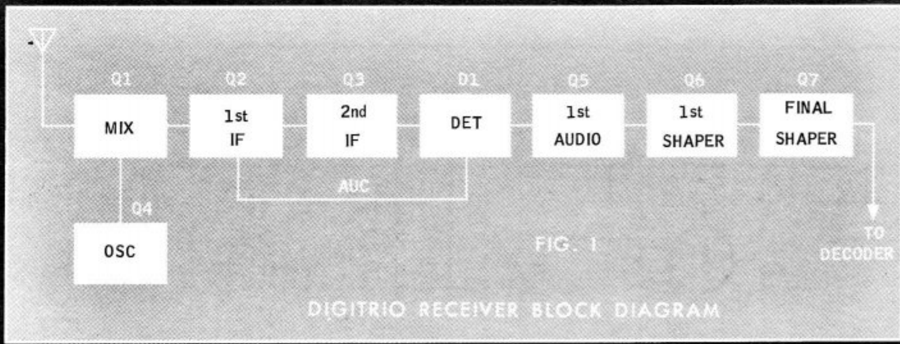


FIG. 1

DIGITRIO RECEIVER BLOCK DIAGRAM

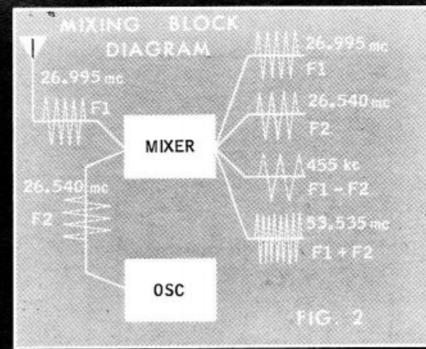


FIG. 2

Part IV: Constructing the Digitrio Receiver

PREFACE

JUDGING from the overwhelming amount of mail and phone calls we have received from virtually every corner of the United States, as well as overseas, we can safely assume that there are well in excess of a thousand RCM Digitrio's presently under construction. Many of our readers have asked for advance construction details, as well as information as to who is kitting the system. Unfortunately, this widespread enthusiasm is the very reason why we cannot meet these reader demands for advance material. In the way of explanation, since the reader response is so great, all of my own available time is being spent re-writing the articles around new packaging, making the articles themselves more complete, and adding artwork to assist you in construction. And, since reproduction of the system itself is of paramount consideration, Don and Chuck are each building new systems around these changes in order to check the validity of the articles prior to publication. This, plus constant proofreading of the manuscript and artwork, has placed the RCM staff on a very tight schedule. I hope that you technicians can appreciate this thoroughness and realize the benefits to the less experienced constructor.

The original system was built entirely with diverted "grocery money," and lacked the advantages of extended research and development that only money can buy. Electronically, very few changes were necessary since the original prototype performed to perfection. I sent it to Don Dewey for evaluation as a prelude to a possible construction series. Based upon Don's evaluation, and subsequent acceptance, I decided to repackage the system more attractively. Don not only accepted the articles, but agreed to help defray the repackaging expenses. So, back to the drawing board I went, this time with the assurance that what I could put on paper mechanically, Chuck Waas (Don's untiring workhorse), could build!

As you can see, the entire project was snowballing. However, with all the assurance and help received to this point, one thing still "bugged" me. Servos! Where was I going to find a suitable servo-mechanism that would not only meet the system requirements, but overcome the horrifying thought of having to scratch-build these units? Just about this time in the overall scheme of things, Jack Port of Controlaire expressed the desire to kit the system, and offered his new proportional servo for the Digitrio. That did it, and off we went! With all systems go, the repackaged unit was completed less than six weeks.

The weekend the repackaging process was finished, I phoned Don and told him to put on the coffee, as I was coming over. (Ed.'s note: The "coming over" consisted of driving approximately 700 miles from Glendale, Arizona, to Sierra Madre, California!) I installed the equipment in a newly completed, and modified Falcon 56, built by Rusty Fried, and headed for California. After a day's work getting everything ready, we sneaked into Don's favorite flying site (after the guard went home) and put in the first test flights on the repackaged system. These were completely successful, and we were by the first hurdle.

The next day, Chuck and I visited Don Mathes and Doug "Mumbles" Spreng at Micro-Avionics, Inc. After trying unsuccessfully to dislodge any secrets about their new system, we decided to go flying. And since I had the only airplane ready to fly, I had the feeling that my system was going to be "nit-picked" to pieces. One consolation was that I couldn't think of any two individuals more qualified to do it! On the way to the flying site, Doug kept mumbling something about – "If it will fly there, it will fly anywhere!" When we arrived, the full impact of his statement was evident. The flying site looked like a tennis court with the surrounding fence lowered to five feet! It was bounded by a skeet range and pistol range (I still think I was shot at!) towering radio antennae, and vehicles with C.B. rigs constantly running up the street. I think I heard some of them talking into their mikes about some "kids" flying toy airplanes.

Doug won the toss to fly – mainly because everyone else was chicken. After a masterful flight that left Don Mathes in a prone position most of the time (he remembered the time that Doug hit himself on a low pass), Doug,

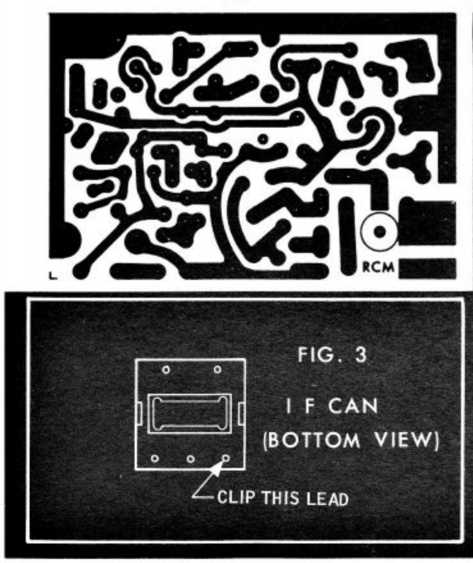


FIG. 3

I F CAN (BOTTOM VIEW)

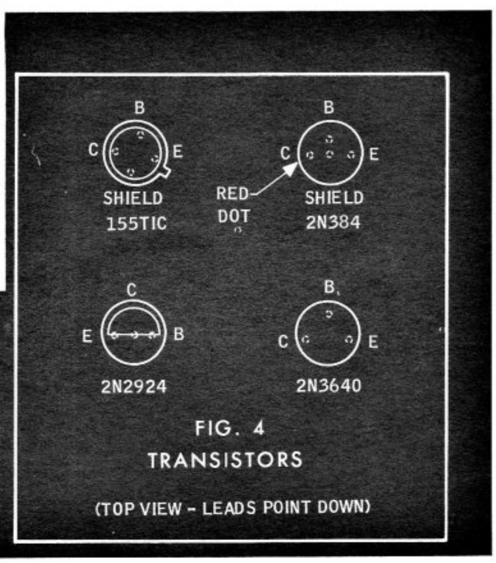
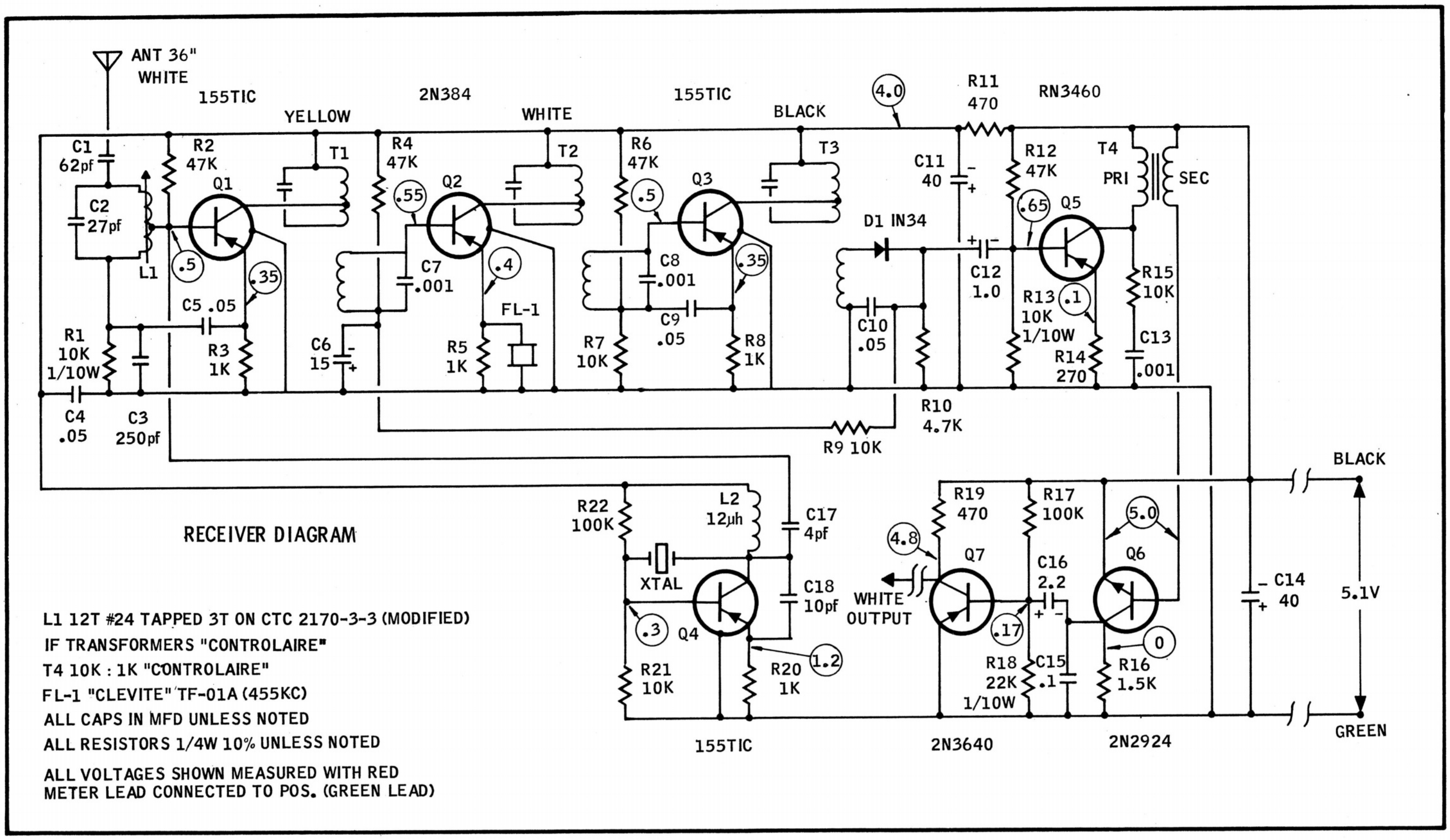


FIG. 4

TRANSISTORS

(TOP VIEW - LEADS POINT DOWN)

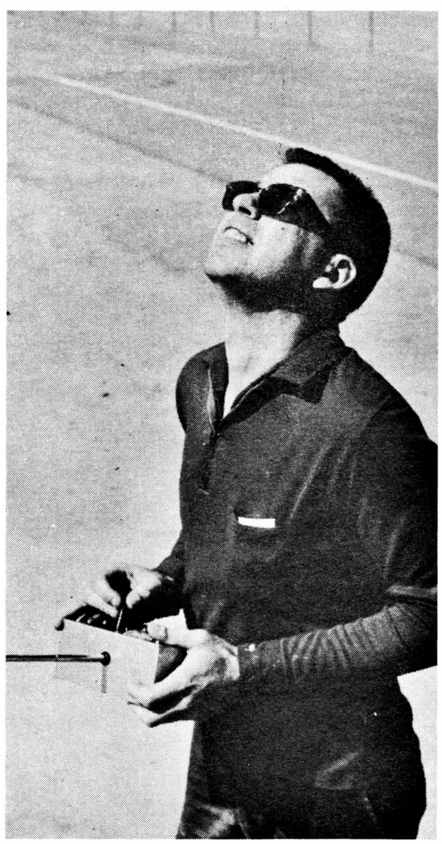


much to my surprise, began talking coherently! This was the tip-off! The Digitrio was destined to become successful. What's more, Doug continued to talk coherently for a full fifteen minutes, which I believe, is a record.

I left the plane with Don Dewey for two weeks, during which time Bill O'Brien flew it for approximately sixty flights without mishap. This included passing the transmitter around to all interested bystanders to try. Upon return of the system, I added another 125 flights without any form of problem or mishap.

And that's the Digitrio, as it stands today. I hope you will be patient until the conclusion of the series, and understand our reasons for having to decline to furnish advance information. We're doing our best, and feel that this additional effort on the part of many individuals will provide you with a proportional system that will render many years of reliable service.

For the advanced technicians, the scope pictures accompanying this article were sent in by Dave Holmes of Grafton, Virginia. Dave's Digitrio transmitter is operating on 6 meters, and he passed on the following infor-



mation for the hams wanting to make this conversion:

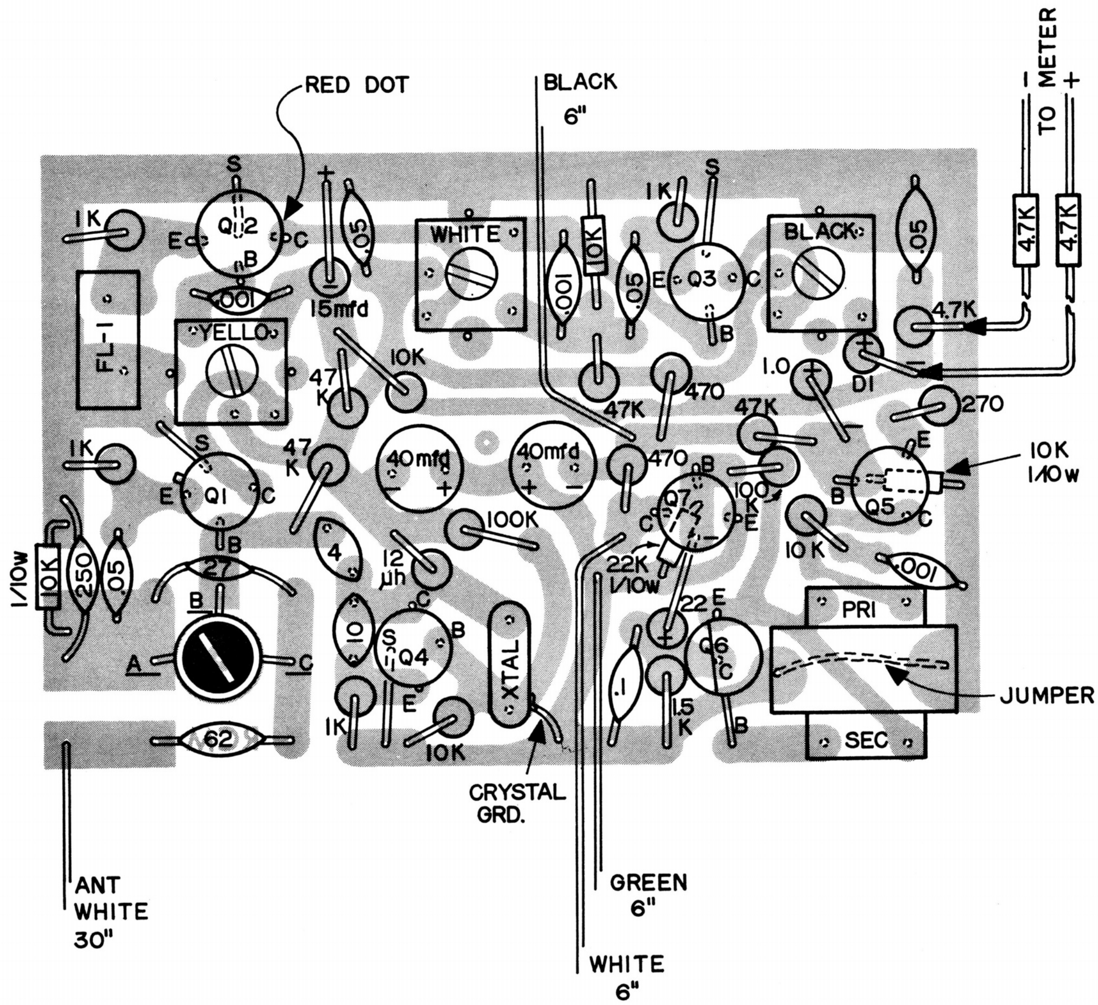
1. Pri L2 is six turns #20 on CTC 2175-4-3 ceramic form.
2. Sec L2 is 2T hook-up wire.
3. L5 is 3T #14.
4. C2 is 10 PF.
5. C6 is 39 PF.
6. C7 is 22 PF.
7. C8 is 7-45 PF.
8. L1 is 10 to 12 uh.

Dave says his transmitter puts out about ⅓ watt.

I will write a complete 50 MC conversion article for publication as soon as time permits but this information should give the more advanced technicians a starting point.

One major manufacturer is kitting the system, the only "designer approved" kit, another company is providing the system ready-to-fly, and several more are offering the printed circuit boards ready for wiring. However you decide to build it, we hope you will do just that — build it. And in so doing, increase your own enjoyment of this hobby by expanding your knowledge and abilities.

The RCM Digitrio was designed for **you.**



RCM DIGITRIO

THEORY OF RECEIVER

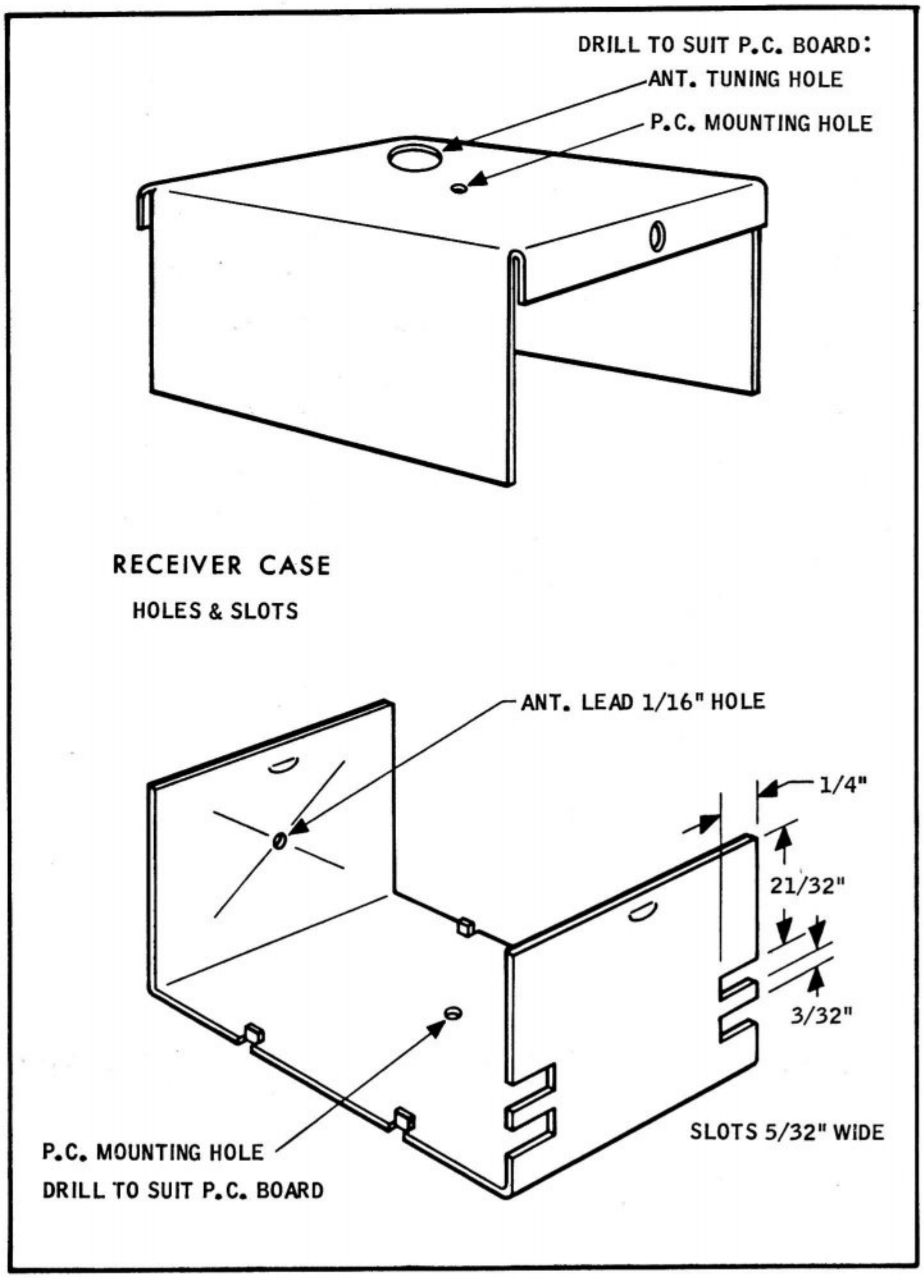
Since receivers fall into the "done to death" category I won't waste much of your time on the more elementary features of superhets. Instead of cluttering up the page with sporatic theory let's take a signal through and apply theory as we go.

Assume we are transmitting our pulse trains at 26.995 MCS, our signal is impressed on the antenna and fed to the tuned circuit (L1 and C2) through C1. This tuned circuit is tuned to 26.995 and will basically reject all others. Since our antenna is short at this frequency it presents a high impedance at the connecting point (top end of tuned circuit). This is proper since a parallel-tuned circuit at resonance presents maximum impedance. However we must transfer this signal to a relatively low impedance (base of Q1. L1 is tapped three turns from the "cold" end to effect an impedance transformation and "suck" our signal out of the tuned circuit without destroying its "selective" properties. C3 supplies the RF ground for the bottom end of the tuned circuit. C5 is connected from the "cold" end of the tuned circuit to the emitter of Q1 to complete the signal path and prevent degeneration of the signal by R3. R3 is used for temperature stabilization of the stage. R1 and R2 provide forward bias and establish the DC operating point of the stage. Let's stop there for now until we cover the oscillator.

Q4 is the oscillator and operates as a series mode crystal oscillator at 26.540 MCS. R21 and R22 provide forward bias for this stage. R20 provides temperature compensation and emitter isolation from ground. L2 is an RFC and provides collector voltage while maintaining a high impedance to RF at that point. C18 increases the collector-emitter capacitance to allow easier oscillation.

Assume we have just applied voltage to the circuit and Q4 starts conducting. This rapid conduction develops a voltage across L2. This instantaneous conduction will be a sharp rise in current rich in harmonics. At some point the multi-frequency characteristics of this sharp wave front will correspond to the series resonant frequency of the crystal. Since the crystal impedance is low at its series resonant frequency and there is a 180 degree phase shift across it, regeneration will occur. The crystal impedance rises sharply on each side of its series resonant frequency so oscillation will occur only at the series resonant frequency of the crystal. As mentioned earlier, C18 allows easier oscillation. It provides regenerative feedback to the emitter and its value is high enough to swamp the inherent collector-emitter capacitance and make oscillation relatively independent of transistor parameters. C17 couples the RF voltage to the base of Q1. The fact that we have two paths of regeneration, the circuit is fairly tolerant of transistor characteristics, and is lightly loaded, makes it a very reliable circuit. The next step is to mix the oscillator frequency with the incoming signal, and I'll try to make it as painless as possible!

To get successful mixing action we must operate Q1 in the non-linear portion of its dynamic transfer characteristic curve or drive it hard enough to exceed the linear portion of its curve. In this case, Q1 is biased in the low current portion of this curve. (Close to the non-linear knee). The oscillator drive then automatically exceeds the linear operating point, and mixing, as well as amplification, occurs. The out-



put of the mixer Q1 contains four frequencies, as follows:

1. Original signal input 26.995 MCS.
2. Oscillator input 26.540.
3. The difference between the two inputs 26.995 minus 26.540 = 455 KC.
4. The sum of the two inputs 26.995 plus 26.540 = 53.535 MCS. (See figure 2.)

T1 is tuned to 455 KC and will pass this frequency on to Q2 while rejecting the other three. This signal will be a replica of our incoming signal, differing only in frequency. The selection of 26.540 MC for our crystal should now be obvious. If your receiver oscillator is operating 455 KC below the incoming signal from the transmitter the same relationship applies, regardless of your transmitting frequency. Another way would be to use a crystal 455 KC higher than the incoming frequency (while you have your pencil handy figure it out).

T1's primary is tapped to provide proper impedance matching to Q1's collector and the primary-secondary turns ratio provides interstage impedance matching. R4, R9 and R10 provide forward bias for this first IF stage. R9 and R10 are used as the AVC voltage divider as well. C6 is used as signal ground for T1's secondary as well as an AVC filter. R5 provides temperature compensation and is bypassed at 455 KC by FL1.

FL1 is a ceramic filter that has series resonant properties at 455 KC. At this series resonant frequency it exhibits very low impedance and effectively bypasses R5. It has a pass band of four to seven percent. At frequencies outside its bandpass it presents a high impedance, and degeneration occurs. The use of FL1 increases selectivity sufficiently so as to pay for itself. C7 loads the secondary of T1 and helps minimize signal ringing. It also seems to have a resonating effect and actually increases stage gain. Our signal is amplified by this first IF stage and is coupled through T2 to the next (second IF) stage. Let's proceed with the signal and cover AVC later.

T2 is also tuned to 455 KC and the signal is further amplified by Q3. R6 and R7 provide forward bias for this stage while R8 is used for temperature compensation. C9 couples the "cold" end of T2 to the emitter to complete the signal path without degeneration. C8 is used the same as C7. T3 is again tuned to 455 KC and couples the signal to the detector diode (D1). D1 rectifies the IF signal and passes only the positive half. C10 removes the 455 KC signal component, by-passing it to ground.

So far we have processed our signal into a train of audio frequency pulses. Look again at R4, R9 and R10. These resistors establish the negative bias voltage for Q2. They also forward bias D1. The rectified positive IF signal from D1 will cause the junction of R9 and R10 to swing in a positive direction. This will in turn cause the negative bias on Q2 to decrease thereby controlling the gain of that stage. C6 is used to filter the signal excursions into a smooth DC control voltage. This AVC (automatic volume control) is necessary to prevent signal overloading of the IF stages and provide a relatively constant signal for the rest of the receiver. Since this AVC voltage varies with signal strength we can use it to peak up the receiver.

C12 couples the detected signal to Q5 (first audio). R12 and R13 provide forward bias and R14 is used for temperature stabilization. R14 is purposely not by-passed so that the stage **is** slightly degenerative. The signal is amplified and coupled to Q6 via T4. R15 and C13 are used to smooth the negative going signal transitions which otherwise would be sharp ringing pulses. Q6 has no forward bias and conducts when the signal level exceeds approximately .3 volts. This lack of bias prevents low level trash and/or electrical noise from triggering the rest of the circuits. When Q6 conducts, the voltage at the top of R16 goes negative, driving Q7 into conduction. C15 is a noise filter and is quite effective. C16 is used as a coupling capacitor between Q6 and Q7. R17 and R18 forward bias Q7. Q7 develops its signal across R19 which goes directly to the decoder. The last two stages are over-driven to shape/square the pulses. C4, C11, C14 and R11 are all used for filtering and decoupling.

I have deliberately omitted references to waveforms to minimize the confusion factor. I would suggest that you reread the foregoing again, only this time include the waveforms with the text. As you can see, all the wave forms are smooth with no "brute force" characteristics. This allows for non-critical tuneup and reliability. Also there are no ringing tendencies or any form of instability. A word of warning: **Don't** indiscriminately substitute parts values or try to improve the circuit unless you thoroughly understand all aspects of the circuits and are willing to take the consequences! Don't be led down the primrose path by those who tell you that range will be increased by reducing the value of R11. It's much more complicated than that! You might get more noise through the IF's but it could be mostly noise generated by the IF's themselves. As you follow the waveforms and block diagram (figure 1) you will note how the signal progresses through the receiver until we get to Q7's collector. This signal going to the decoder is a good replica of the signal at Q10's collector in the transmitter. These pulses will precisely follow stick movements at the transmitter. Let's get this thing built so we can continue.

MAKING THE RECEIVER CASE

The receiver case is a standard LMB #SL-MOO aluminum box. The drawing shows cutouts and holes necessary for packaging the receiver/decoder. If you intend to have the case anodized or painted use emery cloth and steel wool to polish it as described in the transmitter article.

PREPARING THE P.C. BOARD

Whether you make your board or buy it with a kit you should prepare it as follows:

( ) Make sure it fits the case. The receiver board fits into the half of the case with the lip bent up on each end. File the edges of the board until it fits properly. Make sure there is adequate clearance at the ends so the box will go together smoothly.

( ) Locate the mounting hole and drill it with the P.C. board and insulating sheet in place, conductor side down on the P.C. board. Use a drill size somewhat smaller than the mounting screw diameter so it can tap itself into the board.

( ) Find the center of the coil form hole and drill it as above with the same drill.

( ) Remove the board and enlarge the mounting hole in the case to match the diameter of the mounting screw. Enlarge the coil form hole with a #9 drill. Enlarge the coil form hole in the insulating sheet to permit tuning.

( ) Drill all holes in the P.C. board with a #60 drill if they are not already drilled.

( ) Take all components with leads/lugs larger than #60 and drill the board to fit them. The IF transformers will have to be modified as follows before fitting: stand the IF transformers on their tops so that the leads/lugs are pointing upwards. Position the transformers so that the leads are arranged as in figure 3. Clip the lower right lead off flush with the can on all three transformers.

( ) We are only going to use the top portion of the coil form and throw away the end with the lugs. Remove the tuning slug and cut the coil form 9/16" from the top. Enlarge the coil form hole in the PC board to slightly less than required (#9 drill) and finish up with a round file for a press fit.

( ) Place a 6" square piece of fine emery cloth on a flat surface and "sand" the copper side of the board to remove all "burrs."

( ) Clean the copper side with scouring powder until it is bright and shiny.

( ) Insert the coil form until it is flush with the opposite side of board and epoxy it into place.

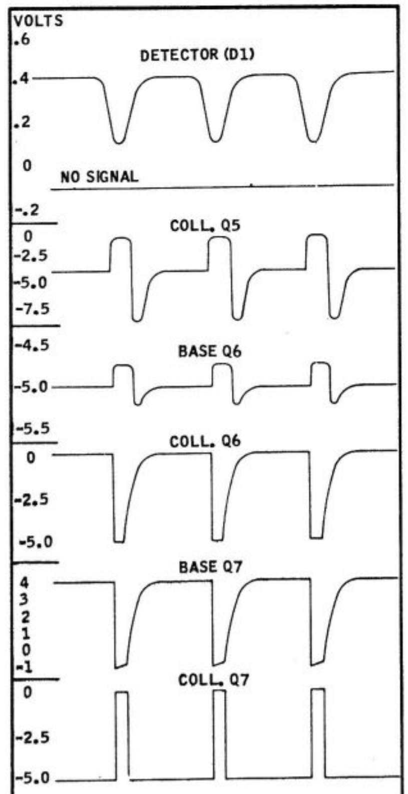
WIRING THE P.C. BOARD

Refer to construction overlay and photographs to wind turns on L1.

( ) Scrape the end of a piece of #24 enameled wire (approximately 12" long), insert, and solder it in Hole "A". Bend the wire over flat against the P.C. board and wind three turns in a clockwise direction. Cut, scrape and insert the other end in Hole "B". Scrape one end of the remaining wire and insert it also in Hole "B" and solder. (You may have to enlarge Hole "B" slightly to accommodate both pieces of wire.) Continue winding, in a clockwise direction for nine more turns. Cut, scrape, and solder the end of the wire in Hole "C." When you are through you should have a close-wound/twelve-turn coil tapped at three turns. Inspect the coil closely for shorted turns. If you are not satisfied with the coil, either mechanically or electrically, simply rewind it. Wire is cheap, and quality at this stage of the game will pay off.

( ) Mount the three IF transformers, observing the color coding of the cores (see schematic and construction overlay.)

( ) The AF transformer will probably have a corrosion-resistant agent on the metal mounting lugs. This should be removed by filing and tinning the lugs thoroughly before mounting. The transformer frame acts as a jumper and must have a good electrical connection. An external jumper across the top of the transformer soldered directly to the P.C. board will insure a good connection. Make



WAVEFORMS

sure the primary and secondary are as shown on the construction overlay.

( ) Mount the crystal flush against the board. Note the wire labeled "crystal ground" on the construction overlay. When you solder this wire make sure you do not "unseal" the crystal.

( ) Solder FL-1 into place by bending the lugs over and avoid overheating.

( ) Mount the two 40 MFD. filter capacitors, observing polarity.

( ) Mount all resistors as shown on the overlay. Do not forget R1 (10K 1/10W) under the 250 PF cap (C3). Use only sufficient heat on the 1/10W resistors to insure a good connection, as they are prone to change value when overheated.

( ) Mount all disc capacitors making sure none of them "overhang" the edges of the board.

( ) Mount D1, observing polarity.

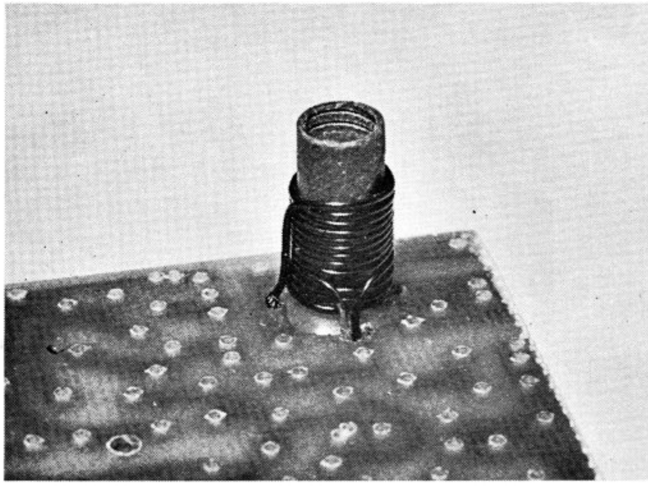
( ) Mount the remaining capacitors, observing polarity.

( ) Mount L2.

( ) Starting with Q1, install all transistors (see figure 4 for lead identification.)

( ) Install antenna and connecting wires as to length and color shown.

( ) Clip all soldered leads off to the board, and using a 1" wide "fine" file, file the conductor side of the board until the solder mounds are "flatted" and about 1/32" to 3/64" high. Finish with emery cloth



This photo clearly shows the winding and placement of leads for L1. First step in assembling receiver. Coil form is epoxied to P.C. Board — we used Hobbypoxy Glue.

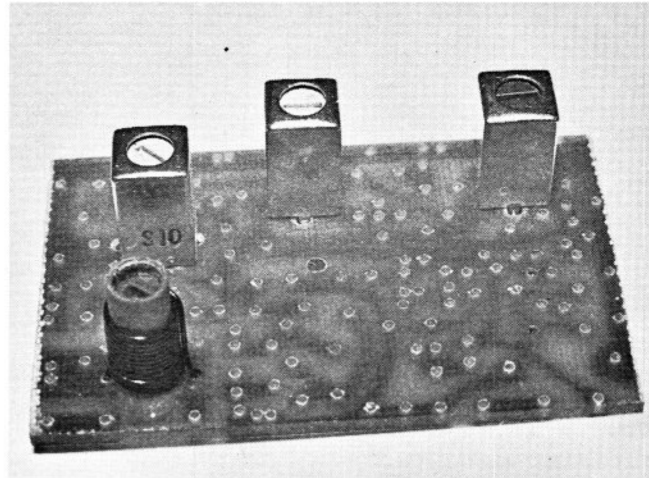
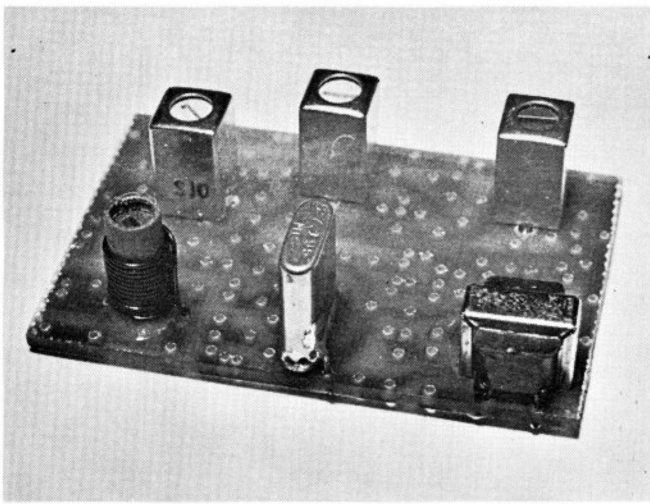


Photo showing installation of T1, T2, T3, World Engines 455 KC IF Transformers. Watch color coding. Holes for mounting lugs must be enlarged for snug fit.



This view shows installation of crystal and T4, 10K:1K Audio Transformer. Note grounding wire soldered to side of crystal can. Exercise caution so as not to destroy seal on crystal.

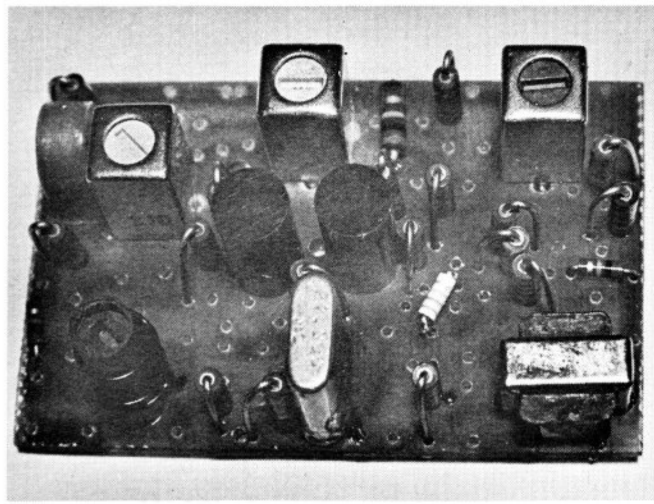
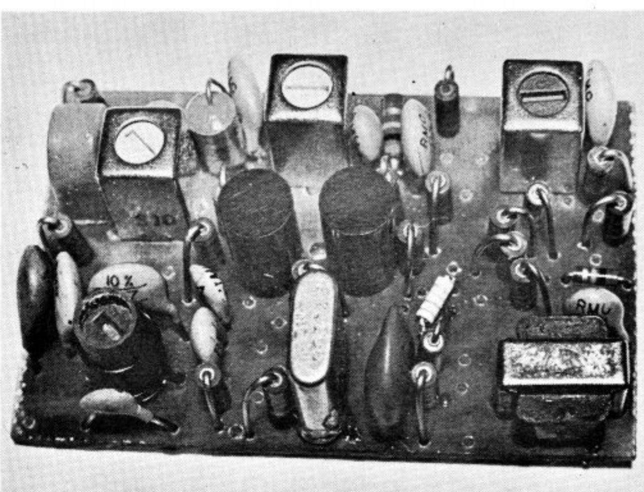
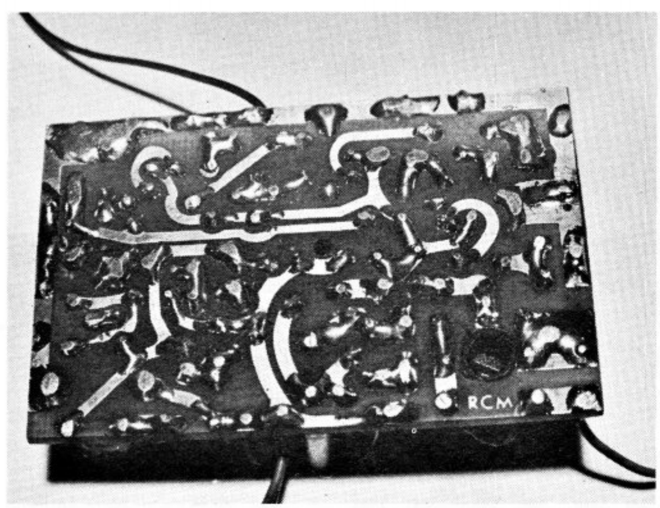


Illustration of placement of resistors R1 through R22. Note FL-1 Clevite transfilter upper left hand corner. Holes must be enlarged to accommodate leads. Be sure to observe polarity on C11 and C14, center of photo.



In this photo, all capacitors are in place, C1 through C18. Observe polarities. Observe proper polarity on C6, C12, and C16, axial lead electrolytics.



Trim all excess leads and solder points on underside of P.C. Board. Clean with dope thinner and a stiff brush. Bevel edges of board with extremely fine toothed file so that neither solder or copper leads can make contact with side of case.

on a flat surface. Visually check all connections and resolder any in question.

( ) Bevel the bottom side of the P.C. board on all sides with the same file to prevent electrical contact of the lands with the case.

( ) Clean the board of all solder resin with a stiff brush and Acetone or Dope Thinner. A toothbrush can be used here if you work fast inasmuch as Acetone will dissolve the bristles and leave a slight non-harmful residue.

PRELIMINARY CHECK OF RECEIVER

( ) Measure the resistance between the black (negative) and green (positive) wires. (Observe meter polarity.) Your meter should indicate approximately 6K ohms. If it is much less, check the board for solder bridges between lands, or improperly mounted components.

( ) If the resistance check was good we can now aply five volts (4 nicads in series). Place your meter (on milliamp scale) in series with the black lead from the receiver. The black meter lead goes to the battery pack negative and the red meter lead goes to the black receiver lead. Connect the green lead from the receiver to the positive side of the battery pack. Your meter should read approximately 4 M.A. If not, recheck the P.C. board for mistakes.

( ) Measure voltages of the different stages as shown on the schematic (voltages are encircled). They should all be within 10 to 20% depending on the meter you use. I used a 20,000 ohms per volt multimeter for all measurements. If all is well so far, and your transmitter is working, you can tune the receiver and make some range checks.

( ) Mount the receiver board in the case (don't forget the insulating sheet).

( ) Temporarily solder two 4.7 to 10K resistors at points X and Y on the overlay.

( ) Place the receiver on a non-metallic surface and extend the antenna.

( ) Place your meter on the lowest voltage range and connect the red lead to the other end of the resistor going to point Y. Connect the black meter lead to the resistor going to point X.

( ) Connect the 5V battery pack to the receiver. Black receiver lead to negative and green receiver lead to positive. The meter should read slightly negative (backwards). This is proper and no cause for alarm.

( ) Collapse the transmitter antenna, turn it on and place it about ten feet from the receiver.

( ) Adjust the IF transformer and antenna cores for maxium reading on meter (meter should be reading in the proper direction now).

( ) Increase the distance between transmitter and receiver as you tune so that final tuning results in a very low meter reading when the receiver is peaked (this prevents AVC overload and allows for sharper tuning.) You can remove the transmitter antenna for final tuning or have a friend walk down the street with the transmit-

PARTS LIST FOR RECEIVER

REFERENCE NUMBER	DESCRIPTION	MANUFACTURER OR SOURCE	MANUFACTURERS' NUMBER
C1	62 PF	RMC	SM-62
C2	27 "	"	SM-27
C3	250 "	CRL	DD 251
C4	.05	RMC	M12 .05 MF
C5	.05	RMC	"
C6	15 MFD. Elec. (Axial Leads)	World Engines	CL-156
C7	.001	RMC	SM .001MF
C8	.001	RMC	"
C9	.05	RMC	M12 .05 MF
C10	.05	RMC	"
C11	40 MFD. Elec. @6V (P.C. Leads)	World Engines	FPC-40-B-O
C12	1 MFD. Elec. (Axial Leads)	" "	CT-105
C13	.001	RMC	SM .001 MF
C14	40 MFD. Elec. @6V (P.C. Leads)	World Engines	FPC-40-B-O
C15	.1 MFD.	CRL	UK10-104
C16	2.2 MFD. Elec. (Axial Leads)	World Engines	CT-225
C17	4 PF	RMC	SM-4
C18	10 "	"	SM-10
D1	Germanium Diode	Ohmite	1N34
FL-1	Transfilter	Clevite	TF-01A (455 KC)
L1	12T #24 Tapped 3 Turns on C.T.C.	Form 2170-3-3 Modified.	
L2	12 uh RFC Choke	World Engines	ES755
Q1	155T1C	" "	155T1C
Q2	2N384	RCA	2N384
Q3	155T1C	World Engines	155T1C
Q4	155T1C	" "	"
Q5	2N3640	Fairchild	2N3640
Q6	2N2924	G.E.	2N2924
Q7	2N3640	Fairchild	2N3640
R1	10K 1/10W	Ohmite	LIDSM
R2	47K ¼W	"	"
R3	1K "	"	"
R4	47K "	"	"
R5	1K "	"	"
R6	47K "	"	"
R7	10K "	"	"
R8	1K "	"	"
R9	10K "	"	"
R10	4.7K "	"	"
R11	470 "	"	"
R12	47K "	"	"
R13	10K 1/10W	"	"
R14	270 ¼W	"	"
R15	10K "	"	"
R16	1.5K "	"	"
R17	100K "	"	"
R18	22K 1/10W	"	"
R19	470 ¼W	"	"
R20	1K "	"	"
R21	10K "	"	"
R22	100K "	"	"
T1	455 KC Input IF Transformer (Yellow Dot)	World Engines	— — —
T2	455 KC Interstage IF Transformer (White Dot)	" "	— — —
T3	455 KC Output IF Transformer (Black Dot)	" "	— — —
T4	10K: 1K Audio Transformer	" "	— — —
Crystal	Frequency Desired	" "	— — —
— —	Receiver Case	LMB	SL-MOO
— —	2⅛" x 1⅜" Piece of 1/64" Insulation Sheet	World Engines	— — —
— —	Sheet Metal Screw #2 or 3 x ¼"	" "	— — —
— —	P.C. Board	" "	— — —
— —	#24 Enameled Wire (24")	— — —	— — —

ter.

( ) Borrow a set of high impedance headsets from your ham friend and connect them between the white and green receiver wires. Use a .05 MFD. capacitor in series with the white lead. You should hear a "buzzing" noise when the transmitter is turned on.

( ) Borrow a yardstick from your understanding wife and tape the receiver and battery pack at one end, extend the antenna lead up the stick and secure it at the top with tape. Connect the headset, and with your buddy holding the transmitter, start walking across the "boon-docks." Your range should exceed ¼ mile on the ground. Take your tuning wand along, and when the signal gets "raggedy," peak up the antenna core. Do not adjust the IF's as they should be adjusted with the meter. Ground range will depend on terrain and system tuning. All of my systems to date were still going strong at 3/5 of a mile over a cement runway.

PARTS LIST FOR RECEIVER

Since size is an important factor for the receiver parts, substitution will require careful selection. Every part in the receiver should be easily obtained from your parts dealers except for the parts marked "World Engines" in the "Manufacturer or Source" column. Most parts' houses have catalogs for the different component manufacturers which they give free to buyers. Sizes are generally listed and you can cross reference parts to those they carry in stock.

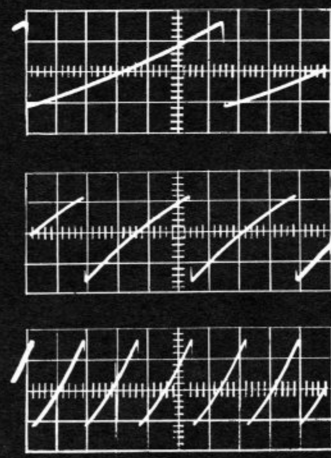
I do not recommend substitution of any parts' **values** in the receiver unless you thoroughly understand the circuitry and can analyze the circuit parameters with proper test equipment.

ERRATA TO ARTICLE II TRANSMITTER

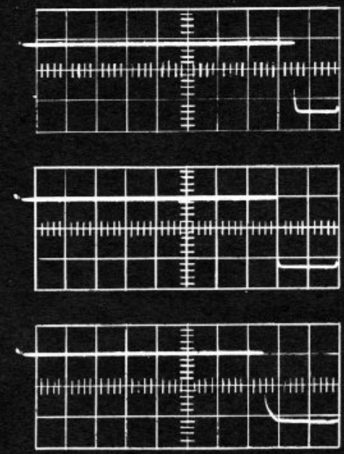
1. **Figure 2**
   a. Top waveform should be marked 6.5 MS not 6.5 us.
   b. Second waveform should be marked $\overline{B}$ not B.
   c. Third waveform should be marked B not $\overline{B}$.

2. **Schematic**
   a. R5 should be 330 not 300.
   b. Wire pointing downward from bottom half of off-on switch should be marked "Y."
   c. Wire connecting J1 and J2 should be marked "black."

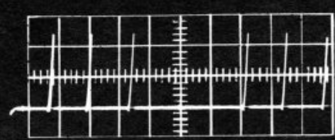
3. **Construction Overlay**
   The .05 capacitor below L3 and L4 is not shown on schematic or listed in parts list. Draw it in on schematic in parallel with C23 and list it as C25 in parts list. It is a Centralab type UK20-503.



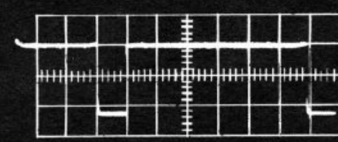
Output of pulse generator taken at point A showing effect of varying R23 and R30.



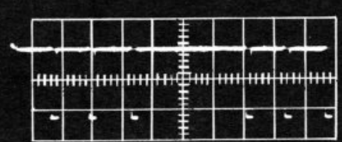
Collector of Q6-500 us/div. 2 volts/div. showing effect of stick movement.



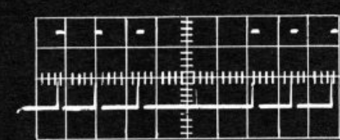
Base of Q10 1ms/div. 2 volts/div.



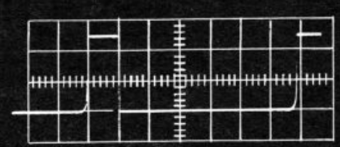
Collector of Q10. 200 us/div 2 volts/div.



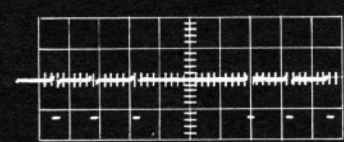
Collector of Q10. 1ms/div. 2 volts/div.



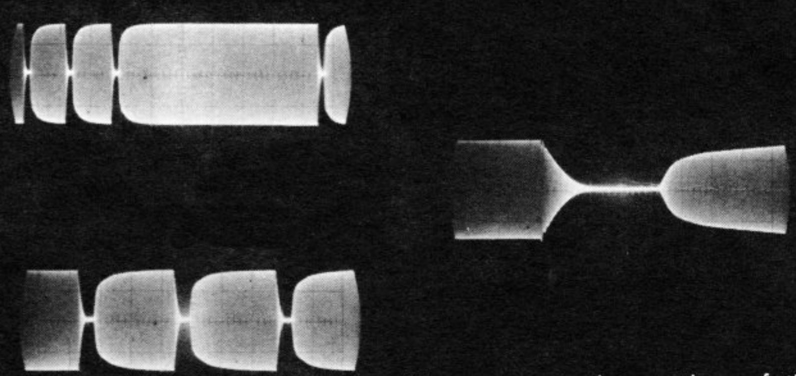
Collector of Q11. 1ms/div. 2 volts/div.



Collector of Q11. 200 us/div. 2 volts/div.



Base of Q11. 1ms/div. .5 volts/div.



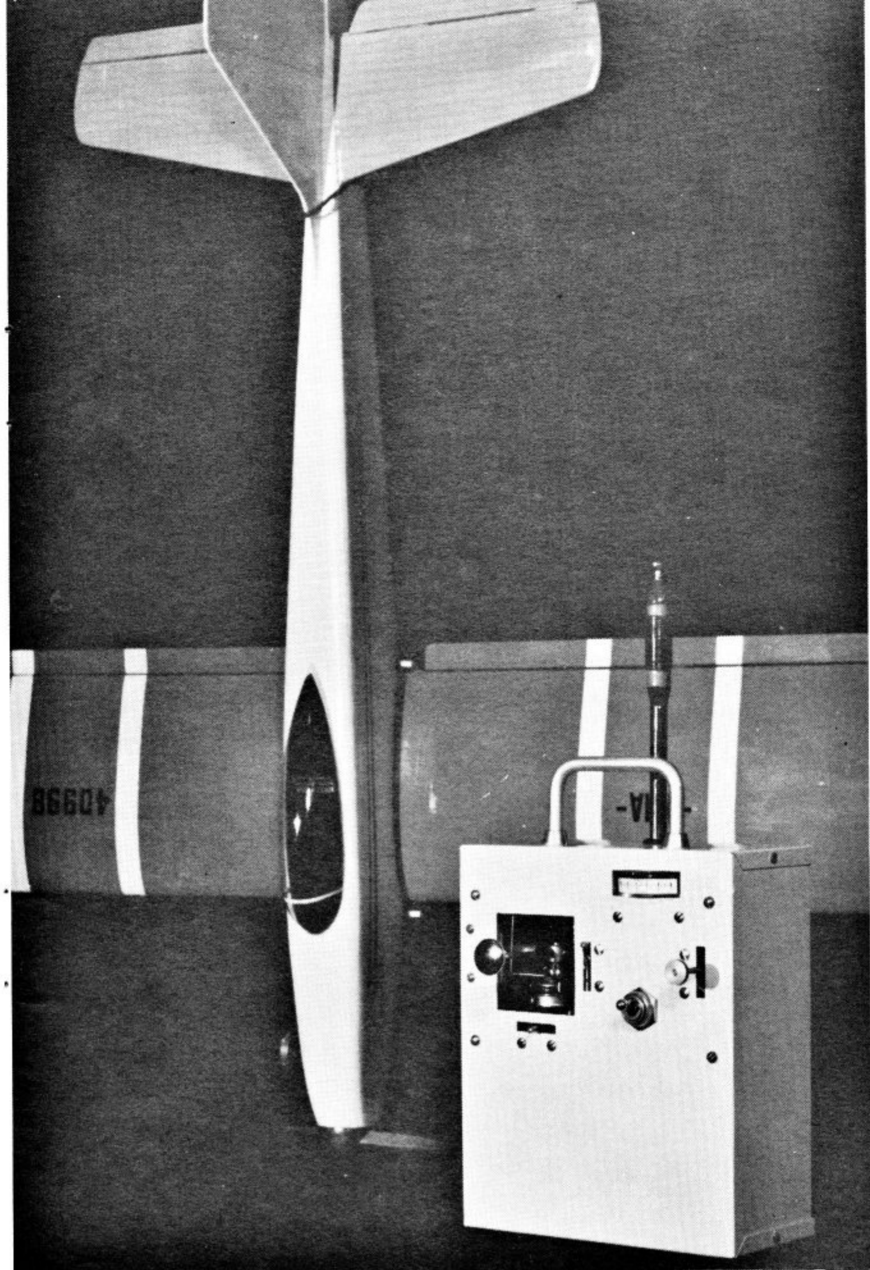
RF output at various settings of time base.

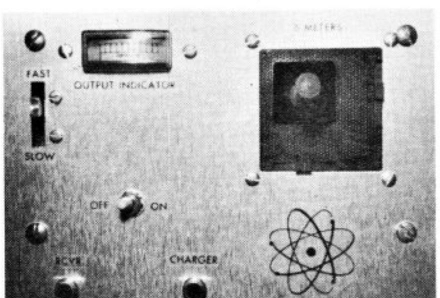
COMING NEXT MONTH: PART V OF THE RCM DIGITRIO CONSTRUCTING THE DECODER

RCM DIGITRIO

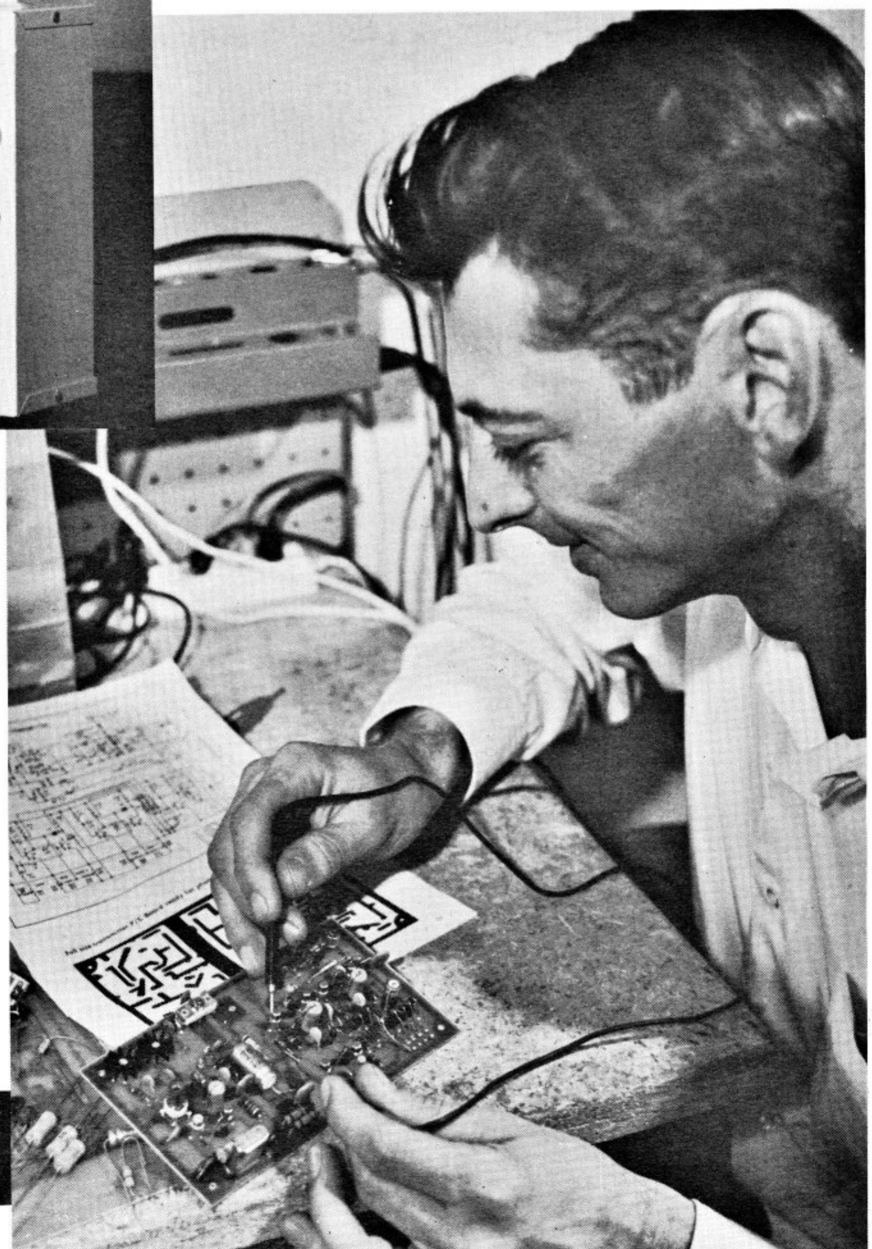
Part V: Constructing the Decoder

ED THOMPSON
RCM Contributing Technical Editor

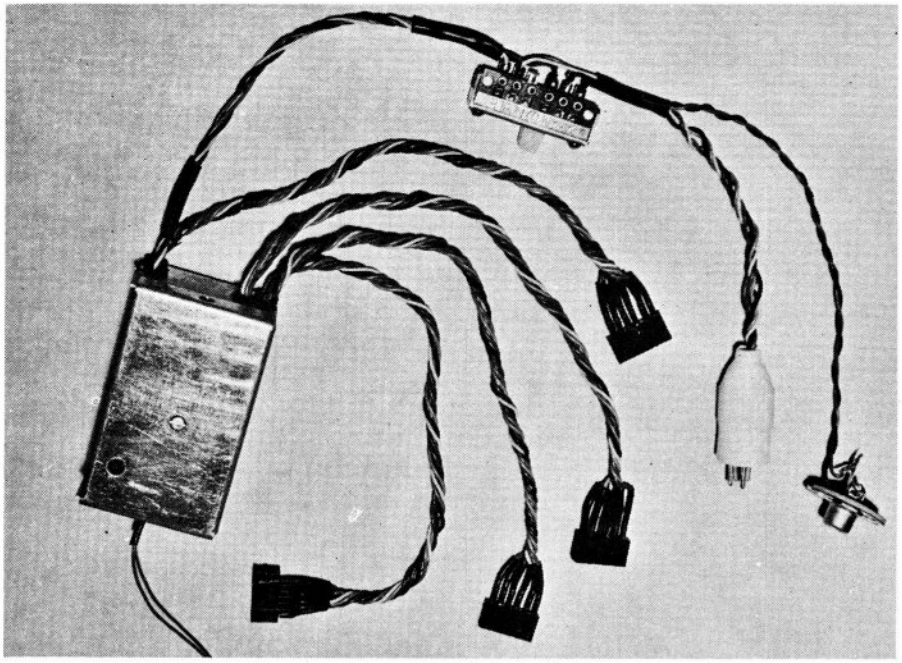


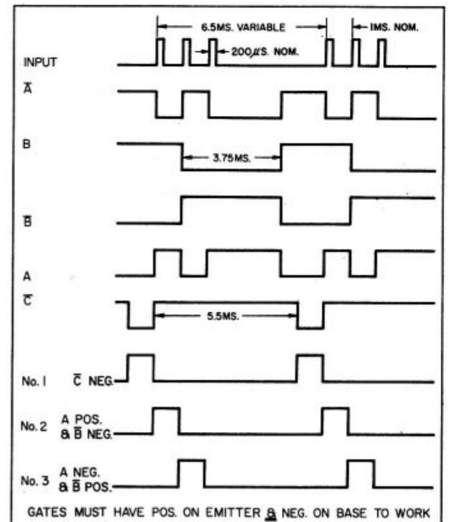


Top: Bryce Petersen's Digitrio modified for left hand operation. RCM "Patriot" in background. Above: Digitrio with Bonner stick assembly. Xmtr is on 53 Mcs. Both modifications will appear in a future article. Right: Slim Snelling working on his Digitrio transmitter board.



An RCM Technical Feature





DIGITRIO DECODER WAVEFORMS

The completed receiver and decoder with switch, battery connector, charging jack, and four servo connectors in place.

Preface

I RECENTLY had the opportunity to spend a couple of days at World Engines so that Jack Port could evaluate the Digitrio and I could get a first hand look at their operation. Jack Port, John Maloney and myself spent the better part of one day at the local flying site. We flew both the Digitrio and the Controlaire 5 Proportional System. After John scrounged up some fuel, a glo-plug, battery, etc., from the local flyers we got in some good flights, having installed the Digitrio in a C.G. Falcon "56" with an O.S. Max 35 up front. To sum up, I had an enjoyable visit in Cincinnati and met some very nice people, capping it all off with a steak dinner, courtesy of World Engines. I would like to express my thanks to Jack and John for their hospitality.

Dave Holmes, who sent the scope pictures of the transmitter waveforms, came through with the receiver scope pictures in this article — his unit being on 50 MC. Dave changed C2 to 18 PF, L1 to 7T tapped at 1 turn, L2 to 4 uh and inserted a 6 meter crystal. To date, all works well. Bernie Murphy is also building a Digitrio and said he will include his comments in a future kits and pieces column.

I asked Don recently if any electronic projects had come in for the design contest that I could evaluate for him. I was disappointed to hear that not many had been submitted to date. I know there are a lot of good ideas around and hope that some of you experimenters will pass on your goodies to the rest of us.

Here are a few questions based on letters I have received about the Digitrio and my answers:

Q. Can a commercial stick be used with digitrio?

A. *Yes. In fact, there are some already built using the Bonner stick assembly. I am building one on 6 meters with a Bonner stick and will present it at a later date.*

Q. You mention that World Engines is kitting the system but fail to mention when or what the price will be?

A. *It is not the purpose of this series to advertise any commercial items. See the World Engines advertisements or write to them directly for information. The kits will be released concurrently with each article and prices will be announced by World Engines.*

Q. Are you going to design circuitry for other makes of servos, four channel operation, 3+1, commercial stick installation, 6 meter conversion, etc.?

A. *If I don't get writers cramp first, I'll write about anything you want. I'll present the articles in the order of most letters received.*

Q. Can I obtain advance information in order to complete my system?

A. *This has been covered before and the answer is no, due to the pressure of time.*

Q. Will a designer-approved kit be produced in the United Kingdom?

A. *I don't know. I have received letters from manufacturers in the U.K., but don't yet know their intentions. I have not as yet approved any foreign kits. Exportations will export to foreign dealers and I suggest that overseas readers see their local World Engines dealers.*

Q. I would like to build a Digitrio but only in a four channel version, when will this information be available?

A. *As stated previously, what I write is based on reader response and this is one of the least requested items to date.*

Q. Will I have to purchase commercial servos and modify them for Digitrio? If so, I don't see how I can build the system for $200.00.

A. *No. The servos will be built up like the rest of the system using only World Engines' mechanical servo parts. It is possible that World Engines will offer the servo built up for the Digitrio, however at a higher price.*

Q. Since you have me interested in the Digitrio can you recommend a good book on transistors?

A. *Yes. I think the Department of the Army T.M. 11-690 is an excellent book. It can be purchased for $1.25 from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

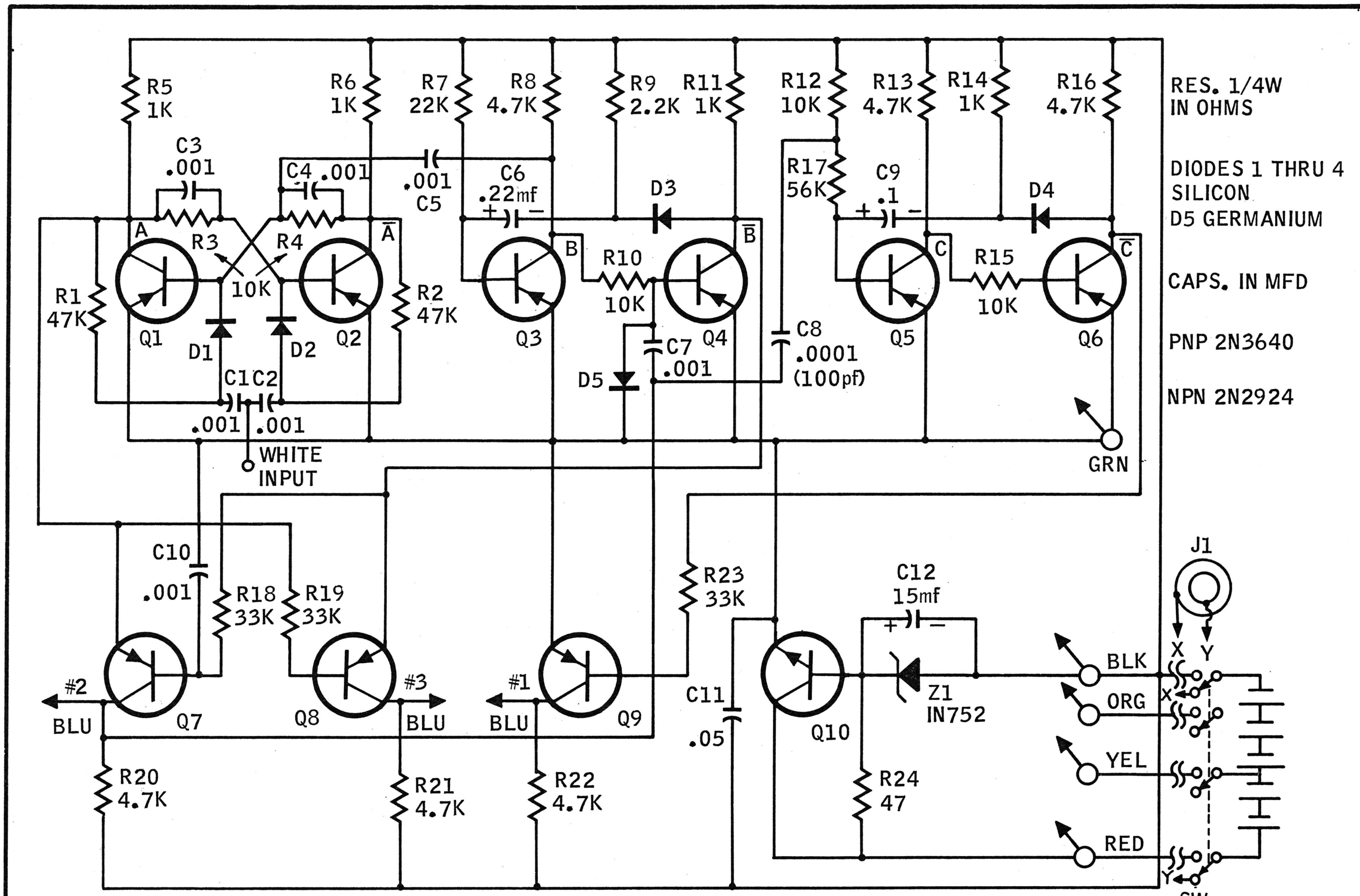
Q. I missed the first two issues of your Digitrio article and hope you can help me obtain them.

A. *Try writing to the RCM Circulation Department, P. O. Box 1128, Laguna Beach, California, for any back copies.*

THEORY OF DECODER

Most of the circuits in the decoder were covered briefly in the first article. One flip flop, two one shots, and two gates (Q9 is merely an amplifier) are used to count/sort the pulse trains into separate channels. Constant reference to the decoder waveforms will be necessary to grasp its operation.

The input to the decoder is a replica of the transmitted signal. Q1 and Q2 (flip flop) are triggered by the leading edge of each pulse. This produces square waves at both collectors (Point A and A). The width of these pulses are determined by the width **between** the leading edges of the pulses in the incoming pulse train. Since Q1 and Q2 cannot be in the same state at the same



SCHEMATIC - DIGITRIO DECODER

time A and A will be inverted replicas of each other.

Q3 and Q4 (B and B) form a one shot that is used to reset the flip flop during the sync pause. It also assists the flip flop sort Channels 2 and 3.

Q5 and Q6 (C and C) form another one shot that is used to measure the time between the #1 pulses in the pulse train. The time between #1 pulses is compared with the timing of this one shot to produce the motor control pulse.

Q7 and Q8 are the output gates for Pulses 2 and 3 respectively. Q9 is the motion control output transistor. Q10 in conjunction with Z1 provide regulated voltage for all the timing circuits including the reference generators in the servos. It also provides regulated voltage for the receiver. J1 is wired to the off side of the switch and is used as the charging jack.

Let's start with the action of the flip flop (Q1 and Q2) and first one shot (Q3 and Q4). Assume that Q2 and Q3 are conducting, Q1 and Q4 are cutoff and we are waiting for the first pulse. This places a negative voltage on the emitter of Q7 and base of Q8 (from collector of Q1). There is also a negative voltage on the base of Q7 and base of Q8 (from collector of Q4), under these conditions neither Q7 or Q8 is forward-biased so they're not conducting.

When the first pulse arrives it changes the state of the flip flop. The collector of Q1 goes to ground and Q2 goes negative. This places the emitter of Q7 and base of Q8 at ground potential. Since the first one shot didn't change state we now have Q7 forward-biased with Q8 still cut off. **The circuit will remain in this condition until the second pulse arrives.** The latter changes the state of the flip flop again and Q1 goes negative while Q2 goes to ground. So we're back where we started (at least for a pico second)! Q7 cuts off because we remove its emitter ground at Q1's collector when Q1 goes negative.

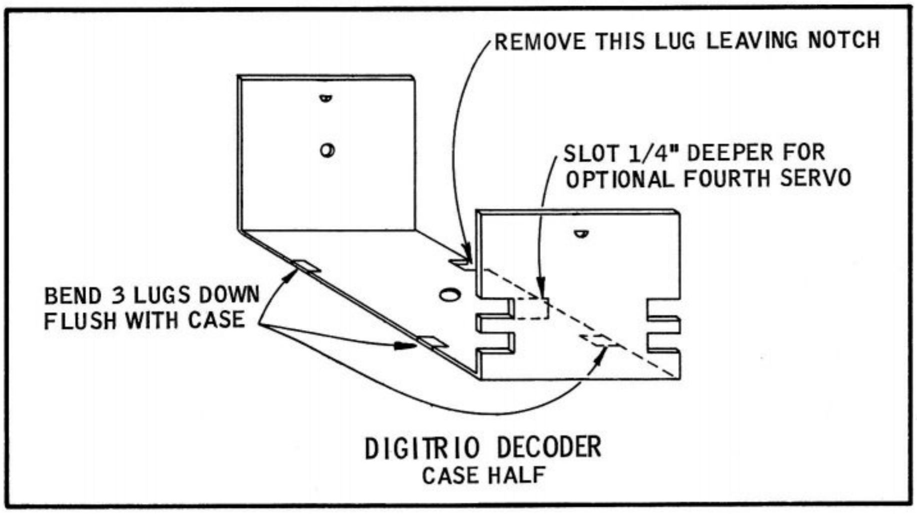
Let's review quickly: The first pulse caused Q7 to conduct and the second pulse cut it off again. So we have a positive square pulse at Q7's collector. The pulse width is determined by the distance between Pulses 1 and 2. Since we vary this distance at the transmitter by moving the stick we can also vary the width of the pulse at Q7's collector.

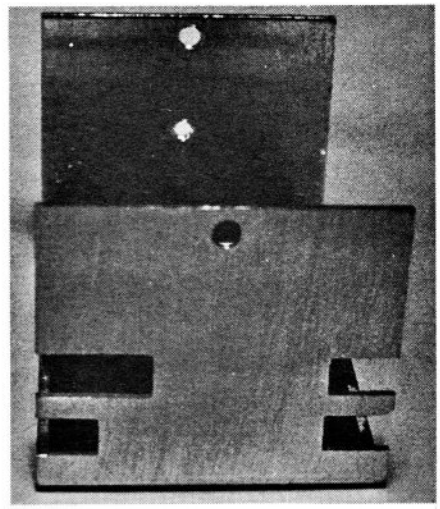
When Q7 cuts off (collector going negative) a negative-going pulse is impressed on the base of Q4 via C7 causing this one shot to change state and start timing. B goes negative and B goes to ground. This places a ground on Q7's base (it stays cut off) and a ground on Q8's emitter (it's base is negative from Q1's collector) so Q8 conducts. It will remain conducting until Pulse 3 arrives.

When Pulse 3 arrives it changes the state of the flip flop again and Q8 cuts off because Q1's collector places a ground on Q8's base. We also place a ground on Q7's emitter but Q4 is still holding Q7's base at ground so neither Q7 or Q8 is conducting.

After 3.75 MS has lapsed the one shot will return to its quiescent state (Q3 conducting — Q4 cut off). When it changes state Q3 going to ground transfers a positive pulse via C5 to Q1's base changing the flip flop's state at the same time. This resets the decoder (Q2 and Q3 conducting — Q1, Q4, Q7 and Q8 cut off) and it is now waiting for another pulse train. Therefore the second pulse not only turns off Q7 but turns on Q8. The width of the pulse at Q8's collector then is the width between the second and third incoming pulses and width is determined by stick movement at the transmitter. The uninterrupted carrier between pulse trains is the "sync pause." During this sync pause the first one shot returns to its quiescent state resetting the circuit.

As you can see we intentionally skipped the #1 output pulse. This is how it works. As stated before, the #1 incoming pulse causes Q7 to conduct (collector goes positive). This transfers a positive trigger pulse to the junction of R12 and R17 via C8. This triggers the second one shot which begins timing. Q (C) conducts placing ground on Q9's base cutting it off. Approximately 5.5 MS later this one shot returns to its quiescent state with Q6 go-





ing negative. This places a negative voltage on Q9's base and it conducts. It will remain in conduction until the second one shot is triggered again when the next #1 pulse arrives. It arrives approximately 1 MS later triggering the second one shot which causes Q9 to cut off. So we have a positive pulse at the collector of Q9 whose width is determined by the interval between #1 incoming pulses and is controllable at the transmitter. Q10 is an emitter follower with its base voltage regulated at 5.6V by Z1. R24 sets the operating point of the Zener and C12 filters voltage excursions. The voltage at Q10's emitter will be this Zener voltage less the base to emitter drop of Q10. It should be approximately 4.8 – 5.1 volts depending on the tolerance of the two devices. C11 is merely a by-pass capacitor.

I recommend that you re-read the theory as many times as necessary for a complete understanding. It may help you analyze symptoms leading to malfunctions if you have to troubleshoot the circuit later on.

PREPARING THE P.C. BOARD AND CASE

( ) File slots in end of case as shown in the drawing. If you want to operate an aileron servo in parallel with the rudder servo, file one slot ¼″ deeper as shown by the dotted lines. This will allow for the additional servo leads.

( ) Square and size the board with a fine file. File out the two notches as shown on drawing.

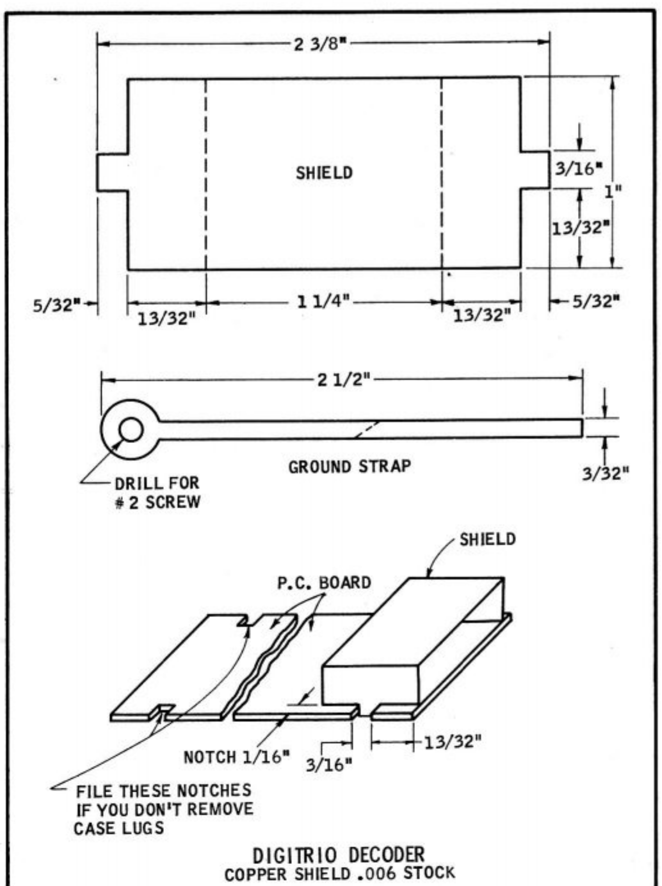
( ) Bend three of the case lugs down flush with rest of case and remove the lug shown on case drawing. If you wish you can use the other three lugs for better case rigidity by filing four notches in P.C. board.

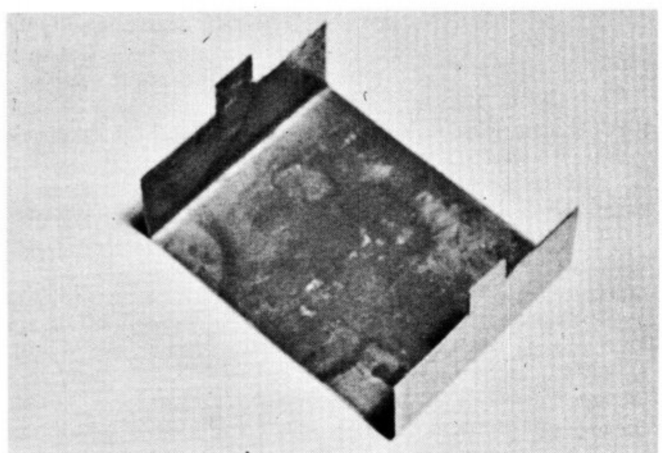
( ) Center the insulating sheet and P.C. board, copper side down, in the case with the five large round lands at the end where you made the slots. Drill the mounting hole slightly undersize so the mounting screw can tap itself into the board.

( ) Remove the P.C. board and insulating sheet and enlarge the mounting hole in the case to match the diameter of the mounting screw.

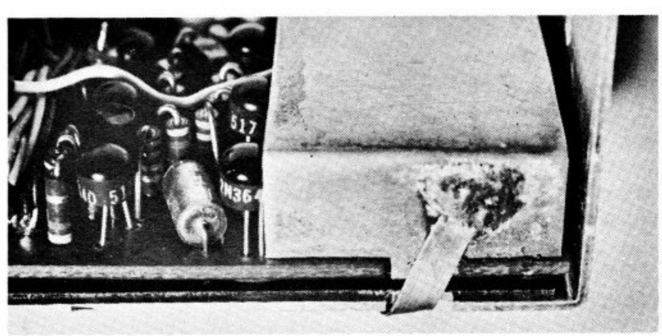
( ) Secure the insulating sheet with contact glue (do the same to receiver also).

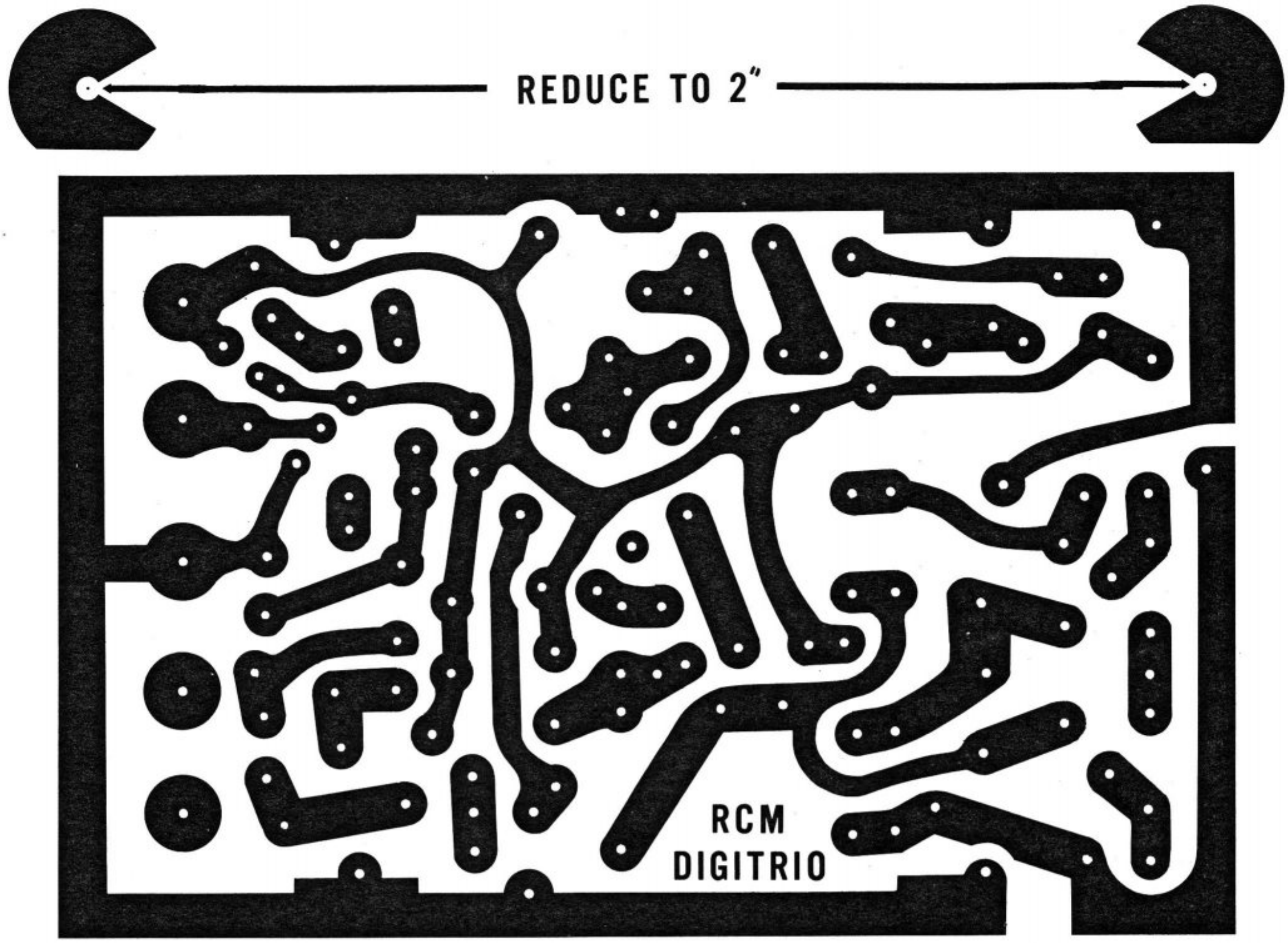
( ) Drill all holes in the P.C. board





Top photo shows completed decoder shield. Photo below shows shield and ground strap in place.





Decoder PC board shown three times full size. Actual size PC board shown at left. Either can be used for photographically reproducing the circuit board.

with a 1/32" drill except the very small lands which should be drilled a little smaller. If you don't have a smaller drill be careful or you'll tear the lands off the board.

( ) Enlarge the holes in the five large round lands at one end of the P.C. board to 1/16".

( ) Place a 6" square piece of emery cloth on a flat surface and "sand" the copper side to remove all burrs.

( ) Clean the copper side with scouring powder until it is bright and shiny.

NOTE: If board was purchased from World Engines it will be silver plated and the last two steps will not be necessary.

( ) Make the copper shield and ground lead as shown on the drawing and check for fit. Do not install this shield yet.

WIRING P.C. BOARD

( ) Install all resistors close to board.

( ) Install diodes including Z1 observing polarity. The bar should be up on all diodes.

( ) Install all disc caps.

( ) Install tantalums (two each — .22 negative up and .1 positive up) observing polarity.

( ) Install 15MFD cap observing polarity.

( ) Install transistors (make sure mounting screw will clear collector lead on Q8). Mount Q1, 2, 3, 4, 7 and 8 slightly higher than adjacent resistor leads to provide platform for copper shield to rest on.

( ) Install the copper shield as shown in drawing and check for clearance. A piece of electrical tape on the underside of shield will insure against unintentional grounding of components.

( ) "Flat" the lands to 1/32"-3/64" with a fine file, bevel the edges and clean board with acetone or dope thinner.

( ) Cut four 9" pieces of orange, yellow and green hook up wire. Cut five 9" pieces of black. Cut four 9" pieces of red. Cut three 12" pieces blue. Cut one 9" piece of white.

( ) For the three sets of servo leads take one each yellow, orange, green, red, black and blue and group them (route all blue and white wires as shown in photo). For battery leads take one each red, black, yellow, orange and group them. Group the above leads so that two sets come out of each side of the board.

NOTE: For coupled aileron rudder take an extra 9" red, blue, yellow, orange, green and black and insert them as shown by dotted lines on the construction overlay and make an extra servo group.

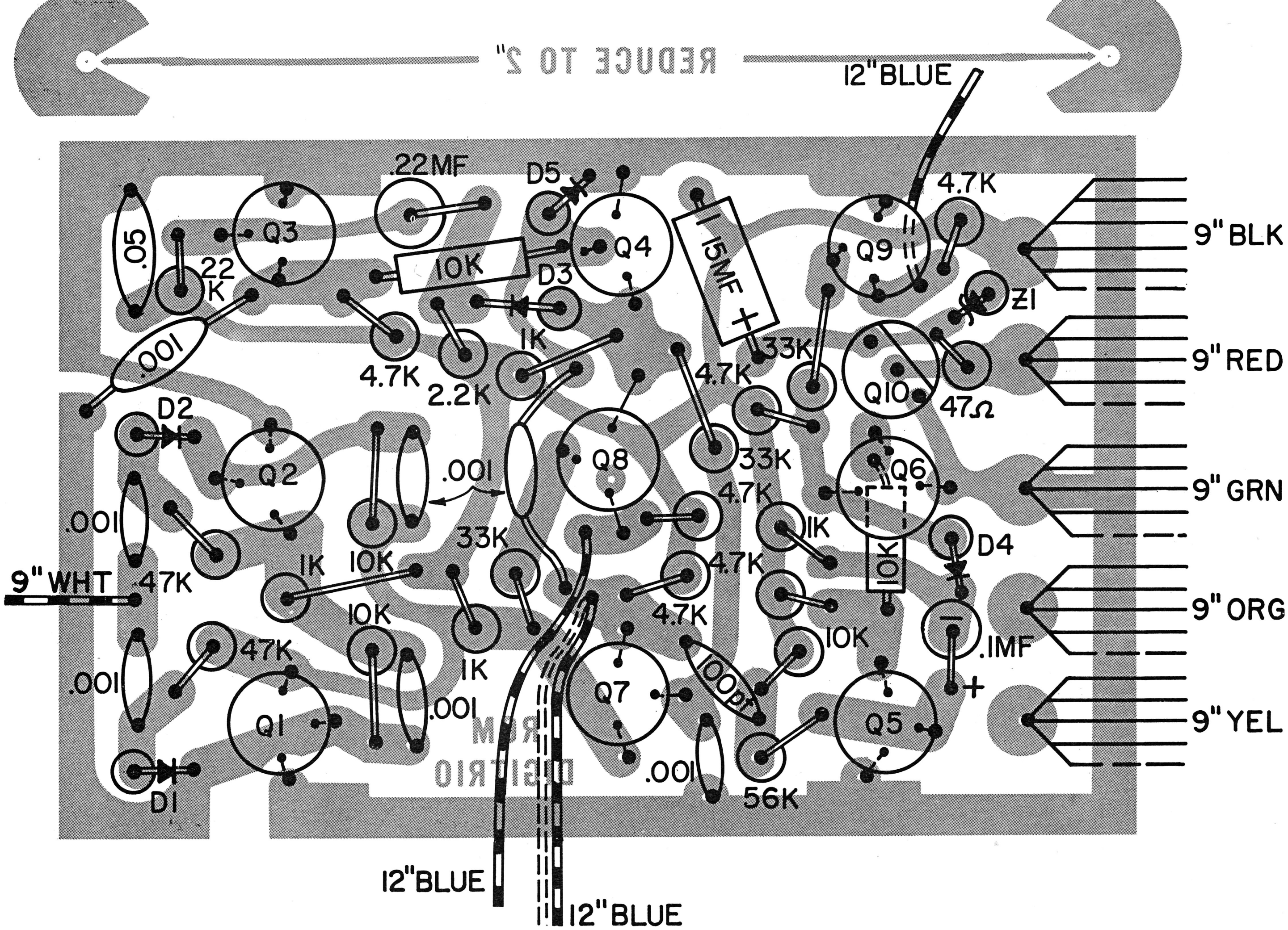
( ) Take the remaining black, green, and white wire and group them for the receiver.

( ) Place a 3/16" long piece of large Controlaire heat-shrink tubing over each set of wire as close to the board as possible.

( ) Slip a 1/4" grommet over each set of wires.

( ) Mount the decoder in the case and form the three servo and battery wires so that the grommets slide into the slots.

( ) Twist and cut the servo leads to the length desired and solder servo



connectors as shown in the drawing. Use a 1″ piece of large heat-shrink tubing to hold each group of wires at the ends and small heat-shrink tubing over each pin.

( ) Wire the switch to the battery leads using heat-shrink tubing as on the servo leads. Wire the charging jack at this time also.

( ) Cut a piece of red, orange, yellow, black wire to length desired for leads between switch and battery connector. Using heat-shrink tubing as usual, solder one end of these leads to the switch and the other to the male battery connector as shown in the drawing. Don't forget to put the connector shell over the leads first. You can wire the plug to match your reed battery pack if you match the plugs and voltages correctly.

( ) Wire five each 600 MA batteries as shown on schematic and drawing and solder female battery connector to the leads.

NOTE: The copper shield is necessary to prevent interference from the decoder which would otherwise be picked up by the mixer. The ground strap insures a good connection between the shield and case and must be used.

Substitution of parts or part values here could be hazardous unless you fully understand the circuit and can test it properly.

As you can see no adjustments (variable resistors, etc.) are used and all timing adjustments will be made at the transmitter which I'll cover in the last article.

CONNECTING RECEIVER AND DECODER

( ) Insert the decoder board into its half of the case and position the servo leads in the slots.

( ) Using the ground strap under the mounting screw secure the board in place. Run the ground strap to the notch in the case and bend it over. Solder the ground strap to the shield (see photo).

( ) Remove the black, green and white wires on the receiver board.

( ) Cut the black, green and white wires on the decoder board to 3″.

( ) Replace the black, green and white wires removed from the receiver with the wires from the decoder board.

( ) Mount the receiver board into its half of the case.

( ) Run the antenna lead through the hole provided in the decoder half of the case. Slip a 1″ piece of small heat-shrink tubing over the antenna lead to protect it.

( ) Slide the case together and check for fit.

PRELIMINARY CHECKOUT

( ) Measure the resistance between any red and black wire at one of the servo plugs (observe polarity red to red, black to black). You should read approximately 5,000 ohms.

( ) Reverse the meter leads and you should read approximately 1,000 ohms.

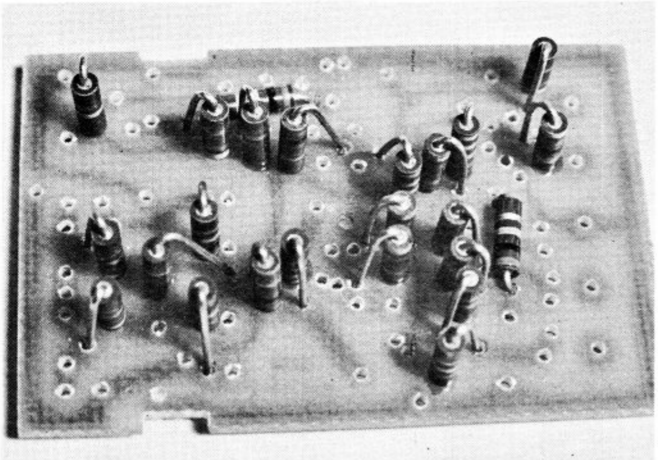
( ) Measure the resistance between any green and black wires at one of the servo plugs (red to green, black to black). You should read approximately 13,000 ohms.

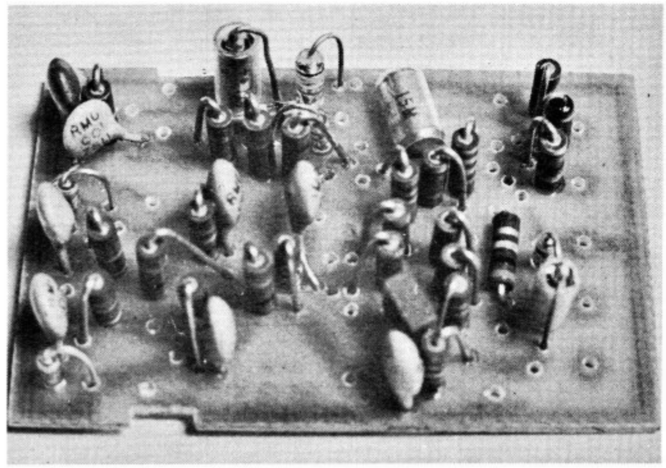
( ) Reverse the meter leads and the meter should read approximately 1,000 ohms higher.

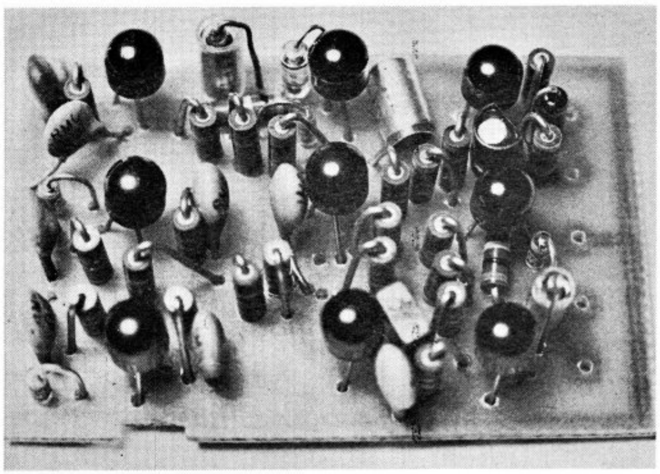
( ) Connect the battery and measure the voltage between any green and black wire (red to green, black to black). You should read approximately 5V with the switch turned on. If not turn the switch off immediately and check the polarity of Z1.

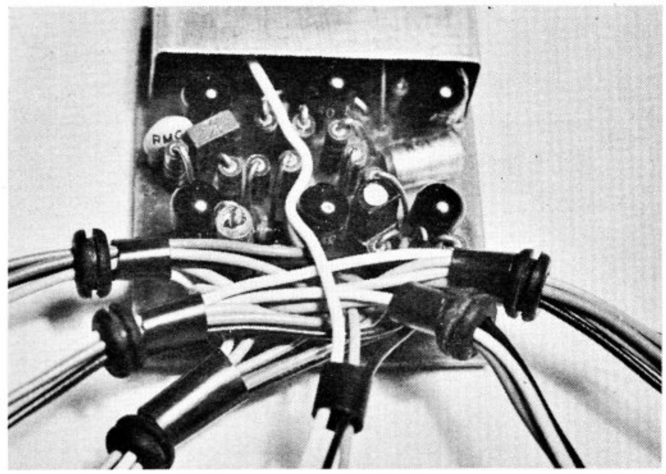
( ) With the transmitter and receiver-decoder operating you should hear a buzzing sound with a high impedance headset connected between the blue and green wires at each servo plug (use a .05 in series with one of the headset leads).

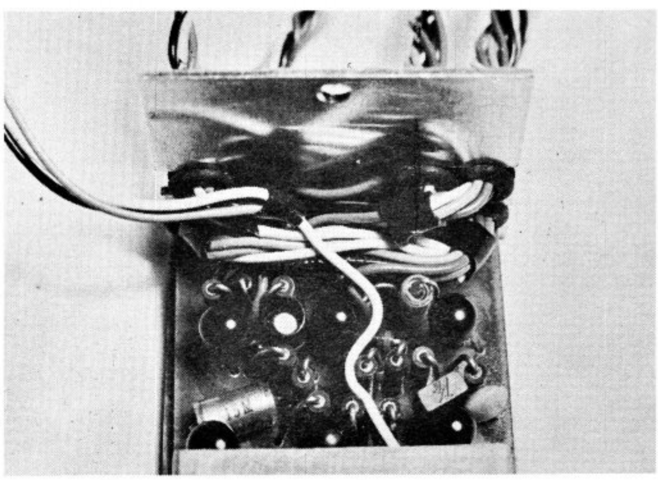
( ) If you have a scope or access to one you can check the decoder waveform as shown in the drawing.

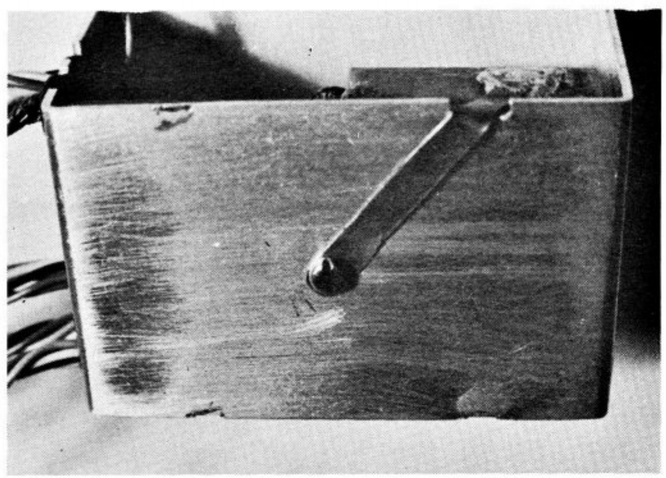


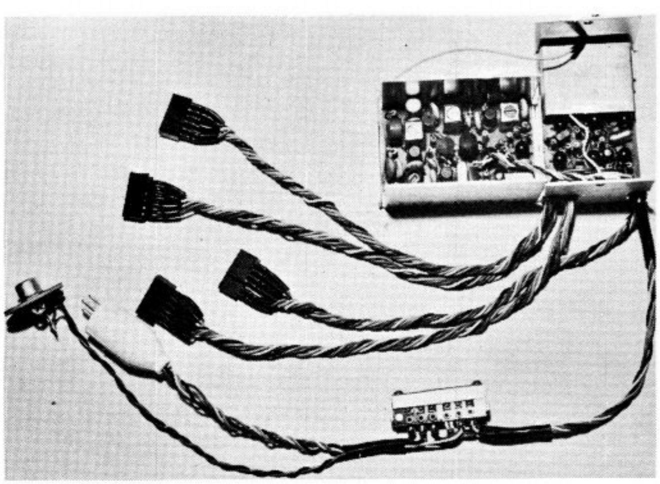




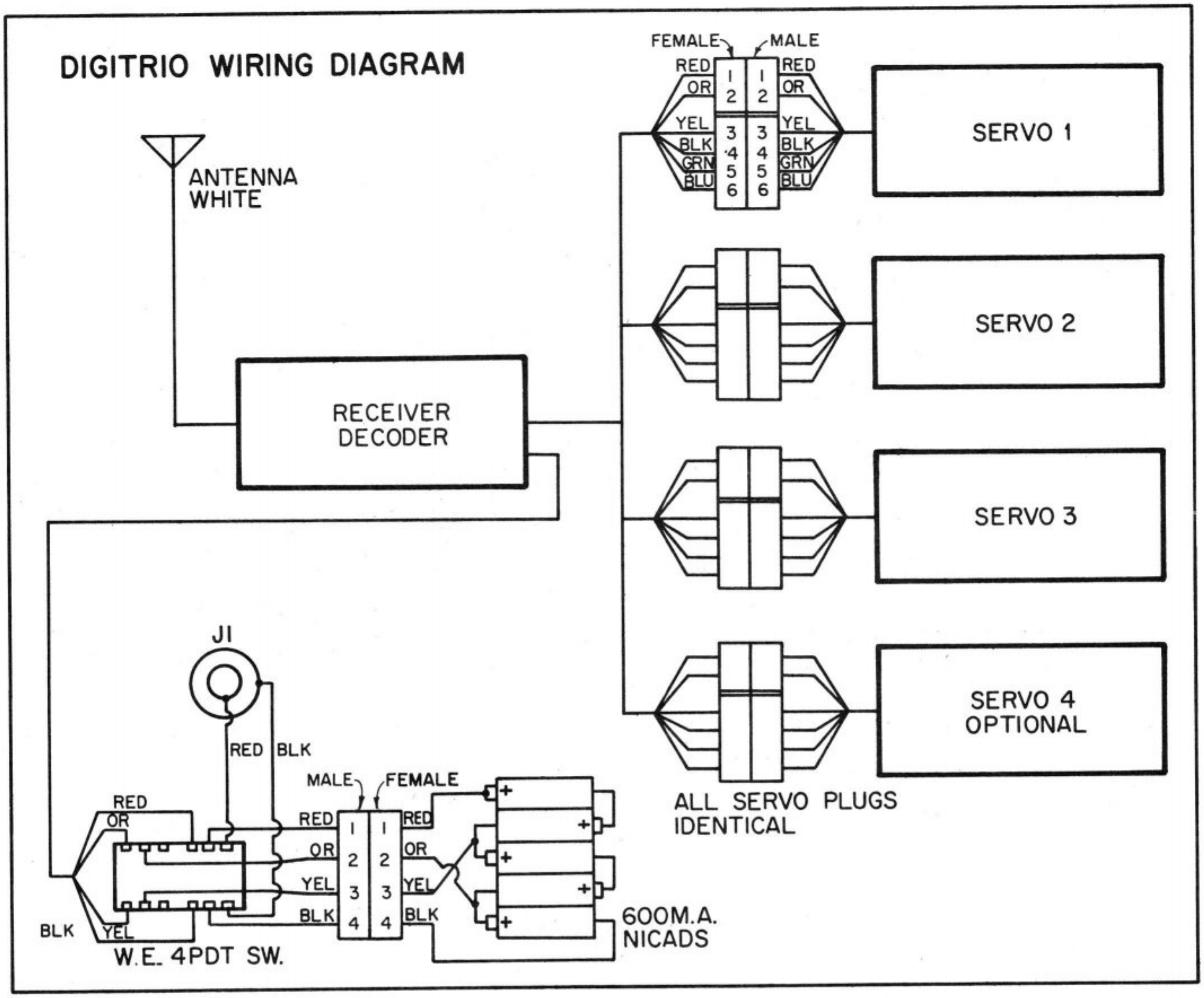


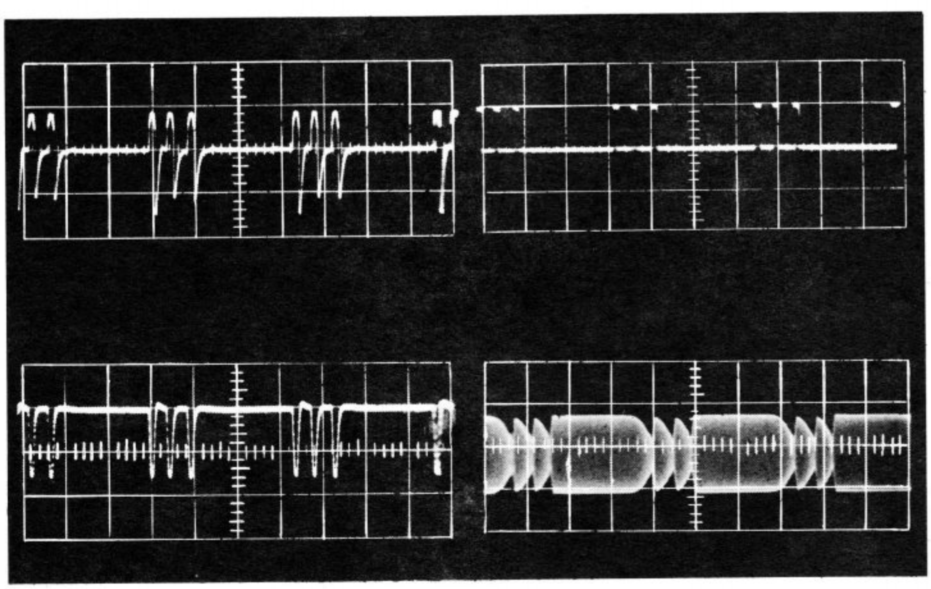




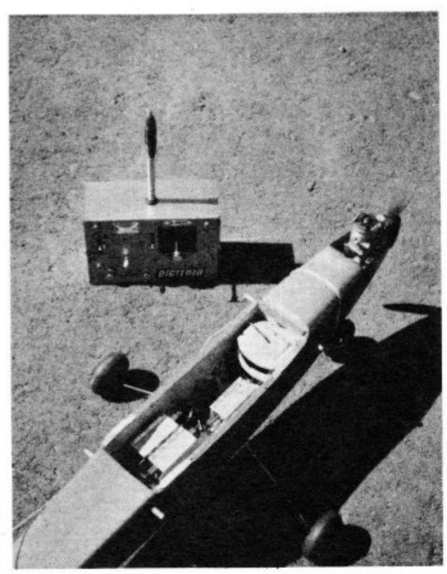


1st row, left: All resistors in place on decoder board. Note notches for shield. 1st row, right: Capacitors and diodes added. 2nd row, left: Adding the decoder transistors. 2nd row, right: Servo wiring with thermoshrink and case grommets installed. 3rd row, left: Decoder board mounted in LMB case. Heat lamp used on thermoshrink. 3rd row, right: Ground strap from decoder shield to case. Left: Completed receiver-decoder unit with all plugs, switches, and jack installed.





Dave Holmes supplied these scope traces from his 50Mc Digitrio receiver. Top, left: Collector Q7 (output) 5V/div 2ms/div. Top, right: Collector Q5 5V/div 2ms/div. Above, left: Diode load (R10) .2V/div 2ms/div. Above, right: Collector Q3 (3rd IF) 2V/div 2ms/div.



The Digitrio installed in an S.T. 23 powered CG Falcon 56. Trimmed 0-0 degrees, a good combination for the sport flier.

NOTE: Don't be concerned if waveform widths are not exactly as shown. They should be close however and we will adjust the transmitter later on to suit your particular system.

ERRATA

SEPTEMBER ISSUE

1. Figure 2—First waveform should be labeled 6.5 MS not 6.5 US.
2. Schematic—R5 should be labeled 330 ohms not 300 ohms.
3. C25 should be added to schematic in parallel with C23. It should be added to parts list as C25 .05 MFD Centralab Part #UK20-503.
4. The following will clear up questions about overlay components going to the wrong pots: Change pot lead labeling in upper left corner of construction overlay to read — R38, R35, R34 and R31 left to right.

NOVEMBER ISSUE

Change pot labeling in November issue on Digitrio stick assembly drawing so pot designations are reversed (i.e., R34 to R38 and R38 to R34).

Change text so that pot numbers (R38 and R34) and (R35 and R31) are reverse also on Page 35 of November issue under "Assembling Transmitter."

The above may sound like a lot of changes but they have no effect on construction or operation. They are merely pen and ink changes.

PARTS LIST FOR DECODER

REFERENCE NUMBER	DESCRIPTION	MANUFACTURER OR SOURCE	MANUFACTURERS NUMBER
C1	.001	RMC	SM .001
C2	.001	"	"
C3	.001	"	"
C4	.001	"	"
C5	.001	"	"
C6	.22 Tantalum	T.I.	SCM224FPO35D2
C7	.001	RMC	SM .001
C8	.0001 (100 PF)	"	SM 100
C9	.1 Tantalum	T.I.	SCM104FPO35D2
C10	.001	RMC	SM .001
C11	.05	"	ERIE Z5E
C12	15 MFD (Axial Leads)	W.E.	— — —
D1	Silicon Diode	"	DHD 806
D2	" "	"	"
D3	" "	"	"
D4	" "	"	"
D5	Germanium Diode	Ohmite	1N34 or Equivalent
Q1	2N3640	Fairchild	2N3640
Q2	"	"	"
Q3	"	"	"
Q4	"	"	"
Q5	"	"	"
Q6	"	"	"
Q7	"	"	"
Q8	"	"	"
Q9	"	"	"
Q10	2N2924	G.E.	2N2924
R1	47K ¼W	Ohmite	LIDSM
R2	47K "	"	"
R3	10K "	"	"
R4	10K "	"	"
R5	1K "	"	"
R6	1K "	"	"
R7	22K " 5%	"	LIDED
R8	4.7K "	"	LIDSM
R9	2.2 K "	"	"
R10	10K "	"	"
R11	1K "	"	"
R12	10K "	"	"
R13	4.7K "	"	"
R14	1K "	"	"
R15	10K "	"	"
R16	4.7K "	"	LIDSM
R17	56K " 5%	"	LIDED
R18	33K "	"	LIDSM
R19	33K "	"	"
R20	4.7K "	"	"
R21	4.7K "	"	"
R22	4.7K "	"	"
R23	33K "	"	"
R24	47 ohm ¼W	"	"
Z1	Zener Diode (5.6V)	T.I.	1N752

MISCELLANEOUS PARTS

#26 Hook-up Wire (2 Pkg.)	W.E. or Bonner	— — —
9" Large Heat-Shrink Tubing	W.E.	— — —
15" Small Heat-Shrink Tubing	W.E.	— — —
3 Female Servo Connectors	W.E.	— — —
1 Battery Connector	W.E.	— — —
P.C. Board	W.E.	— — —
Switch 4 PDT	W.E.	— — —
4 ¼" Rubber Grommets	W.E.	— — —
1 2⅛" x 1⅜" x ¹⁄₆₄" Piece of Insulation Sheet	W.E.	— — —
1 #2 x ¼" Self-Tapping Screw	W.E.	— — —
1 Piece Copper 2⅜" x 1½" x .006	W.E.	— — —

Above: Rusty Fried with Digitrio-Falcon combo at Phoenix "Arcs" flying site. Right: Two shots from our readers during construction of their RCM Digitrios.