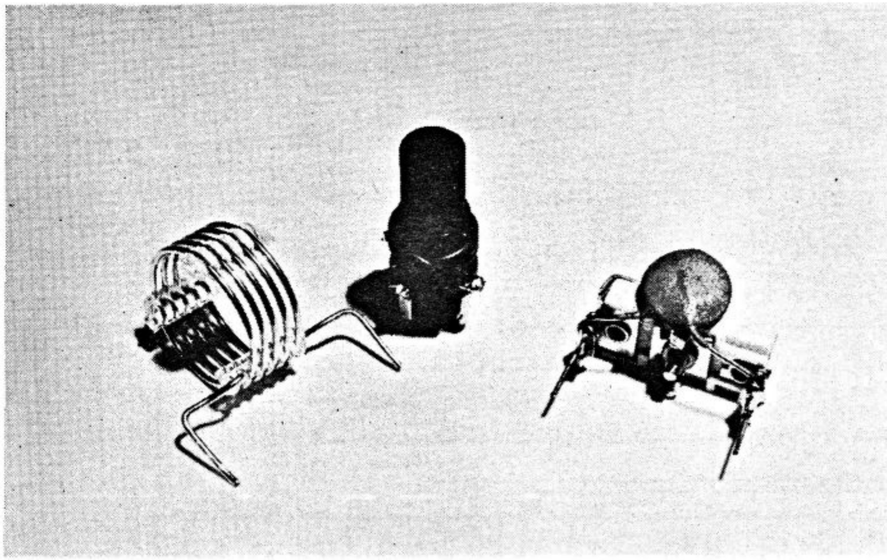
Cut out the full-size printed circuit board layout for the transmitter from your copy of RCM and take it to your local blueprint shop to have a negative made, same size. When you have the negative, you're ready to go. Set the two pyrex trays in the kitchen and pour the entire pint of developer in one and the etching solution in the other. Draw the shades or drapes in order to keep the room light down to a minimum — total darkness is not necessary, just dim light. Cut off a section of your twelve inch square photo-sensitized board just slightly larger than the size of the transmitter board. Wrap the balance of the board up in its light-tight protective wrapper and put away until you're ready to make the receiver-decoder and servo amplifier boards.

Place the section of copper clad board you have cut on a flat surface with the copper side up. Place your negative over the board so that the words "RCM Digitrio" read properly (glossy side of negative up). Wipe your piece of plate glass completely clean and free of dust, then place it over the copper clad board and negative — the glass holding the

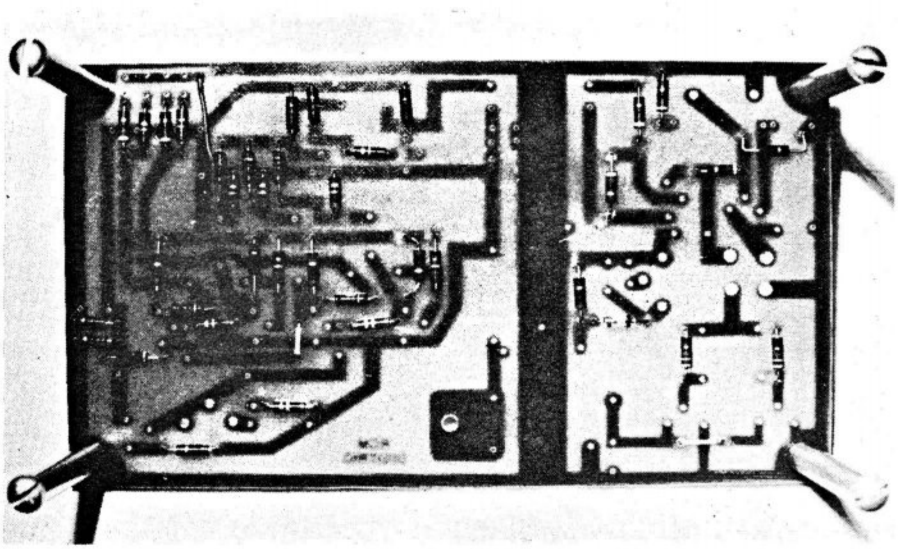


Full size transmitter P/C Board ready for photographer.

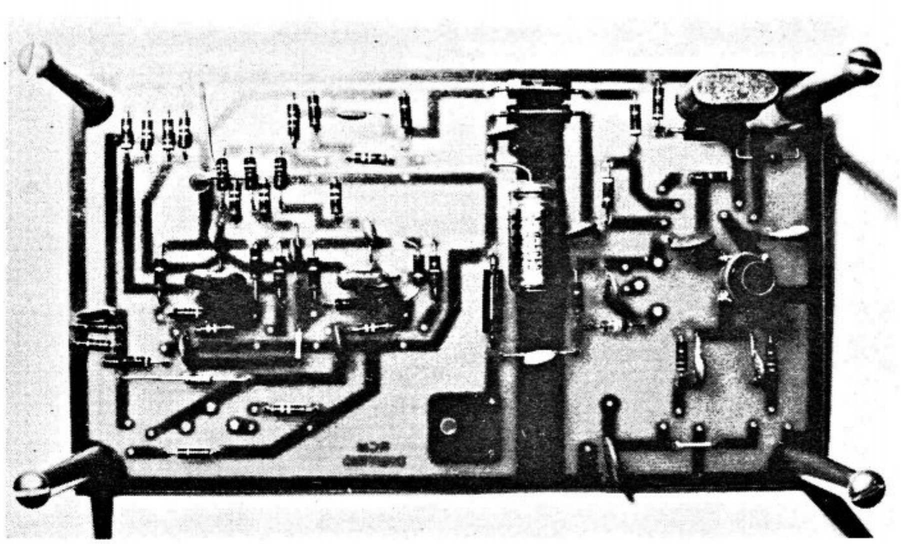




Left to Right: L5 cut from B&W or Airdux prewound stock, hand-wound L2, and C8 assembly (Arco 423 with 50 PF capacitor in place). Preliminary assemblies.



Transmitter PC board with all resistors and diodes in place. Leave 1/32" clearance between resistors and board in case you have to remove a component. Four mounting posts provide a "table" for working on PC board.



PC board with resistors, diodes, capacitors, crystal, 47uh chokes, and osc. coil (L2) in place.

sandwich in place. Now, position the #2 photoflood bulb in position exactly 10" from the plate glass.

When everything is ready, watch the clock, and turn on the #2 photoflood for seven minutes. At the end of this time, turn off the light, remove the copper clad board by its edges, and slide into the tray of developer. Rock the tray of developer slightly to provide agitation of the solution for one minute. Remove from the tray and set the developed board down on a paper towel for a couple of minutes to air dry. **Do Not** shake or blow on the board to dry it! When dry, you will be able to see a faint image on the board. Now, slide the board into the etching solution and turn on the lights in the room.

Etching the board depends upon the temperature of the etching solution, and the amount of agitation provided during the etching process. We place the pyrex tray over a burner on the stove and heat the solution every two or three minutes, agitating intermittently by gently rocking the pyrex tray from end to end. As the copper is etched away from the board, the solution will turn from an orange-brown color to a muddy brown-black. Complete etching should be completed in from 30-45 minutes in this fashion. Inspect the board and make sure there is no copper remaining between lands and that etching is complete. Remove the board from the solution and place in the kitchen sink. Turn on the cold water and let it run over the board for a full five minutes. During this time, you can clean up the rest of the materials. If you pour the etching solution down the drain, use plenty of running water or you'll be presented with a plumbing bill for new pipes!

Dry off the board and drill all holes with a #60 drill. Trim the board to exact size on your jig saw and then sand the edges. Your transmitter board is now completed.

Wiring the Printed Circuit Board

Before we assemble the components on the board, some preliminary work should be accomplished:

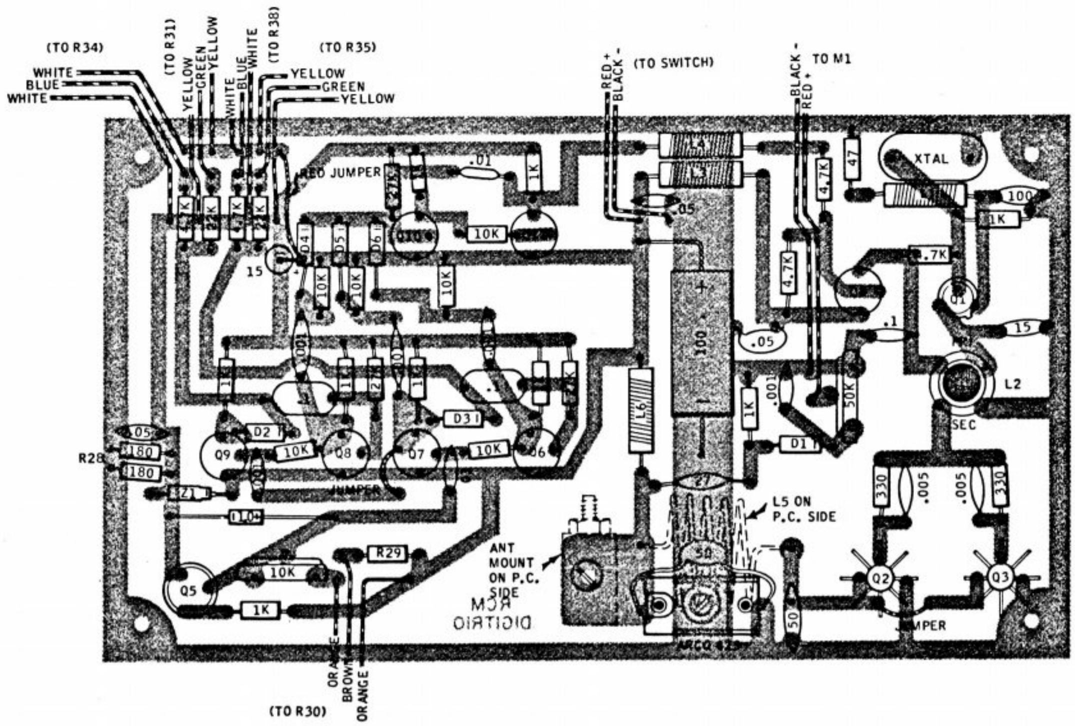
( ) Drill the four mounting holes, in each corner of the board, with a #17 or #18 drill.

( ) Drill the antenna mounting hole with a #31 drill.

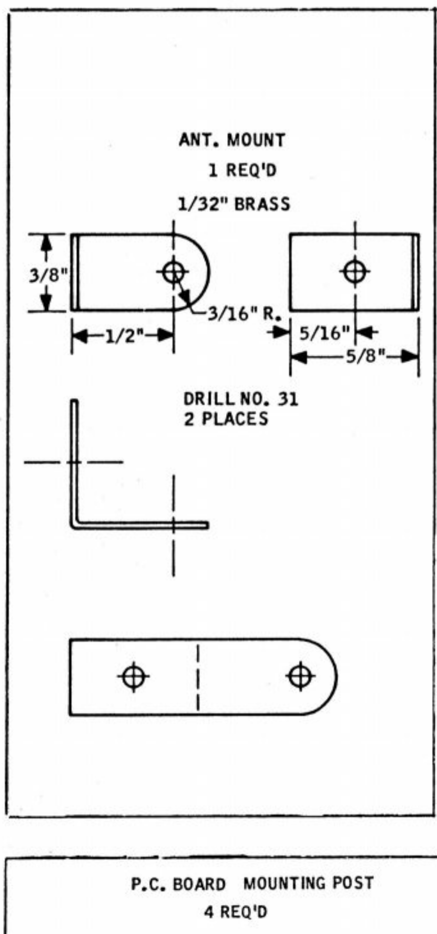
( ) Looking at the overlay, take your parts which will require holes larger than the #60's already drilled, and drill the board so they will fit.

( ) Close wind L2's primary at the bottom of the coil form, as indicated on the schematic. The three-turn secondary utilizes standard insulated Bonner hook-up wire and is close wound on top, and in the middle, of the primary. Coat the completed coil with Ambroid glue.

( ) If you wind L5 by hand, use a



Full-size component overlay shown above. Be sure to observe proper polarity of diodes. Also note location of primary and secondary on L2.



form slightly under ⅜" to allow for expansion when removed. If you use the prewound AirDux coil stock indicated, cut it long enough to allow for 1" leads when finished.

( ) Wrap and solder stiff wire around the lugs on C8 so it can be mounted without drilling excessively large holes. About #24 will be adequate.

( ) Solder C7 directly across C8, making sure it doesn't short across the plates.

( ) Screw your PC mounting posts to the component side of the board and it will form a platform to aid you in assembling the components (see metal work drawings for fabrication of these posts).

Before actually soldering the components in place, here are a few tips on proper soldering techniques. Use a low wattage iron (35 watts or so) with a small pointed tip. Apply the iron to the component lead about ⅛" above the copper lands. Touch your solder (a good, small-diameter resin type such as Ersin Multicore) to the opposite side of the lead. This will "tin" the lead. Slide the iron tip down the lead until it contacts the copper land, put another touch of solder on the opposite side of the lead and copper land simultaneously. The solder will flow around the lead and form a mound. Retract the iron by sliding it up the lead. Clean your iron every five or six "joints" by wiping it quickly with a clean rag or on a damp piece of foam rubber. After every 20-30 joints, clean your iron thoroughly and re-tin. This may sound like a lot of trouble but after a while it will become a matter of habit and will pay many dividends in the form of better looking and better constructed boards.

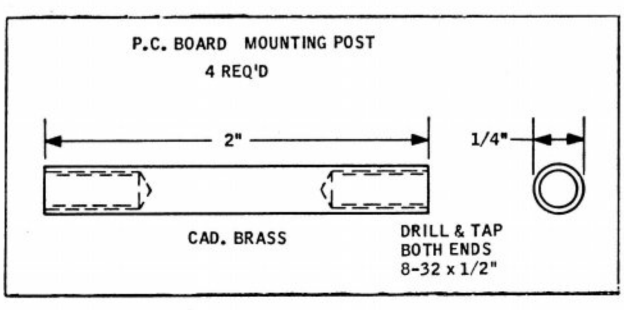
( ) Install the three jumpers as shown on the overlay. One is below Q2, another between Q7 and Q8. Use remnants of the resistor leads for these. The jumper above the 15MFD capacitor (C24) should be a piece of red insulated hook-up wire. Don't solder the bottom end as we'll insert the positive lead of C24 in this same hole later on.

( ) Mount all resistors except the small variable resistors R7 and R13.

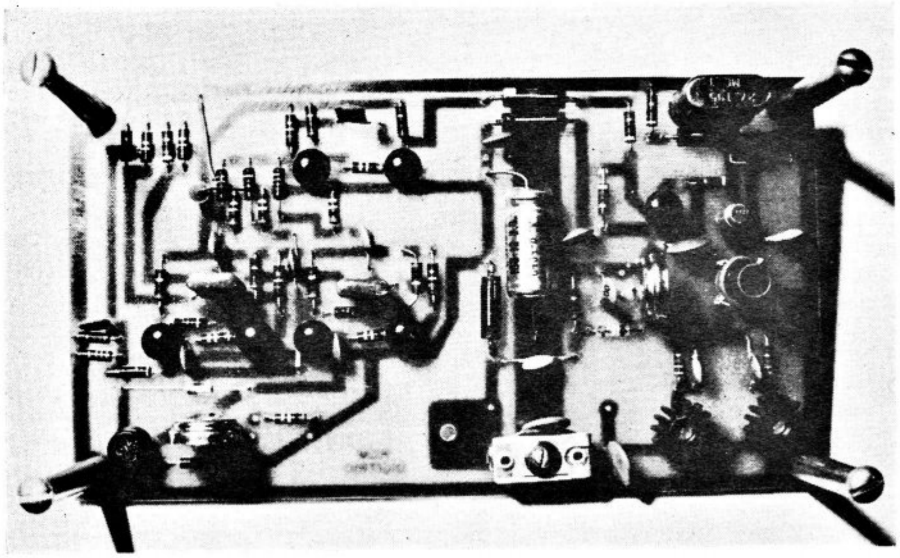
( ) Mount all diodes including Z1. Do this carefully, observing polarity markings on the overlay. When you bend the diode leads, do so from the tip so a radius is formed at the body. If bent too sharply, the glass envelope may crack.

( ) Mount the four 47 uh chokes — L1, L3, L4 and L6.

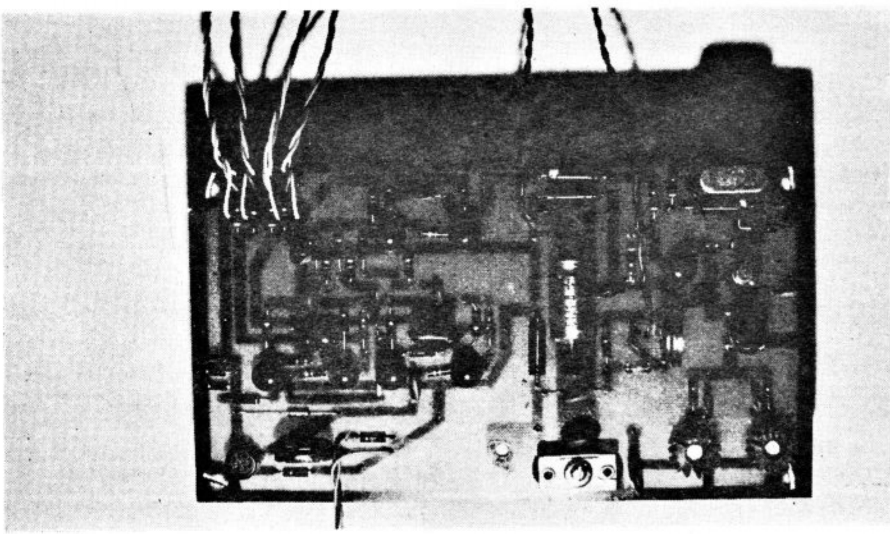
( ) Mount the 1, 15, and 100 MFD electrolytics, observing polarity.



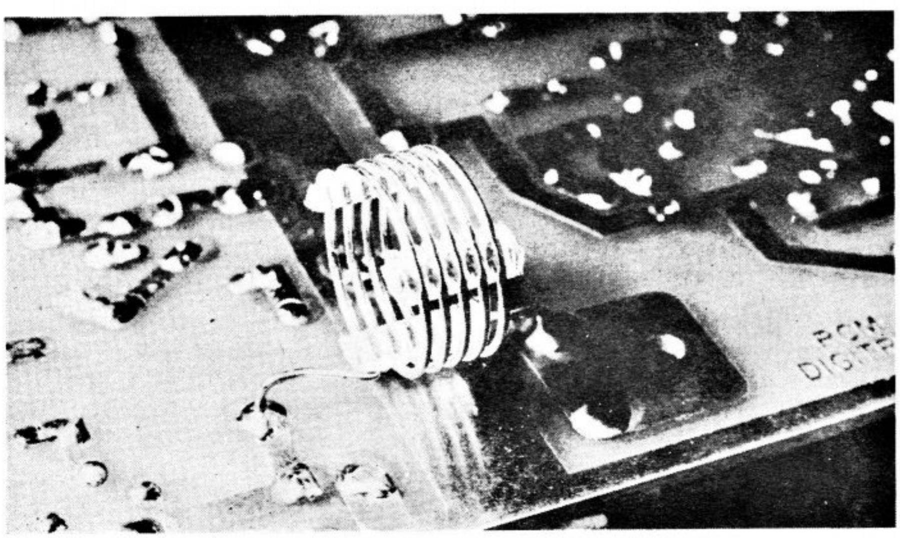
Although the sheet metal work is the subject of next month's installment, the four PC board mounting posts will provide a convenient set of legs — making your PC board a table on which to work. Antenna mount shown upper left.



All transistors and Mallory pots (R7 and R13) in place along with Arco 423. Note heat sinks on Q2 and Q3.



All wiring in place ready for connection to transmitter assembly. Wires in upper left to stick pots; center top to switch; center right to meter; and lower left to R30.



Close-up of L5 installed on PC side of board. This is 5 turns of standard prewound B&W or Airdux stock – saves winding. Be sure to leave clearance between L5 and board. Hole at right is for antenna mount.

(C14, C23, and C24).

( ) Mount remaining fixed capacitors.

( ) Mount crystal and L2 flush against board to provide back cover clearance.

( ) Mount all transistors, starting with the 2N3638's.

( ) Mount C7-C8 assembly, L5, and small variable resistors R7 and R13.

( ) Install heat fins on Q2 and Q3 and mount any remaining parts.

( ) Make and install the antenna mount with 4-40 nut, bolt, and lockwasher (see metal working drawings for fabrication).

( ) Cut 12" lengths of #26 standard hook-wire (I use Controlaire) in the colors shown on the overlay, the orange-brown-orange trio should be 17" long. Insert these in pairs or groups of three as indicated. Twist them and tie a knot at the end. This will keep them separated and out of your way.

Before we proceed further, let's make a preliminary check of the board:

( ) Measure the resistance between the red and black wire going to the transmitter switch. Your meter should indicate approximately 1000 ohms.

( ) Temporarily lift one end of L3 and L6. The meter should not change appreciably. When connecting the meter, observe polarity.

( ) Swap leads (reverse polarity) and a slight decrease in resistance may occur. This indicates that Z1 is connected properly. Don't accept this as final proof, but double check the installation of all diodes (especially Z1) for correct polarity. I would recommend that you apply voltage in steps by tapping down on your transmitter battery pack with the meter on the milliamp range and in series with the negative lead. Don't re-connect L3 and L6 yet. Starting with 5 volts (4 nicads), increase the voltage a cell at a time. The current as indicated on the meter should progressively rise but at no time exceed approximately 50 ma. Re-connect L3 and L6 and start all over. The current should now not exceed approximately 120 ma. If it is much less, your oscillator is not operating. To check this, run your slug clockwise until it is at the bottom of the coil form. Slowly backing it out, adjust it for peak meter reading. Don't operate it very long under these test conditions.

( ) To check operation of Z1, connect your meter across Z1 – the red lead to positive battery, the black lead to the junction of the two 180 ohm resistors (R28) and Z1. Starting at 5 volts, again tap up a cell at a time When you reach the sixth cell, the voltage should stabilize at approximately 5.1 volts. As you continue tapping, this voltage should not rise appreciably. You will note that the Zener diode will feel warm to the touch after a few moments of this test. This is normal and no cause for alarm. If you get carried away and apply more than the recommended voltage (8 nicads in series), or reduce the value of R28, be prepared to buy another Zener!

That's it for the preliminary checkout. If you encounter any difficulty, re-check the board and try to locate any improperly installed, or possibly defective, component. If you can't correct the trouble, call on your "technician type" buddy. Set the PC board aside now, and get your hacksaw, drill, vise, and taps ready for the next part which is the fabrication of the case, stick, and pot assemblies also final assembly and preliminary checkout.

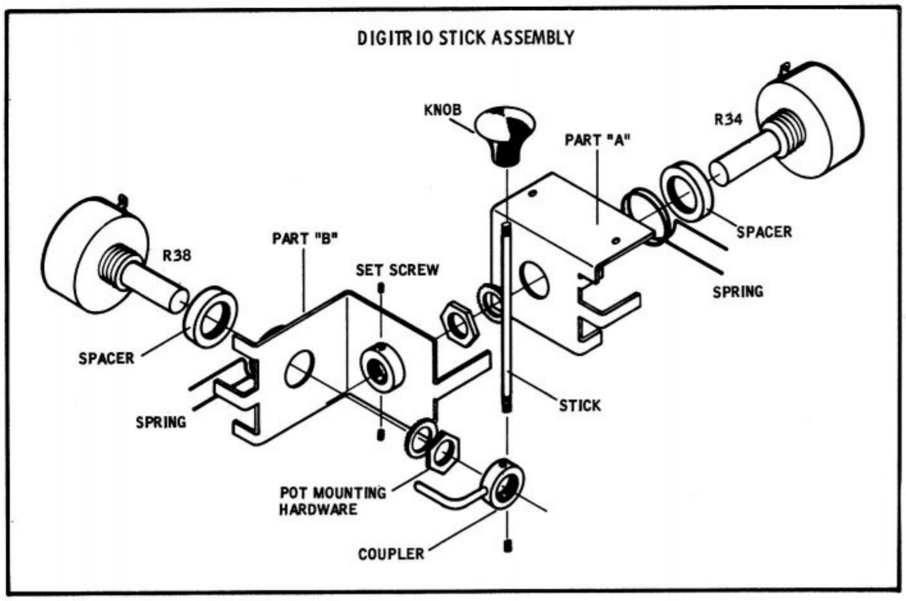
Part III: Transmitter Final Assembly

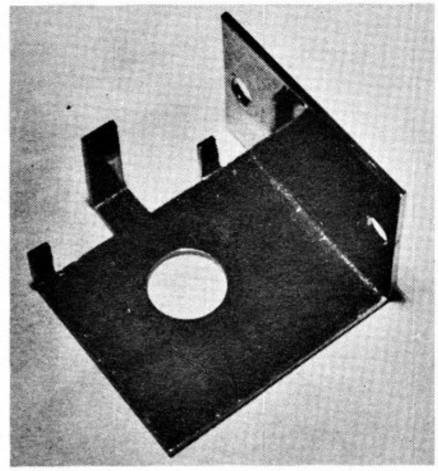
The Transmitter Case

UNLESS you are a frustrated fender bender or ex-Navy machinist's mate, the miscellaneous sheet metal work involved with the transmitter case and stick assemblies will be the most tedious part of the entire RCM Digitrio system. We have tried, through experimentation with various prototypes, to simplify this phase of the construction to a point where it will require only a minimum of time and the normal shop tools. **Do** follow these instructions carefully, however, exercising care in your workmanship, so that each part of the mechanical work will be accurate, and at the same time, produce a presentable finished product.

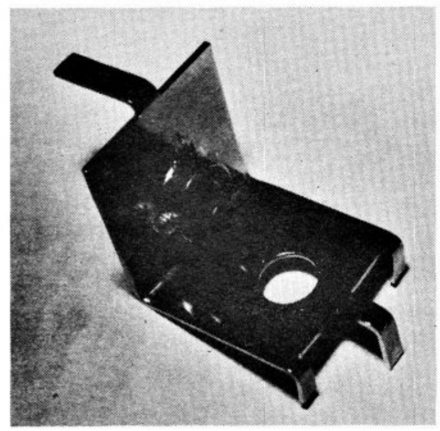
The transmitters for the three RCM Digitrio prototypes were all fabricated from standard LMB #145 aluminum boxes, available at most electronic parts houses. Simply cut out the full size front panel layout illustrated here and paste it to the front of the LMB box with rubber cement. Use an electric drill and drill a series of holes around the inside perimeter of the main stick cut out, trim slots, and meter cutout. Punch out the excess metal, then trim to the actual dimensions of the cutouts with a file. Drill all remaining holes as specified. If you use a panel meter other than the one specified (Ace R/C), change this dimension accordingly prior to commencing fabrication. If you cannot locate the LMB box, the case can be fabricated from aluminum in a vise, using hardwood blocks to prevent surface damage. Alternately, all sheet metal work can be done at any local sheet metal shop for a nominal charge. We would suggest **not** drilling the antenna hole in the top of the transmitter can until final assembly in order that this hole will align properly with the antenna mount on the PC board.

After finishing the sheet metal work, use a fine file to true up all cutouts in the front panel. De-burr all drilled holes, then polish the can with steel wool, followed by a wet sanding with 400-600

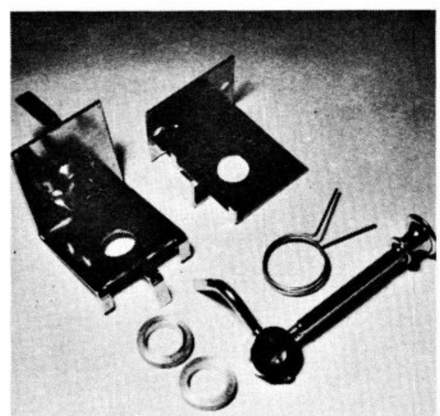




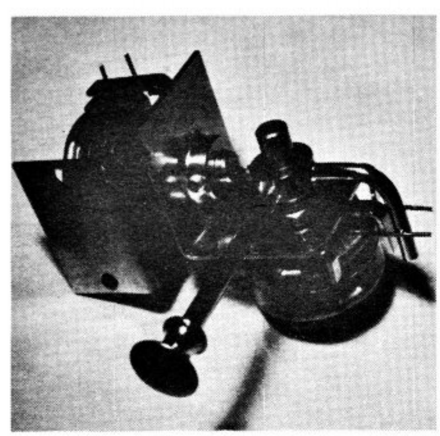
Part A, stick assembly.



Part B, stick assembly.



Stick parts prior to final assembly.



Completed stick assembly.

wet-or-dry paper. The transmitter case can now be anodized or painted. RCM's three prototypes were anodized antique gold and orange-gold at a local plating shop. The minimum charge for anodizing is usually $15, with the price for anodizing a single case, five dollars. So, if you have a couple of friends building the Digitrio, take a minimum of three cases at once to the platers in order that they may be done for approximately five dollars a piece. If you are not choosey about the color, you may have it plated along with another customer's run and beat the minimum also. If you prefer, the case may be given a coat or two of primer followed by several thin coats of spray paint such as automotive enamel in aerosol cans, available at most hardware and paint stores.

Control Sticks

Carefully study all of the drawings for the control stick assembly and obtain a good mental picture of all the parts and the functions they will perform. Adhere as closely as possible to the dimensions shown or you won't end up with the stick centered in the case cutout. Use a coping saw with a fine metal blade, or a jig saw to cut out the parts. A hacksaw will prove to be pretty cumbersome for this work. Clean all cut edges with a fine-toothed file, and before making any bends in the vise, check the drawings once again. Be sure to use hardwood blocks in your bench vise in order to prevent surface damage to the individual parts. One easy method for transferring the templates to the sheet brass stock is by the use of Dykem Blue. The latter, available in 8 ounce cans in most hardware stores, is brushed on the surface of the sheet stock and allowed to dry to its natural dark blue color. The sheet metal templates can then be scribed on the surface, allowing the brass to show through the blue painted surface, giving you accurate lines on which to cut.

If you are long on ambition, but short on tools, you can make some substitutions for the parts shown. For example, the trim and control sticks can be replaced with ordinary 6-32 bolts cut to the indicated lengths. The couplers, which incidentally, are the only items requiring a few minutes of lathe work, can be removed from ¼" shaft couplers used by most "hams." The silver-soldered coupler on Part B can also be taken from a ¼" shaft coupler and bolted in place, although some excess "play" will result. Aluminum can be substituted for the brass parts, although the centering springs will eventually "dig in" and periodic adjustment will be necessary. The mounting posts can alternately be made from standard 3/16" brass tubing, available at most hobby shops, and threaded as indicated with washers to increase the shoulder area. If you utilize the latter substitution, make sure the overall length including the washers is the same as shown on the drawings.

The curving arm on the one coupler can be a 6-32 bolt (with plain unthreaded shoulder), heated with a torch and bent as shown. Thread and solder it to the coupler as shown.

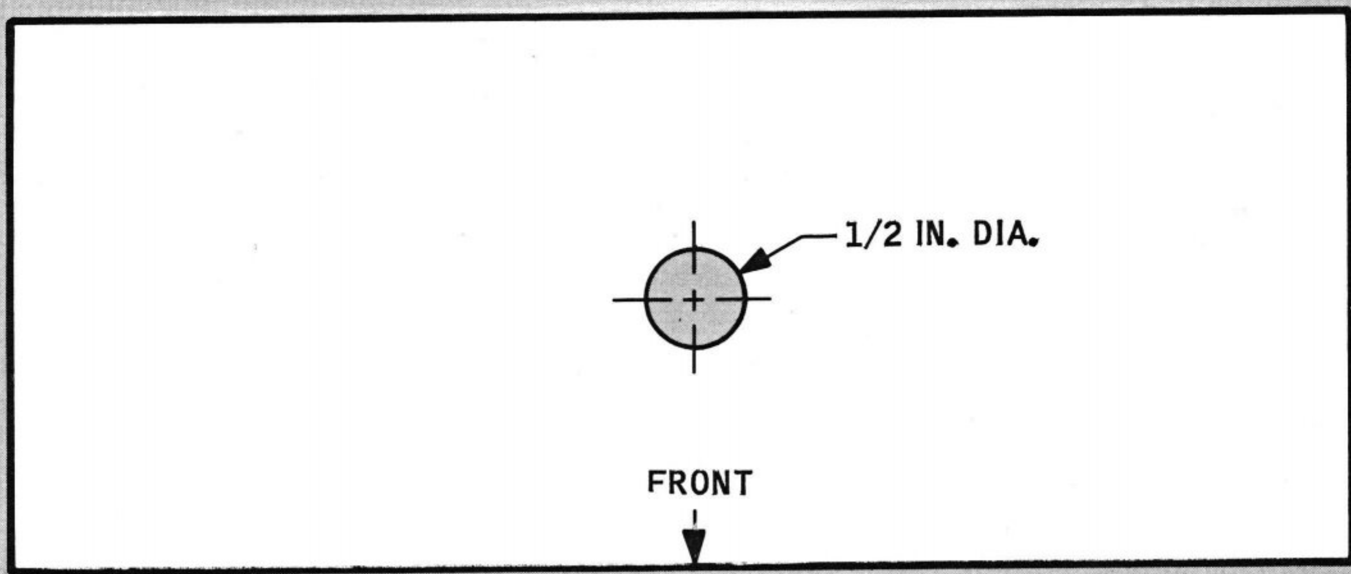
The pot spacers can be standard ⅜" pot mounting nuts rounded off with a file.

All of the above substitutions have been tried on one prototype, and although they are not as nice looking as the specified items, and though some play may be encountered in the control stick, they will enable the modeler with limited shop tools to reproduce this system with more-than-acceptable results.

So much for alternate ways of fabricating the control stick parts. When you get to the centering springs, this will be simply a matter of "bend and try" until you get the desired tension and action. Each one you bend will get progressively better until, finally, you end up with what you want in centering action.

The "knob" on the control stick shown

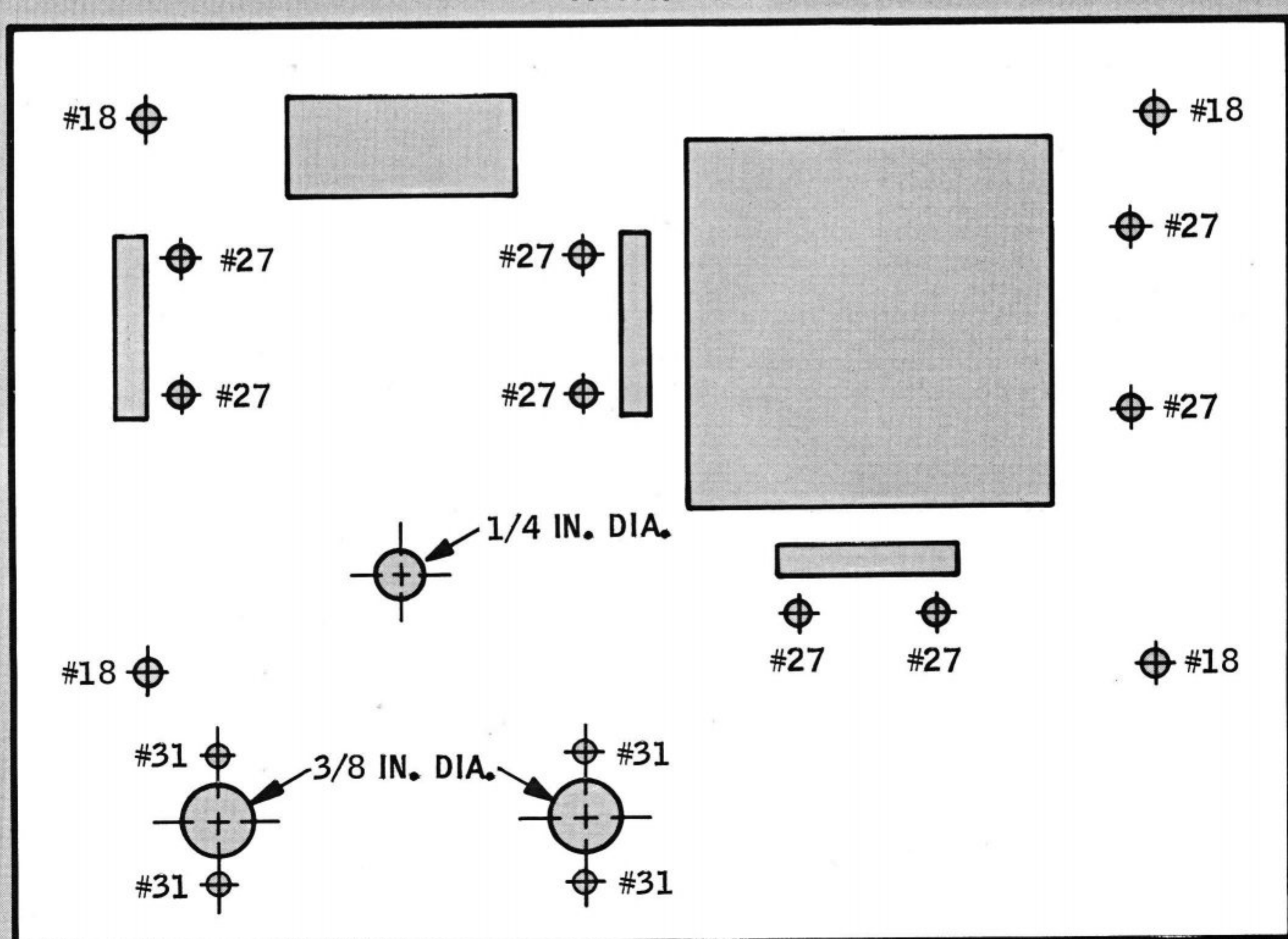
RCM DIGITRIO: FULL SIZE TRANSMITTER TEMPLATES

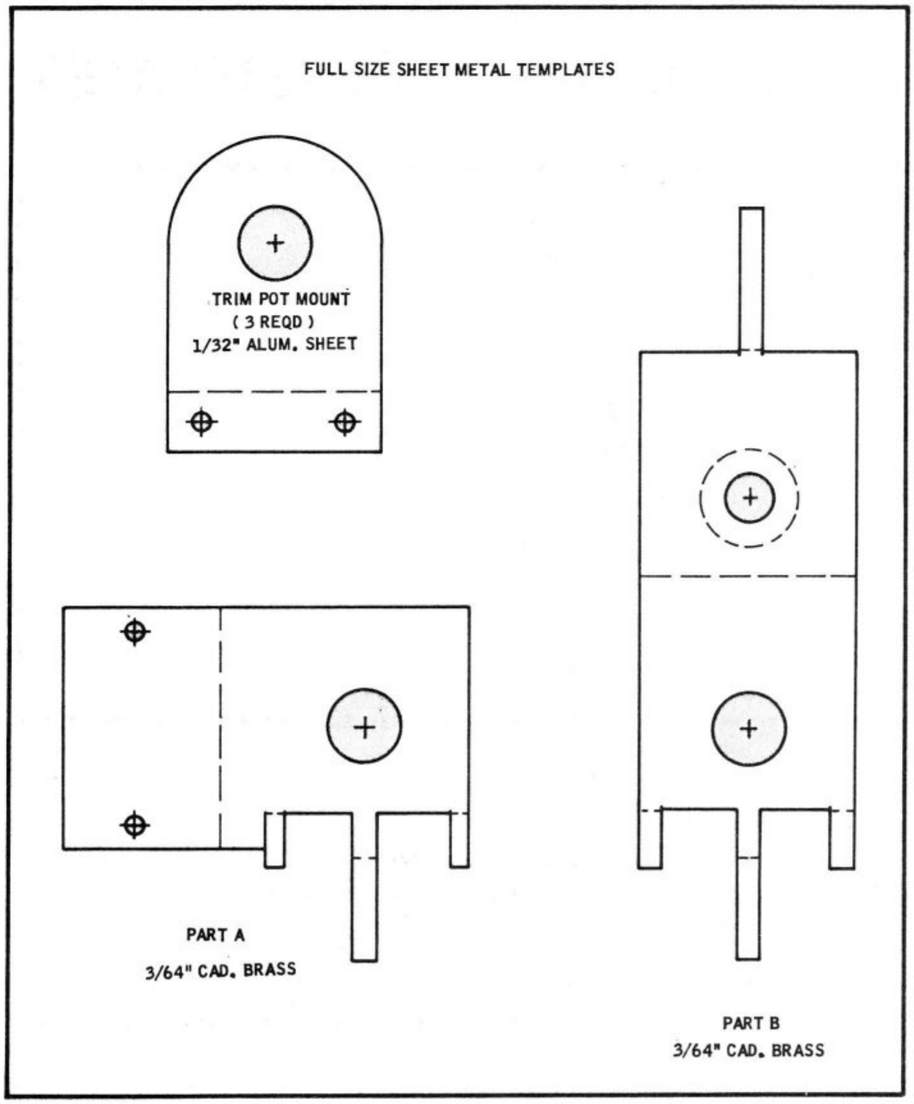


TOP VIEW

NUMBER BESIDE HOLE INDICATES DRILL SIZE OR DIAMETER.
PASTE ON LMB 145 CASE & REMOVE EXCESS MATERIAL.

FRONT VIEW





in the photographs was a chrome plated cabinet knob from the hardware store. On the RCM prototypes, we had all metal control stick parts satin chromed at the same time as the anodizing was done, with the exception of the trim levers and main control stick, which were bright-chromed, giving an excellent final appearance. Insofar as the control stick knob is concerned, almost anything that feels right to your hand can be threaded and installed in place.

By the way, when silver soldering the coupler on Part B, watch closely the temperature of the sheet brass – the melting point of the brass stock is quite close to that of the silver solder. Also, be sure to dunk the completed assembly in cold water while it is still hot in order to retain the original temper.

Now, saw the two pot shafts off at 5/16" and assemble the stick as shown in order to try it out. Adjust the springs for the desired tension and centering. Place one drop of it on each pot shaft bearing and work it in. Bend all of the pot terminals back to keep them out of the way during final assembly.

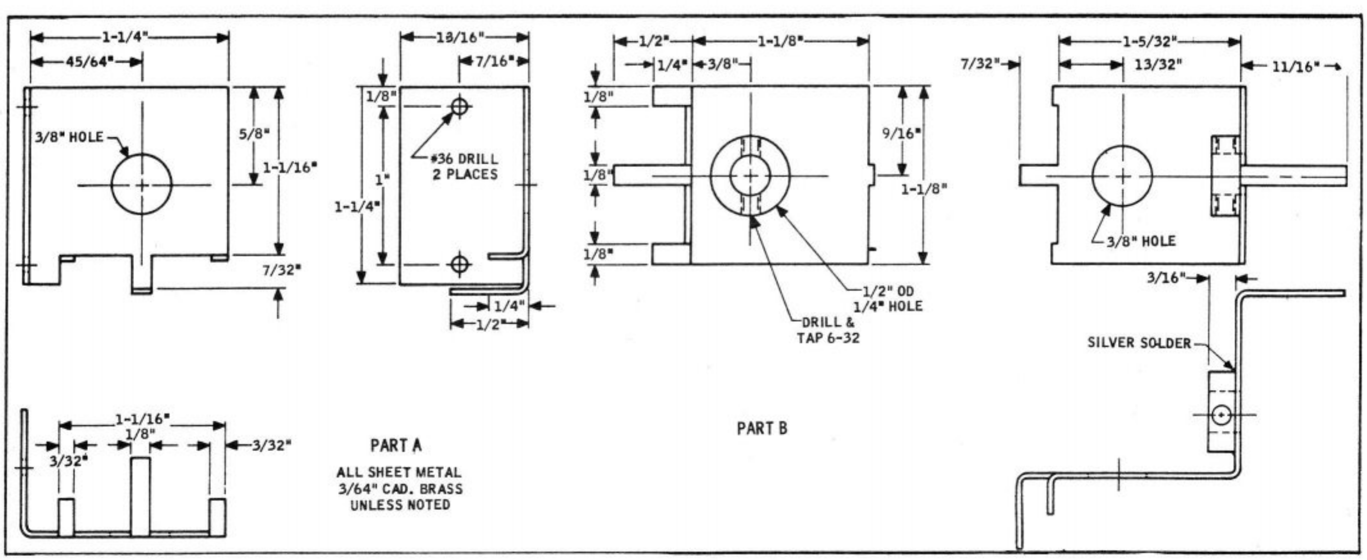
Assembling Transmitter

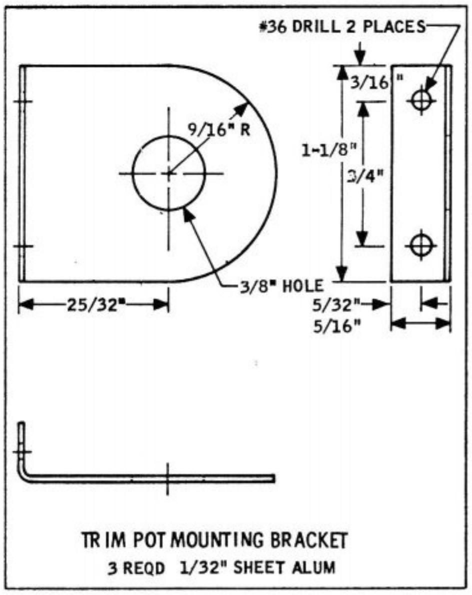
Prior to final assembly, saw the pot shafts to 5/16" and mount all the trim pots in their mounts (3 ea.). The lip of the mount should bend forward away from the pot. Now, file a notch for the locking lug. The terminals should be centered at the top (rounded portion) and bent back. Turn the shafts to the center of their travel, then slip a coupler over each shaft. Temporarily install and tighten the trim sticks so they point straight down past the mounting lip (centered in the cutout).

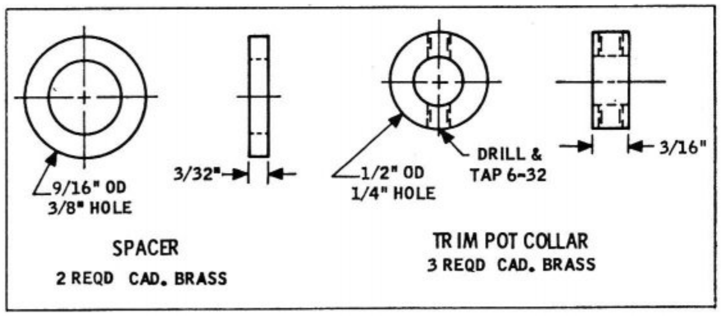
Loosen the shaft couplers on the stick assembly and use the following procedure for exact electrical center of the stick pots. Place your ohm meter on a scale which will read 5000 ohms around midscale. Connect one lead to the center terminal, then by swapping the other lead between the outside terminals while moving the shaft, obtain the same reading on both sides. There are other methods of doing this with batteries in a bridge circuit, but this will be accurate enough. Tighten the couplers securely and double check the pot settings. Repeat if necessary.

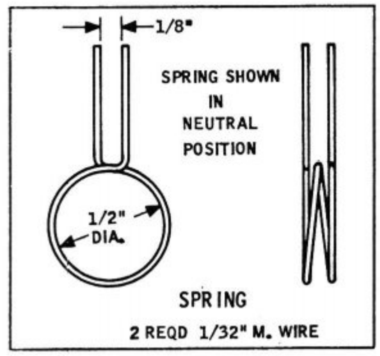
Mount the trim pots and stick assembly to the case with #6 sheet metal screws. Mount the switch and meter to suit the type you will use. Install the four PC board mounting posts to the front of the case with 8-32 x ½" bolts. Use internal lock washers under all bolt heads. Mount the two charging jacks with 4-40 nuts, bolts, and lock washers and bend the center lugs over. Cadmium-plated pan head bolts for all exposed boltheads will enhance the overall appearance of the transmitter.

This would be a good time to decide









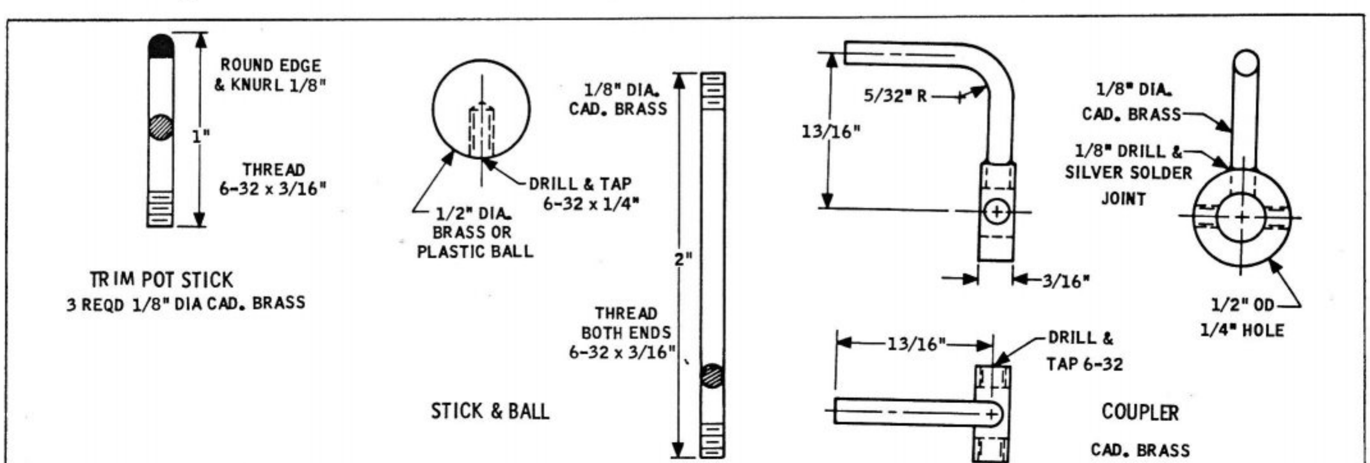
how to mount your battery pack. You can make a strap and bolt it to the bottom or front or however you wish. I used eight 600 mah Gould SCL Pencell Nicads wired in series and taped together with black electrical tape. Allow about 8" leads and color code them red for positive and black for negative. Make sure your mounting strap doesn't cut through the tape or protective covering of the batteries or you'll short some of them out. If you use the LMB box you won't have much choice where to place the batteries. The pack described will set neatly behind J1 and J2.

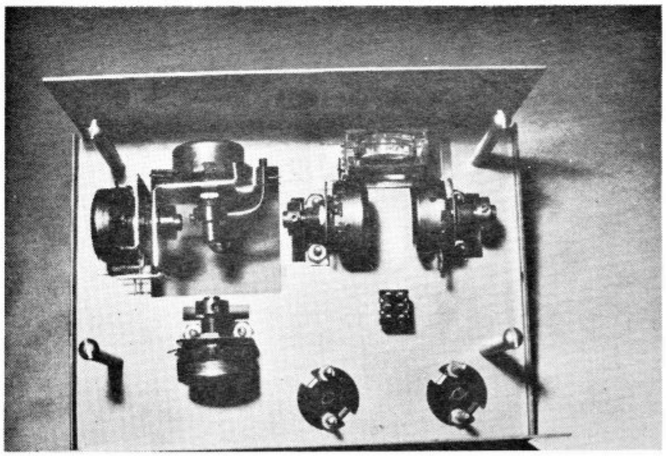
Cut a thin piece of felt and contact cement it to the bottom of the transmitter to prevent damage to the case when you set it on your best furniture. You can drill four holes in the corners and use small push-in rubber feet for this purpose if you can find them.

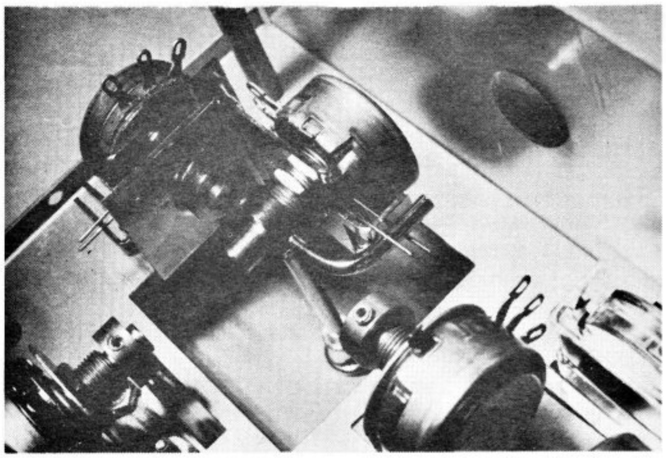
Now, place the transmitter case with all parts mounted, on its top and rear facing you. Place the completed PC board, component side down with L5 and antenna mount closest to you. Run all leads straight out the top of the PC board toward the transmitter (these leads should come from under the board). All the pot leads should be on the right-hand side. The switch and meter leads should be left of center.

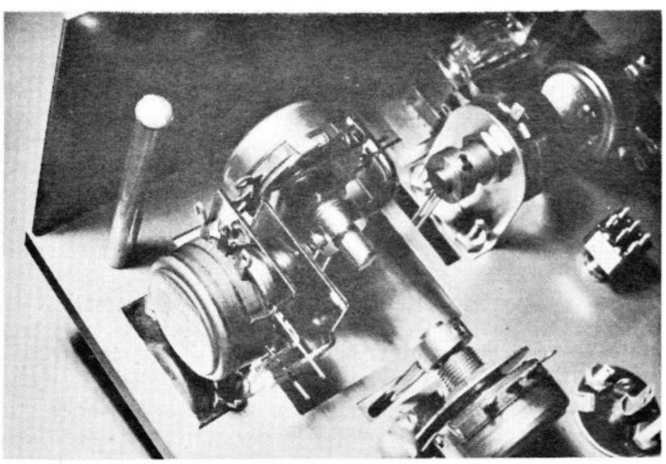
The objective of all this is to wire the leads to their components, and when we're finished, lift the PC board up by its rear edge and secure it to the mounting posts. This will also allow you to work on the transmitter later on without having a rat's nest of wires to contend with.

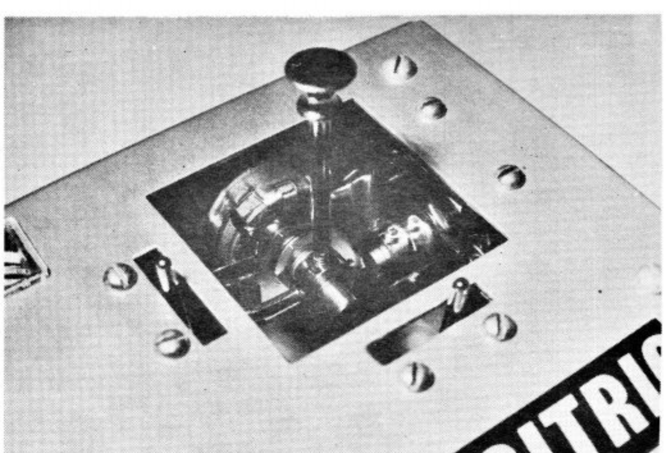
Adjust the board until it is about two inches from the case and maintain this distance throughout final assembly. When connecting pots, the odd colored wire always goes to the center terminal. The other two wires go to either outside terminal. Leave enough slack in these to reverse later. The white-blue-white wires on the far right side go to R34 which is the stationary stick pot. The yellow-green-yellow wires on the far right side go to R31 which is the vertical trim pot across the cutout from R34. Route this wire down, and left across the case at the lower case bend (as viewed now). The other white-blue-white wires go to the moveable stick pot and the other yellow-green-yellow wires to the trim pot, as viewed now, at the top of the cutout. Route this wire under R34 and keep it close to the case. Tie it off to the upper right mounting post (as viewed now). The orange-brown-orange wires go to the remaining trim pot (motor control) at the left side of the case (as viewed now). When connecting the leads to the stick and trim pots, allow enough slack so you can tie the wiring to the lower right PC mounting post (as it sets now) with the exception of the wires to moveable stick pot R38 – they must be free to move, so allow about 1" additional slack. After connecting R38's wires, route them behind R38's locking lug and tie them off to prevent breakage at the terminals (see photo). Tie the motor control pot wires to this same post (lower right) and run the wires across the bottom bend of the case (as it sets now) and secure them along with the vertical trim pot wires to the case with tape in a couple of places to keep them out of the way. Allow enough slack to tie it off to the lower left PC mounting post (as viewed now). Allow enough slack in the switch and meter wires to tie them off to the lower left-hand PC mounting post also (as it sets now). Use a short piece of Controlaire heat shrink

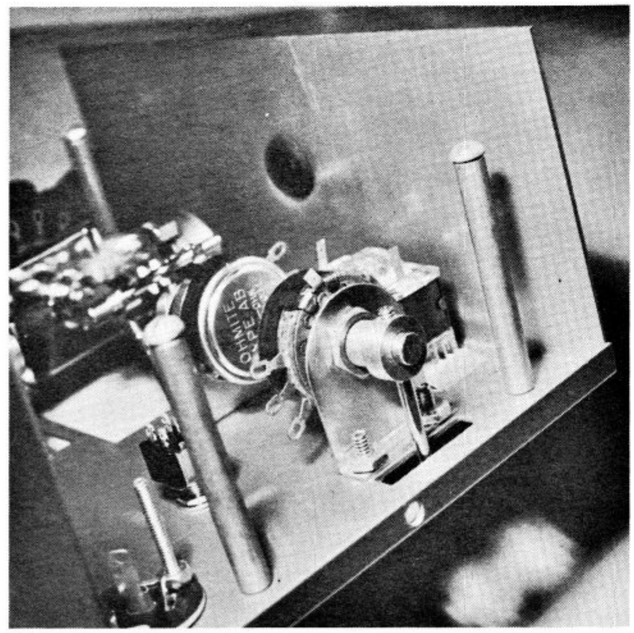


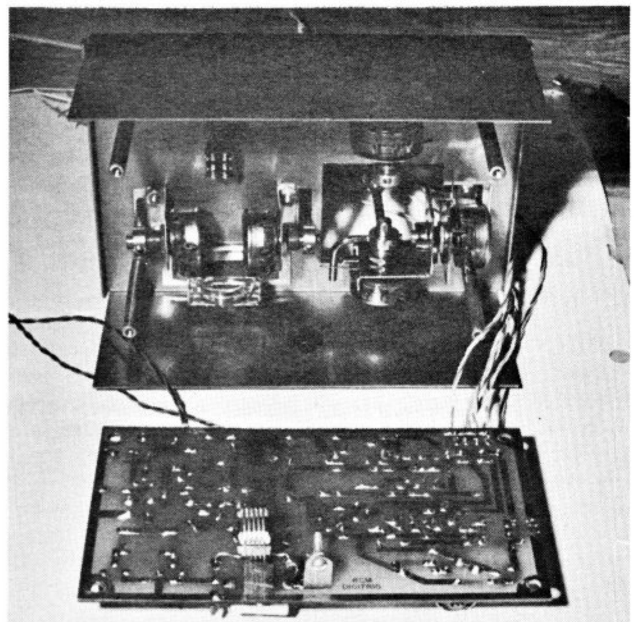












Left, top to bottom: Transmitter case with all hardware mounted. Second and third photos show detailed close-ups of stick and trim pot assemblies. Fourth photo, opposite, shows the completed stick from the front. Above, top; Throttle stick assembly and P.C. board mounting posts. Above: Proper position of transmitter and P.C. board during final assembly and checkout.

tubing 1" from terminals on all wires (large for 3 wires – small for 2 wires) for that extra touch. (See photo.) . You can use plastic insulation stripped from hook-up wire for all "tie offs" or lacing cord or small strips of electrical tape.

Connect the red meter wire to the positive meter terminal and the black meter wire to the negative meter terminal. Connect red and black battery wires to the "on" side of the switch with red at the bottom as viewed now. Check the switch with an ohm meter to find the "on" side. It should be on the left side as viewed now if you use the World Engines switch. Wire J1 and J2 as shown in the schematic. Connect a red wire from the positive side of the "off" side of the switch to the center terminal of J2. (Right hand jack.) Run a black wire from the side terminal of J2 to the side terminal of J1 (left-hand jack). Run a black wire from the center terminal of J1 to the negative "off" side of the switch. Use some positive method of identifying the jacks as follows:

J1 "Receiver" (Left Side)

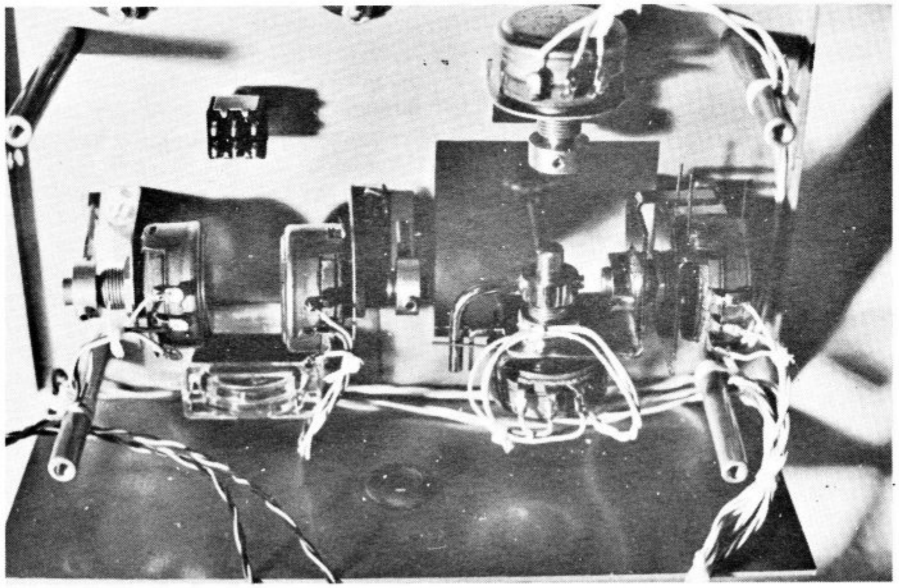
J2 "Charger" (Right Side)

This is important, and if reversed while charging, batteries will be subjected to deterioration. With this arrangement the transmitter and receiver batteries can be charged simultaneously. In any event, the switch must be in the "off" position. You will probably have to increase your present charger's output, however. You can charge the transmitter independently if you insert a shorted plug in the receiver jack. In the latter case, be sure the charging rate is adjusted for use in this fashion.

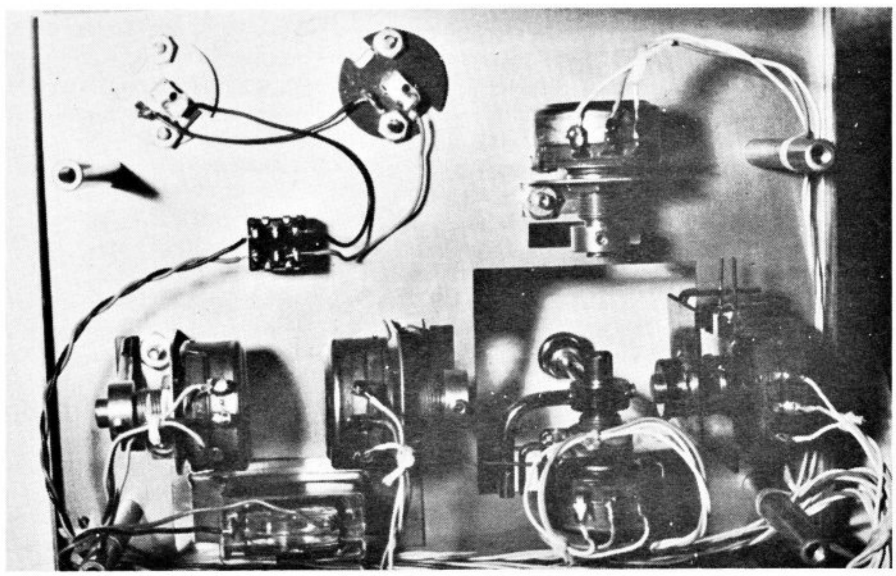
This is important. Whenever, and however, you charge your batteries, always, double check the polarity, plug arrangement and charging current. Connect two 8" lengths of red and black wire to the center terminals of the switch and install the rubber antenna grommet. **Do not connect the battery yet.** Secure the PC board into place. All wiring, except J1, J2, and leads from the switch to the battery should loop over the top of the board (when right side up). Make final adjustments of wiring now to insure that no interference is encountered when moving the stick or when sliding the case together.

Preliminary Checkout

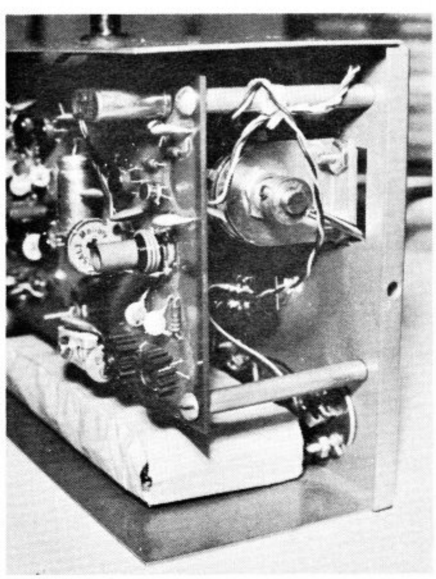
Before installing the batteries and tuning the transmitter, let's double check the wiring. With the switch in the "off" position measure the resistance between the 8" red and black leads going to the center terminal of the switch. If you read anything other than infinite resistance you have either wired the switch backwards or have wired J1 and J2 improperly. Don't proceed until you have corrected your trouble. If you do read infinite resistance "throw" the switch to "on." You should now read



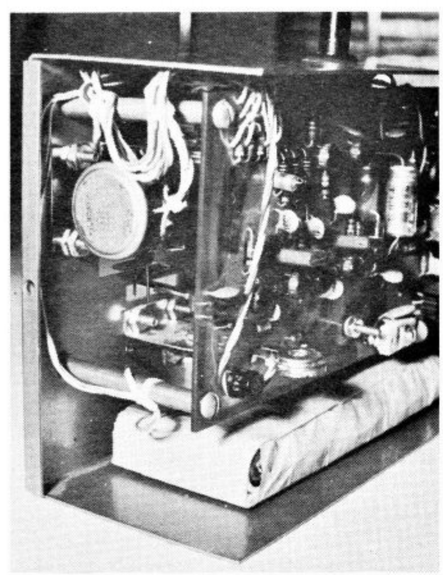
First stages of wiring. Note tie-off strain relief and cabling of wires.



Next stage of wiring with jacks and switch wired in circuit.

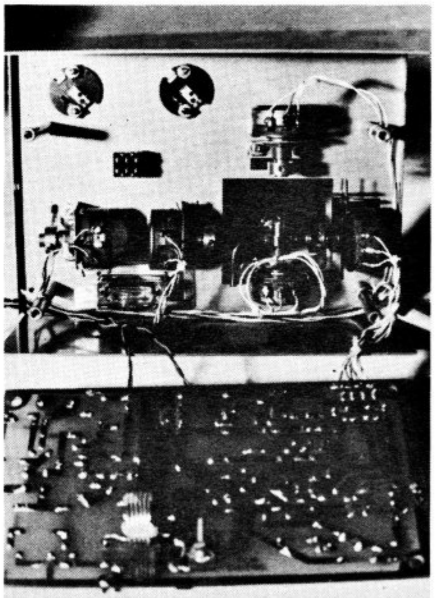


End view of completed transmitter.



Opposite end of completed transmitter.

When completed, the P.C. board simply lifts up and is secured to the four mounting posts.



approximately 1000 ohms resistance. Again I recommend tapping down on your battery pack as we did previously during the PC board preliminary checks.

Throw your switch "off" and connect the battery pack, with your meter on the milliamp scale in series with the negative (black) leads. You should not get an indication on the meter at any tapping voltage. Throw the switch to the "on" position. You should read somewhere between 50 and 120 M.A. Again, if this is much lower, your oscillator is not operating and the slug in L2 must be adjusted.

If everything has gone well so far, we are ready to tune the transmitter. Insert the antenna and place the transmitter on a non-metallic table, and fully extend the antenna. There should be ten sections to the "Controlaire" antenna exposed including the section with the loading coil — count them. Insure that there are no metallic objects or wiring in the proximity of the antenna. With the switch "on" and meter in series with the negative lead, run L2's slug clockwise until it is at the bottom of the form. If your oscillator was running when you started, the meter reading should have read approximately 120 M.A. If not, bottom the slug and back it out slowly until the meter reading peaks.

Due to varying components values in the oscillator circuit some pruning of L2 may be necessary. The oscillator circuit, unlike most, has no critical setting and will operate over a broad range of adjustments. It packs a "wallop" by itself and would make a good RF section for a single channel transmitter. When your oscillator tuning is complete, L2's slug should be about halfway into the windings. If it is sticking out the back of the form, when you're through tuning, remove a turn from L2's primary and try it again — remove enough turns (one at a time) until it peaks with the slug halfway as described. If the slug is completely inside the winding when you're through tuning, add a turn, or turns, to the primary until the slug is halfway as described.

Turn the switch "off" and remove the external meter. Make a field strength meter with it as follows: Wrap the leads of a germanium diode (1N34 is a good one) around the meter plugs and plug them into the meter. Extend the leads upward and connect them to the chandelier or tape them to the wall about 2-3 feet from the transmitter. Keep the leads separated by a few inches. Place the meter on its lowest voltage range.

Connect the batteries to the center terminals of the switch directly or with a plug and place them in their assigned mounting place. If you are using a 1 M.A. meter set R7 for maximum meter deflection. If you are using a more sensitive meter set it in the middle. Turn the switch on and grasp the transmitter firmly. With an insulated tool adjust the variable capacitor (C8) for maximum voltage on the field strength meter. If the F.S. meter reads backwards, reverse the diode or the leads.

Actually all this could have been done with the meter on the front of the case but this method proves out the "radiated" power and should be used for the initial tuneup.

Now get your favorite transmitter, or borrow one, and run a comparative test to further insure your Digitrio's radiated power. Unless you have one of the "King Kong" type presently splattering their way around the flying sites you should find that the RCM Digitrio has the edge. You will also note that the meter jumps around as you grasp the case then remove your hands. This is normal with the antenna system used — your body actually being part of the system. That's also why it is important to tune it up while grasping the case firmly.

Assemble the case and note the panel meter reading with the antenna fully extended while holding the case as you would while flying. This reading will be your reference to indicate proper output from this point on. If you are using a 1 M.A. meter and have set R7 for maximum meter deflection you should read in the upper 1/3 of the scale. Adjust R7 for your reference reading. Adjustment of R7 may affect tuning slightly so if you move it very far touch-up C8. Any major deviation of the meter from now on, either **up** or **down,** will indicate trouble somewhere in the transmitter. Since the antenna has been tuned with you grasping it, it will detune slightly when you set it down. For the following tests be sure you hold at least one hand on the case.

To demonstrate that the antenna is truly resonant place your hand about 6" from one of the bottom sections (below the loading coil) and slowly move it toward the antenna without actually touching it. You should note very little change on the F.S. meter. Do the same thing to one of the top sections (above the loading coil). The effect will be much more pronounced, indicating that your hand capacity is detuning the antenna.

Another test is to retract one of the lower sections of the antenna. This will not have much affect on the F.S. meter reading. Now retract one of the upper sections and you will see what happens if you neglect to extend the antenna fully — especially the section immediately above the loading coil.

Remember this last test, it might save your airplane. Why does the top section (above the loading coil) have more effect on the F.S. meter than the bottom section? An unloaded ¼ wave vertical at the frequencies we use would be about nine feet long. The antenna is loaded to this electrical length to make it resonant while being shorter. Since the bottom sections are only about two feet long we have electrically concentrated seven feet of antenna from the bottom of the loading coil to the tip of the antenna, or, roughly ¾ of the electrical length. This, plus the fact that the impedance rises from feed point to tip, makes the top section much more sensitive to length and body capacity. Prove this to yourself by running the checks we did previously over again. I'll let you take it from there.

From now on tuning can be accomplished with the panel meter — peak it up by adjusting C8. We'll cover final system tuneup in the last article of this series, at which time we'll adjust R29 and R13. For now, set R13 at center resistance. If you have a scope or access to one, you can check the coder against the waveform drawing. If you encounter any trouble tuning up the transmitter, consult your now ex-"technician-type" pal.

Errata

The following corrections should be made to Part II of the RCM Digitrio, which appeared in the September 1965 issue:

1. Figure 2: B should be the second waveform from the top on page 23 — not the third.
2. Schematic, Page 27: the wire from the bottom half of the on-off switch should be shown going to point Y.
3. Schematic, Page 27: The wire connecting J1 and J2 should be labeled *black.*