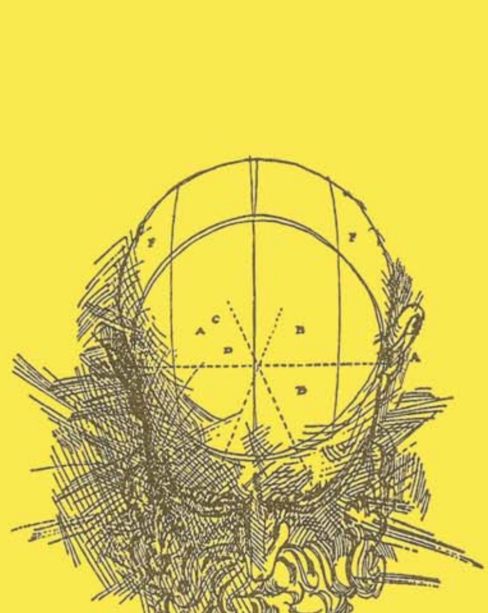
MARCRAFT

KNOWLEDGE TRANSFER PROJECT

SE-1030 R/C RACE CAR



Model SE-1030
Radio Controlled Race Car

KNOWLEDGE TRANSFER PROJECT
SE-1030 R/C RACE CAR

Advanced technology has provided us with an array of time saving, entertaining and useful products. However, these products require an increasing amount of technical information and skill to design, manufacture and service.

With all of its advances, technology will never be able to communicate for us. Therefore, the purpose of this project is to act as a catalyst to expand your understanding of basic transmitter, receiver and electronic switching theories. It also provides an exciting and realistic vehicle for exploring solid state circuits and developing important job related skills.

The SE-1030 project is divided into two construction SECTIONS. The first section involves stage-by-stage assembly and testing of the circuits that make up the project on a breadboard.

In the second section, these circuits are constructed and tested again on printed circuit boards. These construction sections incorporate a full range of circuit exploration exercises and job-skill experiences.

The Model SE-1030 Knowledge Transfer Project will help you to shorten the distance between simple information reception and actual understanding.

NOTE TO INSTRUCTORS: Pages 66 -67 contain detailed photographs of the wired breadboards and answers to the exploration tests of Section III. These pages may be removed at your discretion.

ONE YEAR LIMITED WARRANTY

MARCRAFT warrants that each product manufactured by it will be free from defects in material and workmanship under conditions of normal assembly and use for a period of one (1) year from the date of purchase from an authorized MARCRAFT distributor. MARCRAFT will, at its option, replace or repair any product or component not conforming with the foregoing warranty. MARCRAFT shall not otherwise be liable for any damages, consequential or otherwise. MARCRAFT makes no other express warranties. Any implied warranties (including any warranty of merchantability) are limited in duration to one (1) year from the date of purchase. This warranty does not apply to (1) damage resulting from unauthorized modifications, misuse, negligence or accident; (2) damage resulting from improper assembly, testing or adjustment otherwise that in accordance with MARCRAFT'S Knowledge Transfer Manual, or (3) damage resulting from the use of acid core solder or paste flux. MARCRAFT reserves the right to discontinue any model at any time, or change specifictions or design without notice and without incurring any obligation.

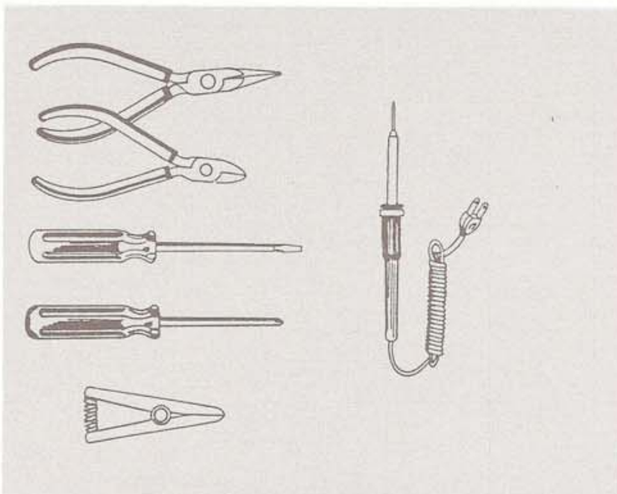
TABLE OF CONTENTS

SECTION I

TOOLS & EQUIPMENT REQUIREMENTS

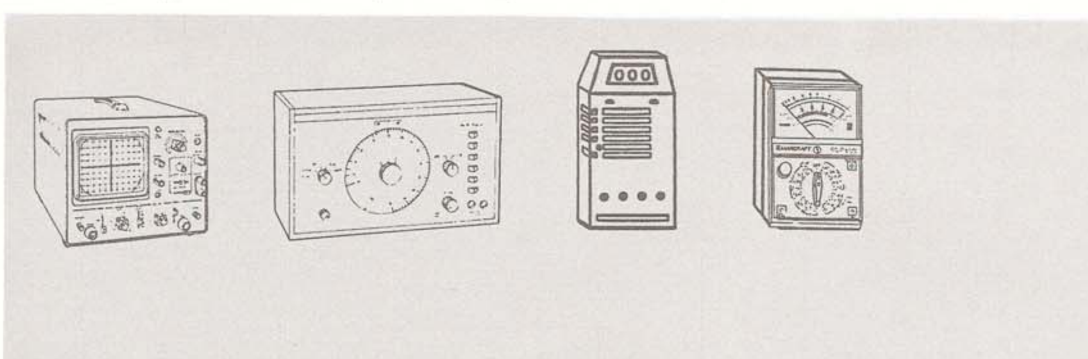
The following hand tools will be required to construct your project:

1. Long nose pliers, small
2. Diagonal cutters, small
3. Screwdriver, phillips head, size No. 1 (small)
4. Wire stripper
5. Soldering Iron, pencil type, 20-30 watt range, with small pointed tip
6. Heatsink (alligator clip may be used)



To perform the tests, measurements and alignments called for in this manual, the following test instruments and items are required. If any specified instrument is not available, you may omit the tests where that instrument is required.

1. AF sinewave/squarewave signal
2. Oscilloscope
3. Multimeter (VOM), dcV, dcA and Ohms functions
4. Batteries, 9-volt (006-P), 1 unit required
5. Batteries, 1.5 Volt "AA" size, 4 units required



KNOWLEDGE TRANSFER OBJECTIVES

RESISTOR/CAPACITOR CODES

Determine resistance values
Determine capacitance values
Determine tolerance values

SOLDERING SKILLS

Select a proper soldering iron
Correctly clean tips
Make proper solder connections
Perform proper component lead dress
Select proper solder

TEST EQUIPMENT SKILLS

Display proper use of the following instruments:
- AF signal generator
- Oscilloscope
- Multimeter

RECORD KEEPING

Inventory parts
Record meter reading in appropriate charts
Complete "Knowledge Transfer Guide"

BREADBOARDING SKILLS

Read and understand schematic diagrams and symbols
Mount components on breadboards
Perform standard electronic tests and measurements
Align RF circuitry

PRINTED CIRCUIT BOARD SKILLS

Practice proper handling of PC Boards
Assemble parts on PCBs
Practice soldering on printed circuit boards
Perform circuit tests and measurements on PCBs
Align RF circuits on printed circuit boards

CIRCUIT COMPREHENSION

Understand schematic diagrams and symbols
Use block diagrams to understand overall circuit operation

TRANSMITTER

IC Signal Encoder Stage

Encoding
IC Devices
IC Pin Numbering
Pulse Generation
Pulse-width Encoding

Modulator Stage

Pulse-width Modulation
Solid-state Switching
Modulation

RF Oscillator Stage

Crystals
Piezoelectric Effect
Crystal-Controlled Oscillators
RF Carrier Wave
Modulating Signal
Oscillation

Output Amplifier Stage

Class-C Operation
Pi Filter Network

RECEIVER

Detector Stage

Super-regenerative detectors
Demodulation
Sensitivity
AC Quench Voltage
Quench Frequency
Regeneration
Parallel-Resonant Circuits
Inductance
Impedance

AF Amplifier Stage

Voltage Amplifiers
Low-pass Filters
Class-A Operation
Decoupling Networks
Bypass Capacitors
Control Signals

IC Decoder/Demodulator Stage

Signal Decoding

Steering Actuator Amplifier/Controller Stage

DC Amplification
Differential Amplifiers
Magnetic Fields
Permanent Magnets
Electromagnets
Polarity (north and south)
Torque
Counter Electromotive Force (CEMF)
Magnetic Flux Lines

Drive Motor Amplifier/Controller Stage

Motor Drivers
Motor Switching
Motor Noise
DC Motors
Armatures
Commutators
Motor Brushes
Inertia

TROUBLESHOOTING

Use Service Flowcharts To Isolate Problems
Set Up & Use Test Instruments
Use Schematic Diagrams As Service Aids
Remove & Replace Defective Components

KNOWLEDGE TRANSFER GUIDE

The purpose of this Guide is to allow you to keep an accurate record of your progress in the construction and exploration of your project. To acheive optimum knowledge transfer or educational benefit from this project, be sure to assemble it in the sequence presented below. Do not proceed to successive LEARNING EXPERIENCES until the current one is finished and fully comprehended.

At the completion of each LEARNING EXPERIENCE, obtain your instructor's evaluation and initials. The FINAL EVALUATION is provided so that your instructor can indicate your degree of acheivement over the entire project.

YOUR NAME ______________________________

LEARNING EXPERIENCE	COMPLETION DATE	INSTRUCTOR	
		EVALUATION	INITIALS
SECTION I			
PARTS INVENTORY			
RESISTOR COLOR CODES			
SOLDERING INSTRUCTIONS			
SECTION II BREADBOARD			
Transmitter			
IC ENCODER STAGE			
Circuit Construction			
Circuit Exploration			
MODULATOR STAGE			
Circuit Construction			
Circuit Exploration			
RF OSCILLATOR STAGE			
Circuit Construction			
Circuit Exploration			
OUTPUT AMPLIFIER STAGE			
Circuit Construction			
Circuit Exploration			
Receiver			
DETECTOR STAGE			
Circuit Construction			
Circuit Exploration			
AF AMPLIFIER STAGE			
Circuit Construction			
Circuit Exploration			
IC DECODER/DEMODULATOR STAGE			
Circuit Construction			
Circuit Exploration			
STEERING ACTUATOR AMPLIFIER STAGE			
Circuit Construction			
Circuit Exploration			
DRIVE MOTOR AMPLIFIER STAGE			
Circuit Construction			
Circuit Exploration			

LEARNING EXPERIENCE	COMPLETION DATE	INSTRUCTOR EVALUATION	INSTRUCTOR INITIALS
SECTION III			
PC BOARD ASSEMBLY, TRANSMITTER IC ENCODER STAGE			
Circuit Construction			
Circuit Test			
MODULATOR STAGE			
Circuit Construction			
Circuit Test			
RF OSCILLATOR STAGE			
Circuit Construction			
Circuit Test			
OUTPUT AMPLIFIER STAGE			
Circuit Construction			
Circuit Test			
ADJUSTMENT PROCEDURE, TRANSMITTER HOUSING ASSEMBLY, TRANSMITTER PC BOARD ASSEMBLY, RECEIVER			
DETECTOR STAGE			
Circuit Construction			
Circuit Test			
AF AMPLIFIER STAGE			
Circuit Construction			
Circuit Test			
IC DECODER/DEMODULATOR STAGE			
Circuit Construction			
Circuit Test			
STEERING ACTUATOR AMPLIFIER STAGE			
Circuit Construction			
Circuit Test			
DRIVE MOTOR AMPLIFIER STAGE			
Circuit Construction			
Circuit Test			
AJUSTMENT PROCEDURE, RECEIVER HOUSING ASSEMBLY, RECEIVER			
SECTION IV			
KNOWLEDGE TRANSFER REVIEW FINAL EVALUATION			

PARTS INVENTORY

Carefully unpack your project and check (✓) each item against the PARTS LIST below. Do not remove the components from the white cards until needed for Circuit Construction (these components are mounted on the cards according to their values). To assist you in the proper identification of the major parts, refer to the illustrations in the PARTS IDENTIFICATION section on the next page. Please note that the hardware sizes are specified in metric quantities (mm).

In the event of a missing, damaged or incorrect part, refer to the REPLACEMENT PARTS section on page 65 for ordering instructions.

Upon completion of the Parts Inventory, have your instructor initial your Knowledge Transfer Guide.

PARTS LIST

✓	SYMBOL	DESCRIPTION	PART#	QTY
	R1,22,23	Resistor, 1/4W, 5%, 270Ω	91724	3
	R2,3	Resistor, 1/4W, 5%, 5.6KΩ	91241	2
	R4	Resistor, 1/4W, 5%, 2.7KΩ	91050	1
	R5	Resistor, 1/4W, 5%, 1KΩ	91052	1
	R6	Resistor, 1/4W, 5%, 330KΩ	91502	1
	R7,9,12,25	Resistor, 1/4W, 5%, 10KΩ	91045	4
	R8	Resistor, 1/4W, 5%, 680KΩ	91150	1
	R10,16,17, 18,28,30,31	Resistor, 1/4W, 5%, 100Ω	91044	7
	R11	Resistor, 1/4W, 5%, 3.3KΩ	91038	1
	R13	Resistor, 1/4W, 5%, 470KΩ	91144	1
	R14,15,19	Resistor, 1/4W, 5%, 1.8KΩ	91300	3
	R20,21	Resistor, 1/4W, 5%, 680Ω	91153	2
	R24	Resistor, 1/4W, 5%, 1M0Ω	91039	1
	R26	Resistor, 1/4W, 5%, 4.7KΩ	91049	1
	R27	Resistor, 1/4W, 5%, 120KΩ	91302	1
	R29	Resistor, 1/4W, 5%, 22KΩ	91305	1
	C1	Capacitor, disc, 10pf	91725	1
	C2	Capacitor, disc, 25pf	91726	1
	C3,20,21 22,24	Capacitor, disc, 47pf	91315	5
	C23	Capacitor, disc, 0.01μf	91059	1
	C4	Capacitor, mylar, 0.0047μf	91727	1
	C5,25	Capacitor, disc, 150pf	91728	2
	C6	Capacitor, mylar, 0.01μf	91522	2
	C7,9,10	Capacitor, disc, 0.005μf	91061	3
	C8,11	Capacitor, electrolytic, 2.2μf	91729	2
	C12	Capacitor, electrolytic, 100μf	91158	1
	C13	Capacitor, disc, 0.001μf	91310	1
	C14	Capacitor, electrolytic, 1μf	91311	1
	C15	Capacitor, electrolytic, 10μf	91524	1
	C16	Capacitor, electrolytic, 220μf	91066	1
	C17 SEE NOTE(2)	Capacitor, disc, 0.047μ(2)	91248	1
	C18,19	Capacitor, disc, 0.02μf	91058	2
	C26	Capacitor, disc, 39pf	91730	1
	Q1	Transistor, 2SC3192-O, NPN	91731	1
	Q2,16,17,18	Transistor, 2SC945-P, NPN	91732	4
	Q3	Transistor, K596C811, N-TYPE	91733	1
	Q4,5,11	Transistor, 2SA733-P, PNP	91734	3
	Q6,9	Transistor, 2SB562-C, PNP	91735	2
	Q7,8,10	Transistor, 2SD468-C, NPN	91736	3
	Q12,13	Transistor, H8550-C, PNP	91737	2
	Q14,15	Transistor, H8050-C, NPN	91738	2
	U1	Receiver IC, FRC-02R	91739	1
	U2	Transmitter IC, FRC-01T	91740	1
	XU1,2,3,4	IC Socket, 16-pin	91741	4
	L1,5	Coil-Variable, 11.5 T, 1.3765μh	91743	2

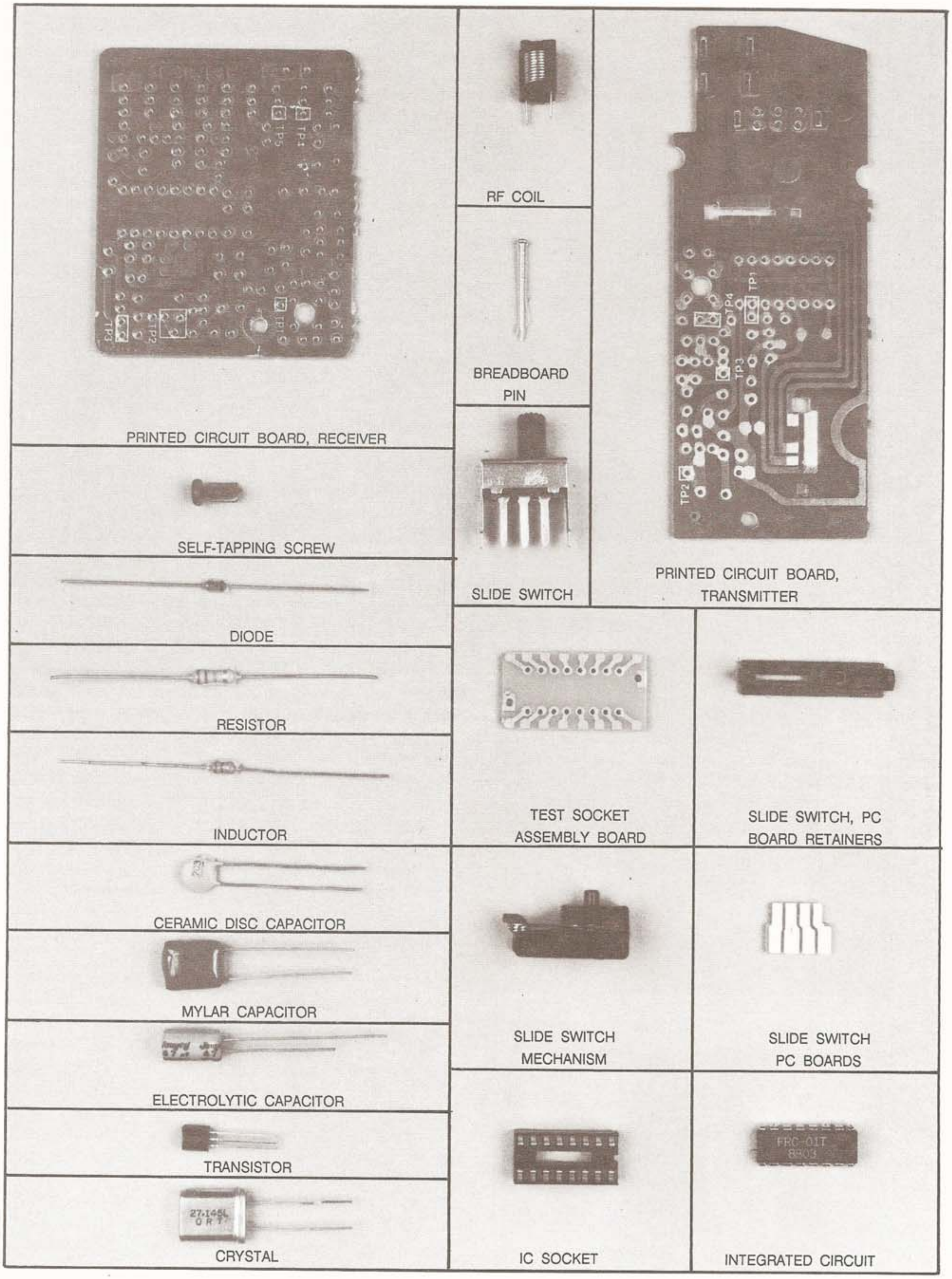
✓	SYMBOL	DESCRIPTION	PART#	QTY
	L2	Inductor, 3.3μh	91744	1
	L3,4	Inductor, 2.2μh	91745	2
	Y1	Crystal, Quartz 27.145MHz	91330	1
	Z1	Zener Diode, BZX790 2V4	91746	1
	S1	Slide Switch, ON/OFF	91753	1
	E1	Antenna, Receiver (Whip)	91756	1
	E101	Antenna, Transmitter(Telescope)	91757	1
	P1	Clip, battery, 5V	91335	1
	H1 SEE NOTE(3)	Screw, Self-tapping(3.0Ox8MM)(3)	91015	11
	H2	Washer, Lock spring, 3.2Omm	91017	1
	W1	Hookup wire, Insulated	91095	1
	W2	Hookup wire, Bare	91096	1
	W4	Solder, Rosin-Core 60/40	91097	1
	A1 SEE NOTE(2)	Car Chassis Assembly (2)	91758	1
	A2	Car Body	91759	1
	A3 SEE NOTE(2)	Transmitter Housing (2 pieces)	91760	1
	A4	PC Board Cover, Receiver	91761	1
	A5	Trigger Mechanism	91762	1
	A6	Battery Cover, Transmitter	91763	1
	A7	ON/OFF Indicator, Transmitter	91748	1
	A8	Air Scoop	91747	1
	A9 SEE NOTE(1)	Tires, Front, Narrow	91754	2
	A10 SEE NOTE(1)	Tires, Rear, Wide	91755	2
	B1 SEE NOTE(1)	Drive Motor Assembly (1)	91770	1
	B2 SEE NOTE(1)	Steering Actuator Assembly (1)	91771	1
	MP1	Antenna Holder, Transmitter	91749	1
	MP2	Slide-Switch PC Boards	91750	2
	MP3	Slide-Switch Mechanisms	91751	2
	MP4	Slide-Switch PC-BoardRetainers	91752	2
	MP5	Printed Circuit Board, Receiver	91764	1
	MP6	Printed Circuit Board, Trans	91765	1
	MP7	Decal Set	91766	1
	MP9	Breadboard pin	91021	133
	MP10	Test Socket Assembly Board	91742	2
	MP11	Breadboard Base, Receiver	91358	1
	MP12	Breadboard Base, Transmitter	91359	1
	MP13	Schematic Diagram (Receiver)	91767	1
	MP14	Schematic Diagram (Transmitter)	91768	1
	MP15	Replacement Parts Order Form	91033	1
	MP16	Knowledge Transfer Guide	91769	1

(1) Factory mounted to car chassis

(2) Preassembled

(3) NOTE: One screw has been used by the factory to hold the two halves of the pistol-grip controller together during shipping.

PARTS IDENTIFICATION



PRINTED CIRCUIT BOARD, RECEIVER

RF COIL

BREADBOARD PIN

SLIDE SWITCH

PRINTED CIRCUIT BOARD, TRANSMITTER

SELF-TAPPING SCREW

DIODE

RESISTOR

INDUCTOR

TEST SOCKET ASSEMBLY BOARD

SLIDE SWITCH, PC BOARD RETAINERS

CERAMIC DISC CAPACITOR

MYLAR CAPACITOR

ELECTROLYTIC CAPACITOR

SLIDE SWITCH MECHANISM

SLIDE SWITCH PC BOARDS

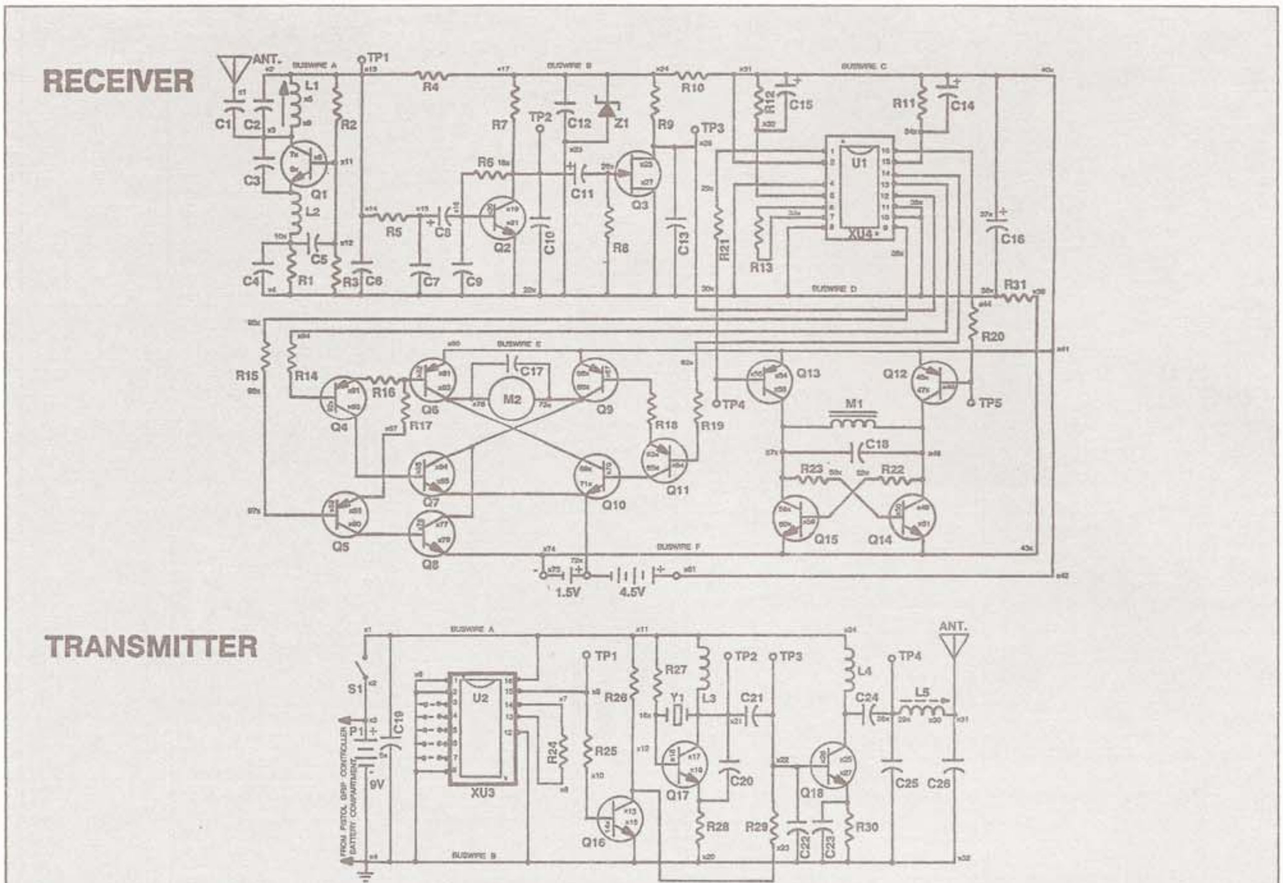
TRANSISTOR

CRYSTAL

IC SOCKET

INTEGRATED CIRCUIT

SCHEMATIC DIAGRAMS



MODEL SE-1030 R/C RACE CAR

RESISTOR/CAPACITOR CODES

- First color (color band nearest the end of the resistor) represents the first figure in the resistor value.
- Second color represents the second figure in the resistor value.
- Third color represents the multiplier of the first two figures.
- Fourth color represents the resistor tolerance.

BAND COLOR	1st COLOR FIRST FIGURE	2nd COLOR SECOND FIGURE	3rd COLOR MULTIPLIER	4th COLOR TOLERANCE
NO COLOR	—	—	—	20%
SILVER	—	—	—	10%
GOLD	—	—	—	5%
BLACK	0	0	1	
BROWN	1	1	10	
RED	2	2	100	
ORANGE	3	3	1,000	
YELLOW	4	4	10,000	
GREEN	5	5	100,000	
BLUE	6	6	1,000,000	
VIOLET	7	7	—	
GRAY	8	8	—	
WHITE	9	9	—	

EXAMPLES

Yellow 4	Violet 7	Brown 0	Gold 5%	= 470 ohms 5%
Red 2	Red 2	Orange 000	Gold 5%	= 22000 ohms (22KΩ) 5%

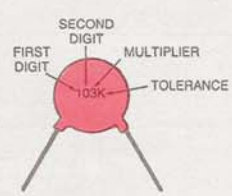
MULTIPLIER		TOLERANCE OF CAPACITOR		
FOR THE NUMBER:	MULTIPLY BY:	10 pF OR LESS	LETTER	OVER 10 pF
0	1	±0.1 pF	B	
1	10	±0.25 pF	C	
2	100	±0.5 pF	D	
3	1000	±1.0 pF	F	±1%
4	10,000	±2.0 pF	G	±2%
5	100,000		H	±3%
			J	±5%
8	0.01		K	±10%
9	0.1		M	±20%

Note: All values referenced to picofarads (10^{-12}).

EXAMPLES

103K = 1- 0 - 000 pf = 0.01 µf

472L = 4 - 7 - 00 pf = 0.0047 µf



SOLDERING INSTRUCTIONS

In order for your project to function properly, it is imperative that you make good solder connections. If you have not had previous soldering experience, it is strongly recommended that prior to starting the construction of this project, you practice soldering pieces of wire and used components together following the rules given below.

1. SOLDERING IRON - Use a pencil-style iron in the 20-30 watt range. The iron should have a thin pointed tip designed for working on printed circuit boards. Do not use a higher-wattage soldering gun.

2. SOLDER - Use only rosin-core solder similar to that supplied with the project. If additional solder is required, use only 60-40 rosin core type, such as Kester 44. NEVER use acid-core solder or paste fluxes.

3. TIN THE TIP - Be sure the tip of the iron is well tinned (coated with a thin layer of solder) so that it will conduct heat properly.

4. KEEP THE TIP CLEAN - To keep the tip clean and free of excess solder and oxidation, wipe it from time-to-time on a damp sponge or cloth (See Fig. 1).

5. LEAD DRESS - Component lead dress and placement is very important. All wiring and parts placement should be made as neatly as possible before soldering in place (See Fig. 2 and 3 for component placement).

6. PREHEAT THE WORK - Position the tip of the iron firmly against the component lead and pc board's solder pad (or breadboard pin) to preheat the connection.

7. APPLY THE SOLDER - While the connection is being heated, apply solder to the heated area. DO NOT apply solder directly to the tip of the iron. Take care to prevent solder from flowing or bridging to adjacent foil traces and pads. When enough solder has been melted to form a thin coating between the component lead and the solder pad on the pc board, stop feeding solder to the connection (See Fig. 5).

8. USE SUFFICIENT HEAT - The key to good soldering is to use sufficient heat and a small amount of patience. Continue to apply heat to the connection for a short time after you've stopped applying solder to the joint. Allow the solder to spread freely over the entire copper pad and form around the component lead. DO NOT paint the solder on the connection with the soldering iron's tip. If the solder forms into a round ball of rough, flaky solder, you are not applying enough heat to the connection (See Fig. 6).

9. REMOVE THE IRON FROM THE CONNECTION - Once you've formed a good concave solder connection with a bright finish (See Fig. 7), remove the iron from the connection in a smooth motion. DO NOT allow the component lead to move until the solder has cooled to a solid condition.

When you fully understand the rules of good soldering, and you have practiced soldering, have your instructor initial your Knowledge Transfer Guide.

FIG. 1 CLEAN TIP

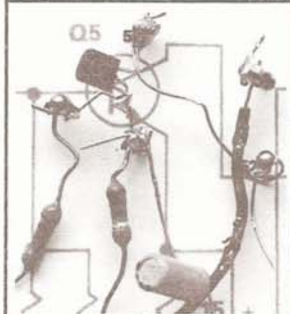


FIG. 2 INCORRECT

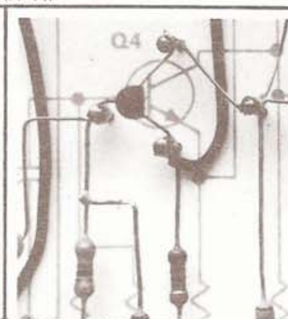


FIG. 3 CORRECT

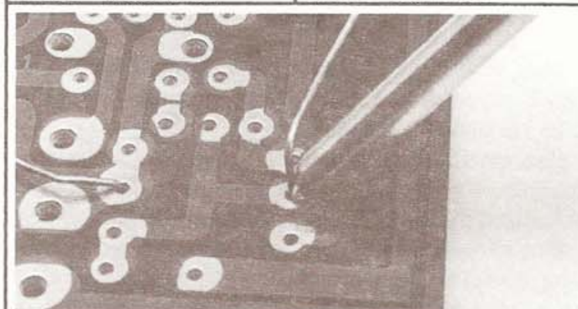


FIG. 4 PREHEAT

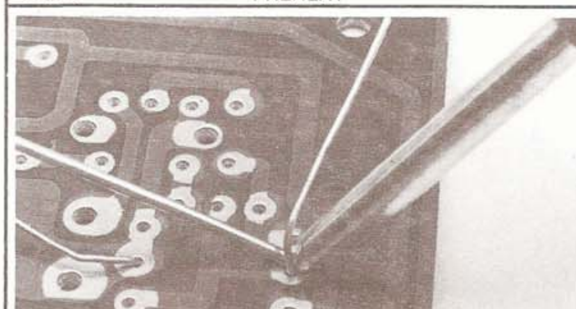


FIG. 5 APPLY SOLDER

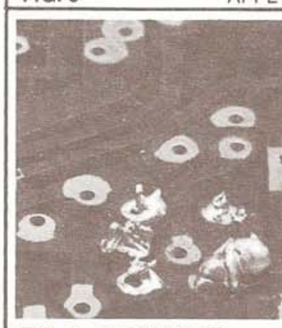


FIG. 6 INCORRECT

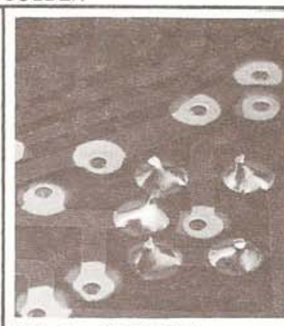
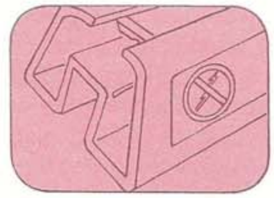


FIG. 7 CORRECT

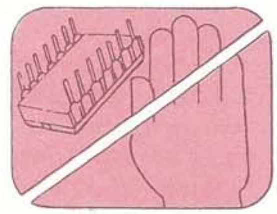
IC HANDLING INSTRUCTIONS

WARNING: Follow these instructions and understand them thoroughly before unpacking the ICs from your project, in order to avoid possible damage to them.

The ICs used in your project may be static-sensitive devices that can be destroyed by electrostatic discharges during handling or insertion. In order to minimize the chances of this happening, follow these instructions.



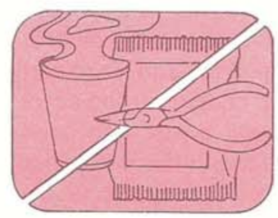
1. Do not unpack ICs until instructed to do so. Keep them in their protective container until the instructions request you to remove the individual IC. Remove only the IC requested.



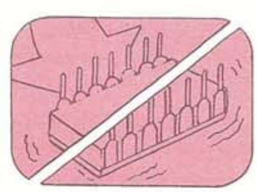
2. Do not touch the IC's pins. At no time should the pins of the IC ever be touched. Hold the IC by the ends of its package.

3. Minimize handling of the IC. Handle the ICs as little as possible.

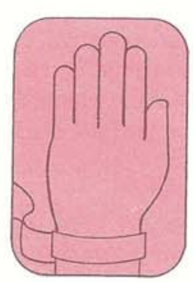
4. Keep foreign objects away from the ICs. Avoid allowing tools, metal objects, plastic bags, styrofoam, and other foreign objects from coming into contact with the pins of the IC.



5. Do not slide the ICs over any surfaces. This action will generate static buildup.



6. Discharge built up body static prior to handling an IC. Connect a grounding strap around your wrist prior to handling or inserting an IC.



7. Use an IC insertion tool if there is one available. This will be your best protection. Follow the manufacturer's instructions for usage of the tool.

8. Use care once the IC has been inserted. Avoid allowing tools and other objects to touch the foil side of the printed circuit (PC) board.

9. Use extreme caution when soldering on or around circuits containing IC or other semiconductor devices. These devices are extremely sensitive to excessive temperature conditions.

Be sure you thoroughly understand these rules before continuing with your project.

SECTION II

BREADBOARD ASSEMBLY

In this section you will construct experimental circuits on breadboards. This is a common practice used by design engineers in industry. A breadboard circuit is one where the components are layed out and wired in such a manner that they physically follow the schematic diagram. The components can be added or removed easily during exploratory work. Unlike the printed circuit board, the breadboard provides good accessibility to the circuitry when performing tests and taking measurements.

DISCUSSION

The SE-1030 is a radio-controlled car project consisting of a receiver mounted in a scale-model frame buggy body and a transmitter, which controls both the car's operation and direction of travel. The car is powered by a dc motor that drives the rear wheels. The steering is controlled by a differential amplifier arangement that drives a small magnetic actuator mounted over the front axle.

When the transmitter is activated, it begins transmitting a continuous string (or train) of control pulses to the receiver. Information about the conditions of the various switches on the hand-held controller is encoded in the pulse train. Each switch has a particular pulse in the train which corresponds to its condition. When the controller is activated, a particular pulse in the pulse train is changed (shortened). This change is sensed by the receiver which turns on the car's drive motor. This causes the car to move in a forward direction. Whenever the transmitter is deactivated, the pulse's width is restored and the car will stop moving forward.

Rotating the transmitter's steering wheel activates a different switch, which in turn changes the width of a different pulse in its output signal train. Since the particular pulse that is varied is directly related to which switch is activated, the receiver will sense the difference and convert the signal into a directional steering signal. The steering signal is applied to the steering actuator, causing the front wheels to turn in the direction originally indicated by the motion of the transmitter's steering wheel. The car will then turn in the indicated direction just like a real car.

Refer to the block digram of the transmitter in Fig. 8. The transmitter produces a continuous string of control signal packets modulated on an RF carrier frequency of 27 MHz. An IC (Integrated Circuit) modulator generates an output pulse string that corresponds to the combination of switch closures present at its inputs. This signal is applied to a transistor switching circuit and modulated (mixed with) on a 27 MHz RF carrier signal from a crystal controlled variation of a Colpitts oscillator. A quartz crystal determines the precise 27 MHz RF carrier frequency. The modulated signal train is applied to a Class-C transistor amplifier and pi-filter network which, in turn, amplifies it and applies it to the antenna for transmission. The entire transmitter is powered by a single 9-volt battery.

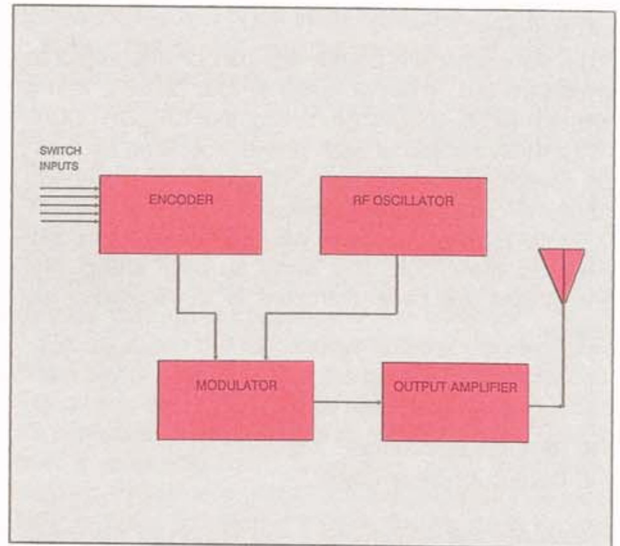


FIG. 8

In the car's chassis, there is a corresponding RF receiver unit that accepts and detects the transmitted signal, demodulates (decodes) it, and applies it to the various motors that operate the car. Refer to Fig. 9. The receiver's detector stage is tuned to accept the 27 MHz signal from the transmitter while rejecting all other signals. The encoded pulse train signal information is also removed from the carrier signal (demodulated) and applied to the AF (audio frequency) amplifier stage from this stage.

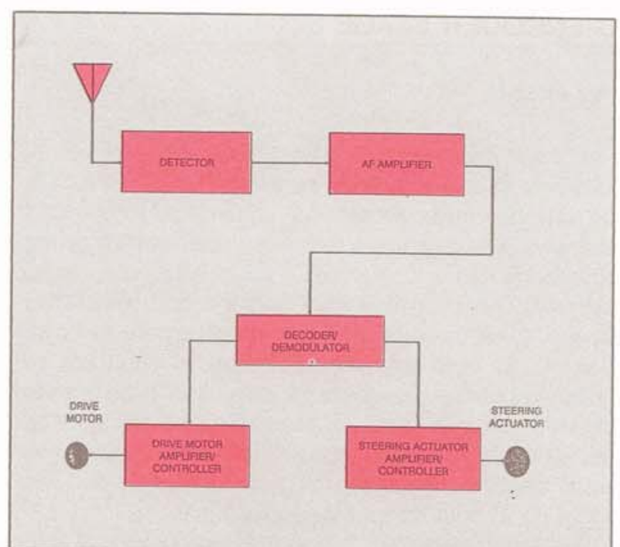


FIG. 9

The demodulated pulse train is applied to a special IC decoder which converts the train into individual control signals for the drive motor and steering actuator. Both devices are bi-directional, meaning that they will rotate in two directions. The devices' direction of rotation determines the direction the car will run and turn. The receiver's power supply consists of four 1.5-volt (AA) batteries.

The transmitter will be the first part of the project to be constructed. This will occur in four phases, with a CIRCUIT DISCUSSION preceding the CIRCUIT CONSTRUCTION section of each phase. Following each circuit construction section, you will be asked to perform various circuit tests and measurements in a CIRCUIT EXPLORATION section. This will allow you to thoroughly explore the circuits that make up each phase. The four phases will be constructed in the following sequence:

1. IC Encoder Stage
2. Modulator Stage
3. RF Oscillator Stage
4. Output Amplifier Stage

Following the construction and testing of the transmitter, the receiver will be constructed. This will occur in 5 phases as listed below:

1. Detector Stage
2. AF Amplifier Stage
3. IC Decoder/Demodulator Stage
4. Steering Actuator Amplifier/Controller Stage
5. Drive Motor Amplifier/Controller Stage

TRANSMITTER

IC ENCODER STAGE

Discussion

In your transmitter, a small, self-contained set of electronic circuits known as an INTEGRATED CIRCUITs (or ICs) performs the task of continuously collecting controller switch setting information and converting that information into a form suitable for transmission. An IC is simply a collection of semiconductor circuits assembled on one, small piece of semiconductor (silicon) material. A single IC may hold the equivalent of hundreds or thousands of discrete electronics circuits. These circuits are enclosed in a small package to give them stability, and so that you can handle and use them easily. (You would need a magnifying glass to effectively see the actual IC without its packaging material).

Working With Integrated Circuits

This IC is packaged in a form known as Dual-In-line-Package style. With this package style, the connecting pins of the circuit run parallel along the sides of the package in matched pairs, as illustrated in Fig. 10. The packge is marked with either a small, round indention by one of the connecting pins, or a semi-circular indention at one end of the package. These marks are used to indicate the location of package's pin #1. This pin is located just to the left of the semi-circular indention (looking down on the package), or directly adjacent to the round indention. The rest of the pins are numbered in sequential order, around the package in a counter-clockwise direction (looking down on the package).

There are literally thousands of different types of integrated circuits available. The overall operation of any IC is described by the operation of its individual pins. This information is generally supplied in the form of DATA (or SPECification) sheets published by the IC's manufacturer. The exact type of the IC contained in a package is specified by an alphanumeric code stamped on the top of the package. See the previous section covering IC Handling Precautions.

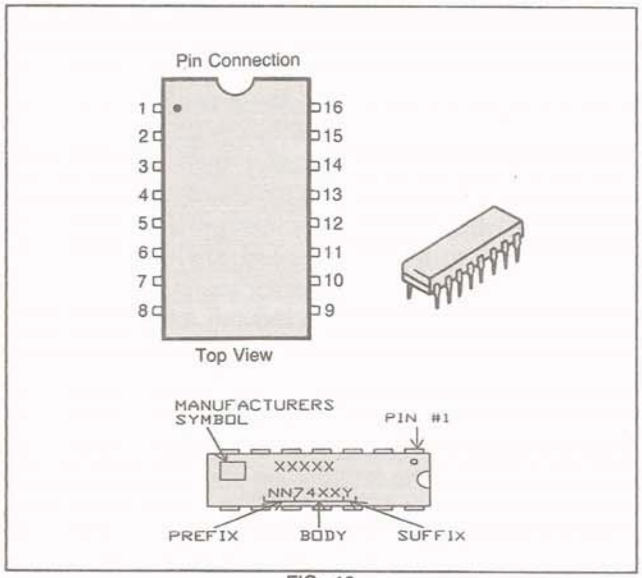


FIG. 10

The ICs in the SE-1030 project are proprietary. This means that they are not commonly available ICs, but instead are special ICs developed by the manufacturer of the project. This precludes finding out information about these ICs through normal channels (such as commercially available DATA BOOKS). In cases such as this, the most common method of obtaining information about ICs is to contact the manufacturer of the system it is being used in.

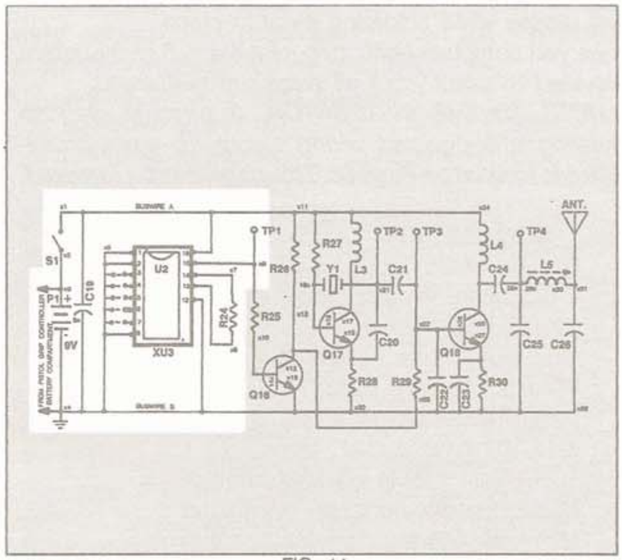


FIG. 11

The particular IC device used in the transmitter has been developed to gather status information from five f switch contacts in the pistol grip controller and convert it into a form acceptable for modulation and transmission. This circuitry is depicted in Fig. 11.

With none of its input switches activated, the transmitter's Encoder IC produces an output signal identical to the one illustrated in Fig. 12. The signal consists of repetitive bursts of pulses generated at fixed intervals. Each burst of pulses contains the same number of pulses. The information about the condition of the five switches is ENCODED in the pulse information. In other words, the condition of each switch is represented by one of the pulses in the pulse train. In addition to the five pulses corresponding to the switch information, the IC also generates a fixed number (3) of START pulses, just prior to the coded pulses, and a fixed number (5) of STOP pulses, which follow the coded pulses. These extra pulses are used to synchronize the transmitter and receiver with each other. This form of communication between devices is called ASYNCHRONOUS (not synchronous) communications, because the transmitter and receiver must be synchronized to each other each time information is transmitted. This is one of the most common methods of conducting non-voice information transfers in use.

Notice that in this case the frequency at which the packets of pulses are produced is also constant (62.5Hz). The frequency of both the individual pulses and the packets is dictated by an internal oscillator circuit built into the IC package. The operating frequency of the IC's internal oscillator is determined by the value of an external timing resistor (R24). This resistor acts with a fixed capacitance inside the IC to form an RC time constant circuit. The charge/discharge rate of this circuit dictates the output frequency of the oscillator.

Fig. 13 shows the IC Encoder in block diagram form. When any of the switches in the controller are activated, that switch drops the voltage level at the pin to which it's connected to a LOW level (ground). This low voltage level is stored in the IC in an area called the holding register. Periodically, the IC's internal circuitry sequentially samples the stored voltage values (high or low) for each input pin. The IC assembles the individual values it finds into a pulse train by shifting them out of the holding register one-by-one, on successive cycles of its internal oscillator (i.e. the value present at input #1 is encoded on pulse #1 and then the level of input #2 is encoded on pulse #2 and so on). If the IC finds a LOW voltage level at input #1, the duration of the pulse in position #1 will be long. For each input that has a HIGH level of voltage present, a shorter duration pulse will be generated in that pulse position. This is known as PULSE WIDTH, or duty factor MODULATION (PWM or DfM), since the information is actually carried by the width of the pulse.

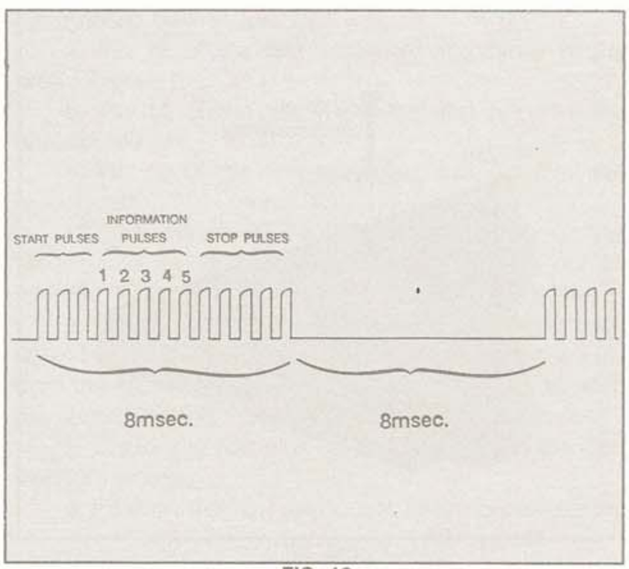


FIG. 12

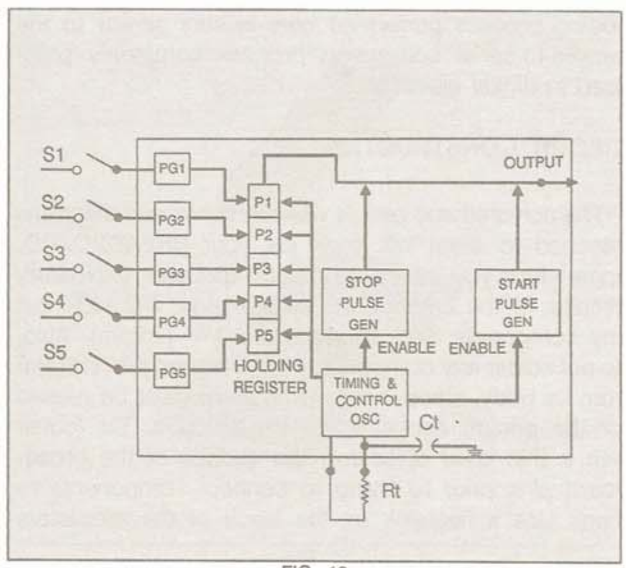


FIG. 13

In addition to the information pulses, the IC's internal circuitry also generates a burst of Start and Stop pulses. These pulses are added to the pulse train inside the IC. Once all of the pulses have been assembled into a pulse train, they are sent out of the IC's Data Out pin, one after another on successive TICKS of the IC's internal clock circuitry. The actions of the Encoder IC are illustrated in Fig. 14.

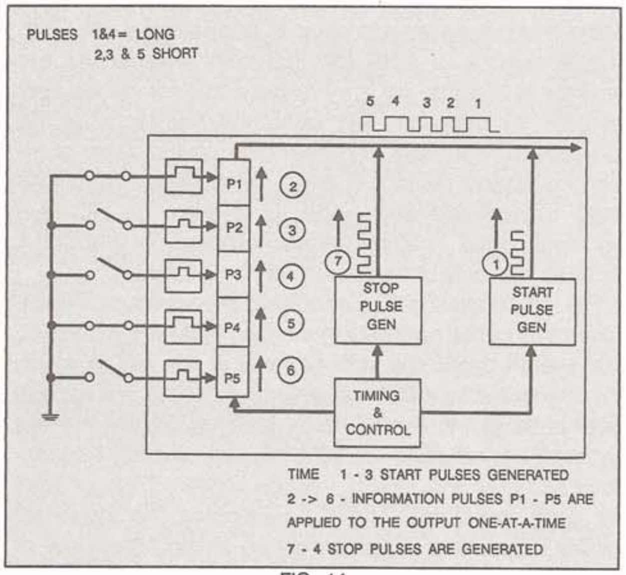


FIG. 14

After the complete pulse train has been CLOCKED out of the IC's output pin, there is a fixed pause at the output while the IC's internal circuitry assembles the next pulse train for transmission. When a new pulse train has been completed, the IC will clock it out of its output in the same manner as the previous pulse train.

This concept of linking information and transmission pulses together and then sending them to some other location, one after another along a single communication path is refered to as SERIAL ENCODING. The encoding process performed here is very similar to the parallel-to-serial conversion process commonly practiced in digital electronics.

CIRCUIT CONSTRUCTION

The polyurethane panels with the schematic diagrams attached to them will serve as your BREADBOARD, upon which you will construct and test your exploatory circuits. In the breadboard construction, DO NOT cut any component lead shorter than 3/4" (20mm). Also, do not solder any component lead less than 5/8" (15mm) from its body, since these component must be reused for the printed circuit board construction. Tin (cover with a thin layer of solder) the surface of the breadboard pins prior to trying to connect components to them. Use a heatsink on the leads of the transistors and diodes while soldering them in place.

As you complete each step, place a (√) in the space provided to assure that all steps are performed.

NOTE TO THE INSTRUCTOR: A pictorial diagram showing a suggested wiring layout for each breadboard is located on Page 66. This page may be removed.

PARTS LIST
__R24 Resistor, 1MΩ
__C19 Capacitor, disc 0.02µf ("203")
__P2 Clip, battery 9-volt
__W1 Hookup wire, insulated
__W2 Hookup wire, bare
__MP9 Breadboard pins (34)
__XU3 16-pin IC socket
__MP10 Test socket assembly board
__MP12 Breadboard base, transmitter
__MP14 Breadboard schematic, transmitter
__U2 Transmitter IC, FRC-01T

__1. The components shown in the Parts Lists section are necessary to construct the IC Encoder Stage of your transmitter. Identify these components and set them aside.

__2. Attach the transmitter breadboard schematic to the breadboard base by peeling the protective paper off the back side of the diagram. Starting at one end of the base, carefully position the diagram on the base, then press down firmly to seal it in place.

__3. Insert thirty-two (32) breadboard pins into the breadboard, with one positioned through each numbered "X" on the schematic diagram. The pins should extend 1/4" (5mm) above the board (See Fig. 15).

__4. Connect and solder bare (no insulation) connection wire between the following pins to form buswires.

__a. Buswire A: Pin 1 to pin 11 to pin 24

__b. Buswire B: Pin 4 to pin 20 to pin 32

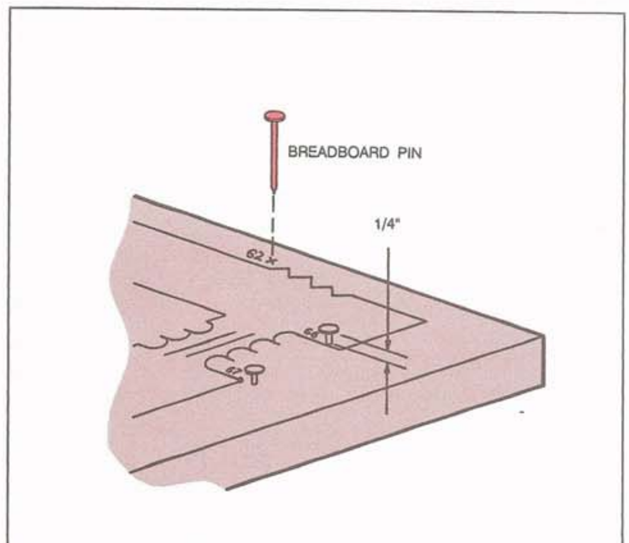


FIG. 15

__5. Using bare wire, connect and solder jumper wires between the following points on the schematic. Keep the wires as short as possible.

__a. Pins 5,6 and 15 to Buswire B

__b. Pin 16 to pin 18

__c. Pin 10 to pin 14

__d. Pin 12 to pin 13

__e. Pin 2 to pin3

__6. Using insulated hookup wire, connect and solder a jumper between pins 13 and 23 on the breadboard.

__7. IC U2 plugs into a specially designed IC Test Socket Assembly. Attach the IC socket (XU3) to the NON-FOIL side of the IC test socket assembly board (MP10). Solder all 16 of the socket's pins to their corresponding solder pads.

__8. Use bare wire to make connection points at pins 3 through 7 of the IC Test Socket Assembly. Solder each test point wire into place and then cut them off approximately 1/4" (5mm) above the board.

__9. Using bare wire, solder jumper wires to the solder pads associated with pins 1,2, and 8 of the IC test socket assembly. Cut the wires to the approximate length indicated on the schematic diagram to connect these points to the wire running from pin 6 to Buswire B. DO NOT solder the wires to the Buswire at this time.

__10. Using bare wire, solder a jumper wire to the solder pad associated with pin 12 of the IC test socket assembly. Cut the wire to a length capable of reaching Buswire B, as indicated on the schematic diagram. DO NOT solder the wire to the Buswire at this time.

__11. Solder a jumper wire to the solder pad associated with pin 16 of the IC test socket assembly. Cut the jumper to the length required to reach Buswire A. DO NOT solder the wire to the Buswire at this time.

__12. Using insulated wire, solder jumper wires to the solder pads associated with the following pins of the IC test socket assembly. Cut the wires to the proper length for connection to their corresponding pins on the breadboard. DO NOT solder these wires to the breadboard pins at this time.

__a. Pin 15 of the test assembly and pin 9 of the breadboard

__b. Pin 14 of the test assembly and pin 7 of the breadboard

__c. Pin 13 of the test assembly and pin 8 of the breadboard

__13. Mount the IC Test Socket Assembly on the breadboard as depicted in Fig. 16. *NOTE: Do not install the IC in the test socket assembly at this time.*

__a. Insert two breadboard pins into the designated holes in the IC Test Socket Assembly. Insert these pins from the NON-FOIL side of the board. The top of each pin should extend 1/4" (5mm) above the board.

__b. Solder the two pins on the FOIL side of the Test Socket's board.

__c. Position the IC Test Socket Assembly above the schematic symbol for U2 on the breadboard. Push the Socket Assembly down flush against the breadboard surface.

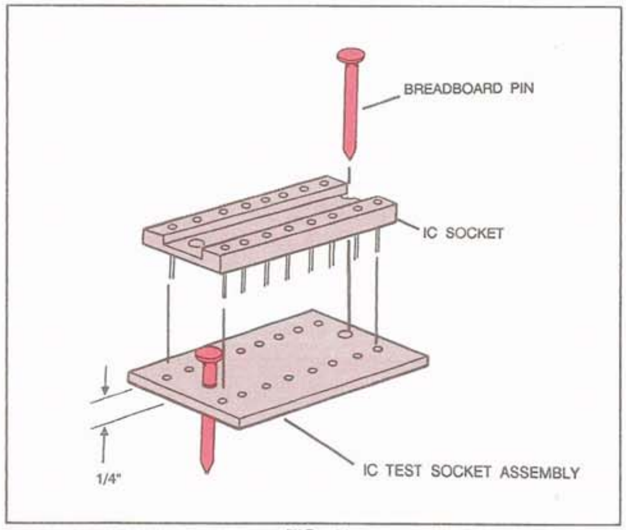


FIG. 16

__14. Solder the free ends of all the wires listed in steps 9 through 12 to their respective termination points.

__15. Solder Resistor R24 (1MΩ) into place between pins 7 and 8 on the breadboard. *REMEMBER: Do not solder any component lead less than 5/8" (15mm) from its body.*

__16. Solder Capacitor C19 (0.02µf) into place between Buswire A and pin 5 on the breadboard.

__17. Connect the battery clip (P1) by soldering the RED (+) lead to pin 3 on the breadboard and the BLACK (-) lead to pin 4.

__18. Following the instructions given in the **IC Handling Section** on page 12 , insert IC U2 into the socket on the IC test socket assembly (See Fig. 17) as follows.

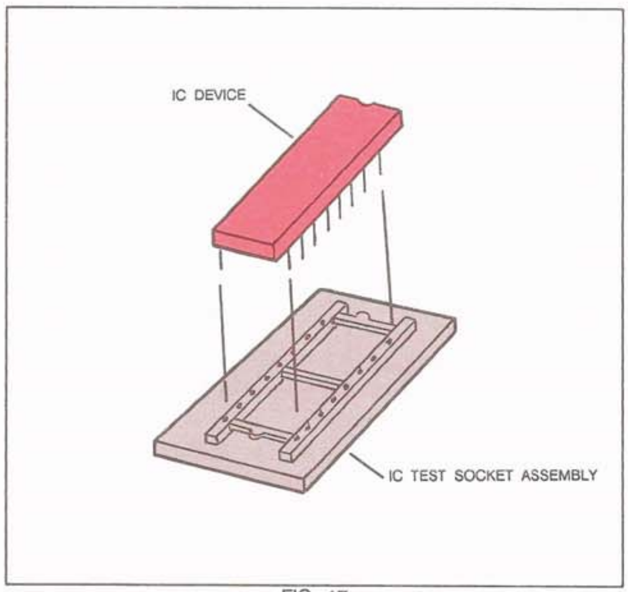


FIG. 17

_a. Wrap a length of UNINSULATED wire around your wrist and connect it to a grounded point near your work bench. This will remove any static build-up from your hand and protect the IC from static damage.

_b. Using the hand that is grounded, CAREFULLY remove U2 from its protective container. Avoid touching any of its pins while doing so.

_c. The IC's pins are bent on an angle, preventing them from lining up with the socket. Straighten them by placing the IC on a flat surface, then slowly rolling the IC toward the pins, as shown in Fig. 18.

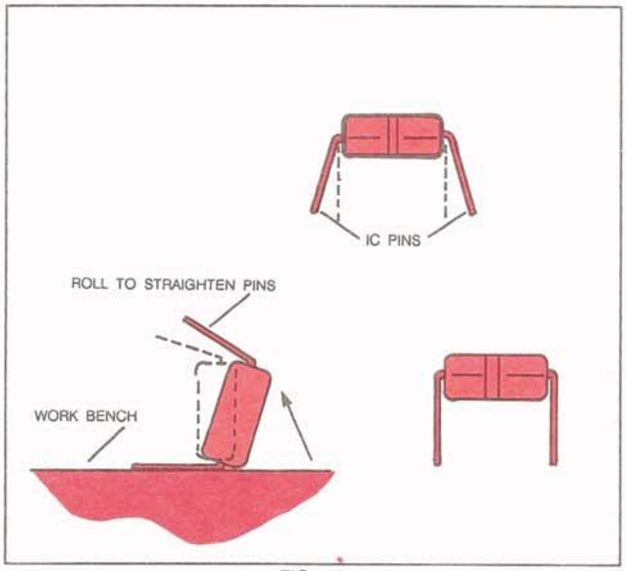


FIG. 18

_d. While houlding the ends of the IC between your finger tips (WITHOUT TOUCHING THE PINS), position the IC over the socket so that the notched end is aligned with the small notch in the end of the socket, as illustrated in Fig. 17.

_e. Press the IC gently down into the socket. Take great care to avoid bending any of the IC's pins. Also make certain that ALL of the IC's pins are aligned with the slots in the socket (IC pins can be bent under the body of the device and still appear to be inserted properly from the outside).

_19. This completes construction of this stage. Confirm all of the wiring connections made thus far.

_20. Have your instructor initial your Knowledge Transfer Guide.

CIRCUIT EXPLORATION

In the following circuit explorations you will test the IC Encoder Stage circuitry and learn HOW it works.

The answers and typical test results for each exploration are shown in **ANSWERS** on Page 67. (If this page has been removed, have your instructor approve your test results). If you fail to achieve similar results, turn off the transmitter immediately, then confirm your test equipment connections and re-check your breadboard wiring. If this fails to solve the problem, refer to **TROUBLESHOOTING** on Page 60.

_1. OPERATIONAL TEST

Purpose: To determine if this stage is functioning properly.

Equipment: Oscilloscope

Refer to Fig. 19 for this test.

_a. Connect the oscilloscope probe to test point TP1 and the ground lead to Buswire B.

_b. Connect a fresh 9-volt battery to the battery clip. An alkaline version is recommended for longer life.

_c. Connect a clip lead (or solder a jumper wire) across the S1 slide-switch position (pins 1 and 2) on the breadboard.

_d. Adjust the scope controls so that two complete packets of squarewaves appear on the display with an amplitude of about 4 cm (peak-to-peak).

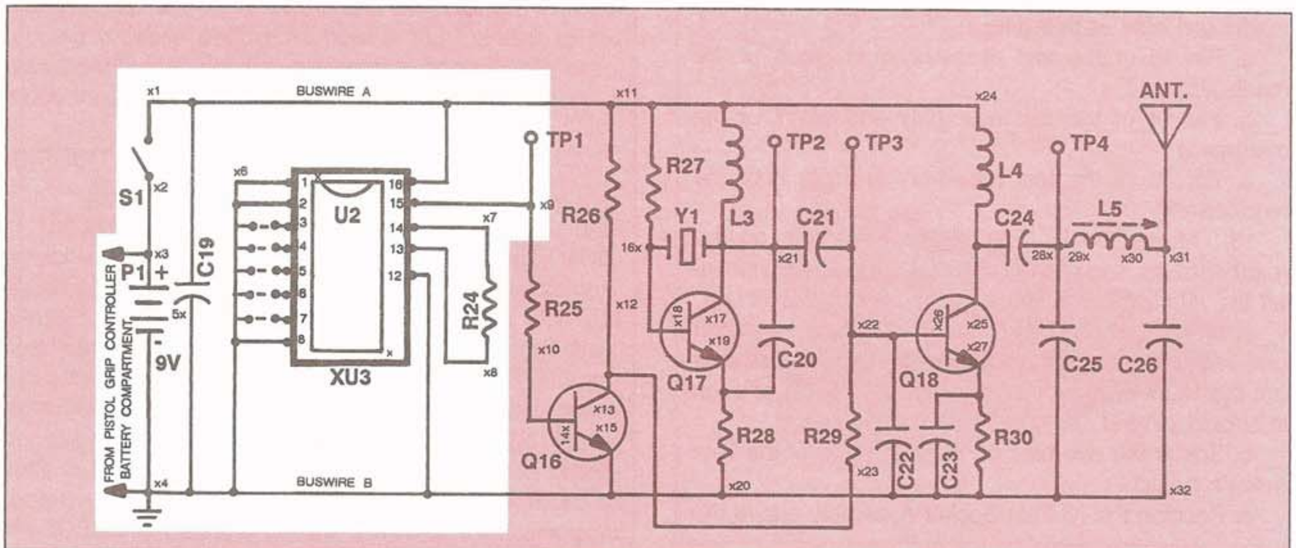
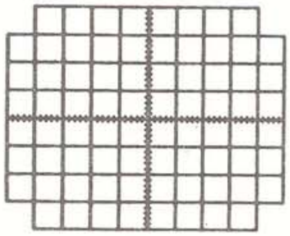


FIG. 19

__e. Draw your scope display.



__f. Remove the jumper at the slide switch position.
__g. Disconnect the scope leads.

__2. OUTPUT FREQUENCY MEASUREMENT

Purpose: To determine the frequency of the signals at the IC Encoder's output.

Equipment: Oscilloscope.

__a. Connect the scope probe to testpoint TP1 and the ground lead to Buswire B.

__b. Set the CALIBRATED scope controls to $1^{V}/_{cm}$ and 2ms/cm sweep time. If a 10:1 probe is used, set the vertical defection to $0.1^{V}/_{cm}$.

__c. Connect a jumper across the slide switch position and make certain that the battery is still connected.

__d. Adjust the scope's VERTICAL position control so that the beginning and end points of one complete squarewave packet are located on the horizontal center line See Fig. 20.

__e. Adjust the HORIZONTAL position control to move the start of the first squarewave packet to the first graticule line on the display.

__f. Measure the horizontal distance between the start of one packet of pulses and the beginning of the second pulse packet, and record.

____ cm

__g. Multiply the distance measured above by the setting of the horizontal sweep control (2ms). This represents the PERIOD (T) of one pulse packet.

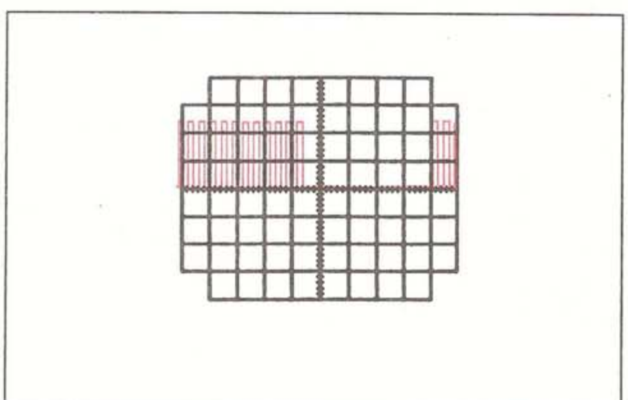


FIG. 20

T = ____ X 2ms

T = ____ms

__h. Calculate the frequency at which the IC Encoder produces pulse packets by taking the reciprocal of the time period measurement in Step g ($F = {}^{1}/_{T}$).

F = ____ Hz

__i. Measure the horizontal distance between the start of one pulse in the packet and the beginning of the next pulse in the packet and record.

___cm

__j. Use the procedures from Steps g and h to find the time period (T) and frequency (F) of the information pulses.

T = ____ms F = ____Hz

__k. Temporarily connect the 10KΩ resistor from the project across resistor R24 on the breadboard. Use the procedures above to measure the time period and frequency of the pulse packets and information pulses with this resistor installed.

T = ____ms F = ____Hz (packets)

T = ____ms F = ____Hz (pulses)

__l. Use a clip lead to short the solder pad associated with pin 3 of the IC test socket assembly to the bus wire running between pin 6 on the breadboard and Buswire B. Short the connection while watching the scope display. Note which pulse in the pulse train changed.

pulse # ___

__m. Repeat step l for pins 4,5,6, and 7 respectively of the IC test socket assembly.

pulse # ___
pulse # ___
pulse # ___
pulse # ___

__n. Remove all external connections from the circuiti. Remove the battery from the battery clip and the temporary load resistor from the circuit.

__o. This completes the circuit exploration of the transmitter's IC Encoder Stage. Have your instructor initial your Knowledge Transfer Guide.

MODULATOR STAGE

Discussion

The transmitter's Modulator Stage is shown in Fig. 21. The stage consists of transistor Q16 and its related components. The transistor is forward biased on each POSITIVE half-cycle of the squarewaves produced at the output of the IC Encoder. The transistor's configuration is such that it is forced to operate as a solid-state ON/OFF switch. When Q16 is turned on by the pulses from the IC Encoder, it goes into saturation, which in turn causes its collector to swing in a negative direction (towards ground potential), as illustrated in Fig. 22.During this time, the output of the Oscillator Stage is allowed to pass through the output amplifier and be transmitted from the antenna.

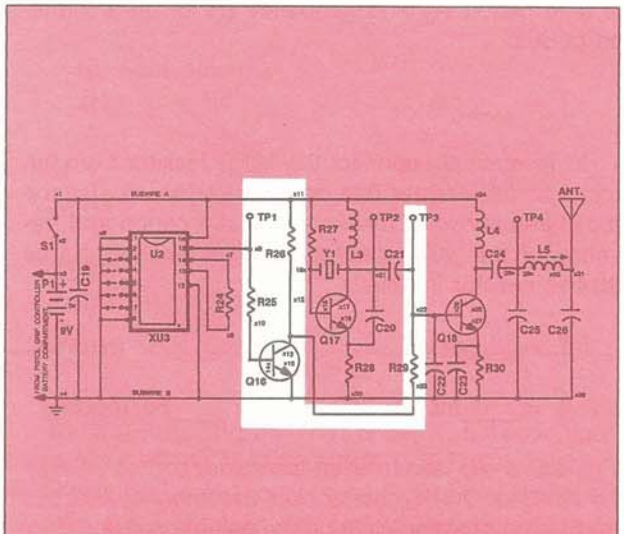


FIG. 21

During the negative swing of the pulses from the IC Encoder, and during the IC's sampling time (which follows directly after each pulse packet), the modulator is turned-OFF and the voltage at the collector of Q16 is approximately equal to the supply voltage. This effectively blocks the Oscillator Stage's output from passing to the Output Amplifier Stage. Therefore, this signal modulates the oscillator's output at the frequency of the pulses in the pulse train. This is illustrated further in the RF Oscillator Stage section which follows later in the manual.

CIRCUIT CONSTRUCTION

PARTS LIST
- __R25 Resistor, 10KΩ
- __R26 Resistor, 4.7KΩ
- __R29 Resistor, 22KΩ
- __Q16 Transistor (NPN)

__1. Mount and solder Resistor R25 between pins 9 and 10 on the breadboard.

__2. Mount and solder Resistor R26 between pins 11 and 12 on the breadboard.

__3. Mount and solder Resistor R29 between pins 22 and 23 on the breadboard.

__4. Tin (coat with a thin layer of solder) the leads of transistor Q16. Use a heatsink on the leads while soldering, as illustrated in Fig. 23. See Fig. 24 for proper lead and number identification. *CAUTION: THE LEADS MUST BE CONNECTED PROPERLY IN THE CIRCUIT OR THE TRANSISTOR MAY BE DAMAGED*

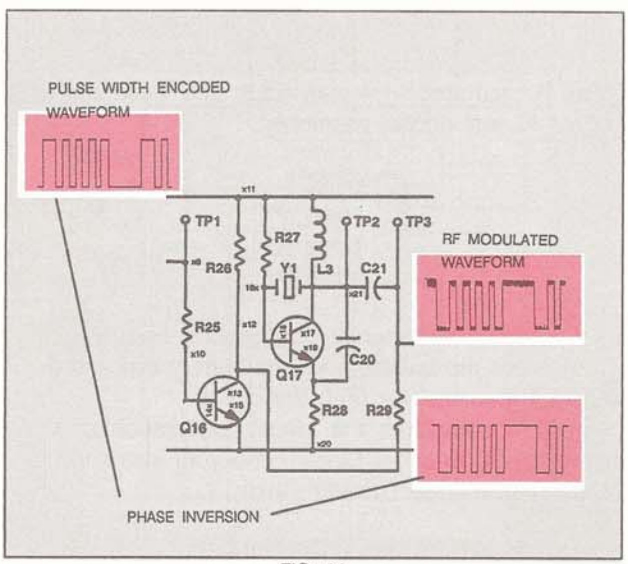


FIG. 22

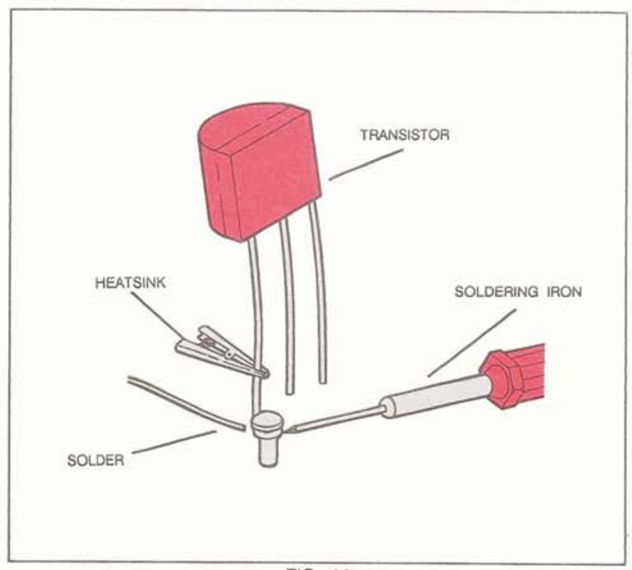


FIG. 23

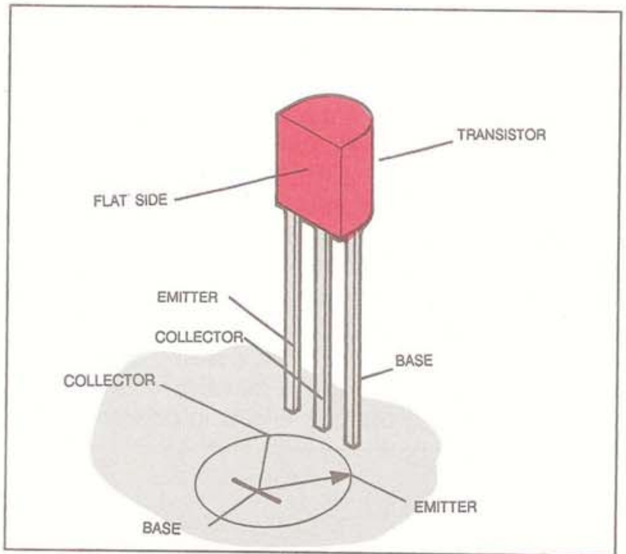


FIG. 24

CIRCUIT EXPLORATION

__1. OPERATIONAL TEST (Switching Demonstration)

Purpose: To determine if this stage is functioning properly.

Equipment: Multimeter, Oscilloscope.

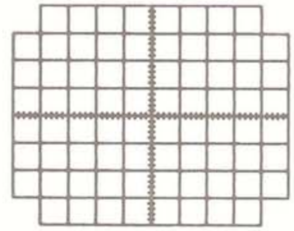
Refer to Fig. 25 for this procedure.

__a. Connect the oscilloscope probe to Test Point TP3 on the breadboard and the ground to Buswire B.

__b. Connect the 9-volt battery to the battery clip (P1).

__c. Connect the clip lead or jumper wire across the slide switch position (pins 1 and 2 on the breadboard).

__d. Draw the waveform as it appears on your scope display.



__e. Set the multimeter to a range suitable for measuring 10Vdc.

__f. Connect the meter between the test point (TP3) and Buswire B.

__g. Read the meter and record.

_____dc

This reading shows (without using a scope) that the transistor is switching its collector to ground (0 volts) for a portion of time. This signal is used to modulate the output of the crystal-controlled RF oscillator in the next stage.

__h. Remove the jumper wire at the slide switch position.

__i. Disconnect the scope and meter leads from the circuit.

__2. This concludes the Circuit Exploration for the Modulator Stage. Have your instructor initial your Knowledge Transfer Guide.

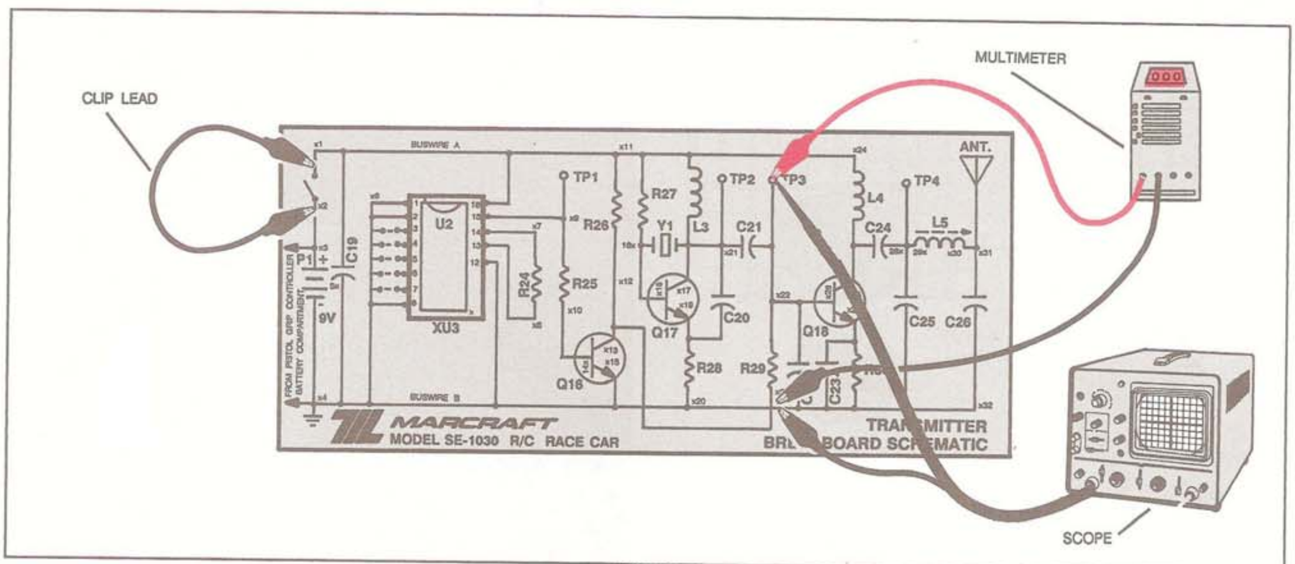


FIG. 25

RF OSCILLATOR STAGE

Discussion

Oscillators are circuits designed to generate a constantly reoccurring waveform. Of the various types of oscillators commonly found in electronic circuits, those having the highest degree of frequency stability are the ones which are controlled by CRYSTALS. These crystals are generally quartz and exhibit a characteristic known as the piezoelectric effect.

When a piezoelectric material is compressed or strained (stretched) in certain directions, an electric charge appears on the surfaces that are perpendicular to the axis of strain (See Fig. 26). Conversely, when a piezoelectric material is placed between two metallic surfaces and a voltage potential is applied across it, a mechanical strain is created within the crystal. When the voltage is removed, the mechanical strain is releived and the crystal snaps back to its original position. In doing so it creates a small voltage. If the voltage potential is reversed, the strain occurs in the opposite direction. When the voltage is removed again, the crystal returns to its original position and generates a reverse voltage potential.

Crystals are made by cutting quartz into very small slabs and polishing them. The final dimensions, particularly the thickness, determine the frequency at which the crystal will resonate (vibrate back and forth). Due to its nature (high Q), the crystal requires that much less external electrical energy be applied to it than it returns to the circuit.

Your transmitter uses a crystal-controlled oscillator circuit with a crystal rated to resonate at 27.145MHz. This signal forms the CARRIER portion of a MODULATED transmission signal. Recall from the previous discussion of the Modulator Stage that Modulation is the process by which an information signal is superimposed on a carrier wave (in this case the 27MHz RF signal) for transmission. In this case, PWM (pulse width modulation) uses the modulating signal to change the duration of time over which the carrier signal is transmitted. This concept is illustrated in Fig. 27. Notice that when the modulating pulse enables the oscillator's output signal to be passed to the output amplifier stage, the carrier frequency is produced at the transmitter's output. The carrier frequency is transmitted for a period of time equal to the duration of the enabling pulse. Note the difference in duration of the transmitted carrier between the short and the long encoding pulses.

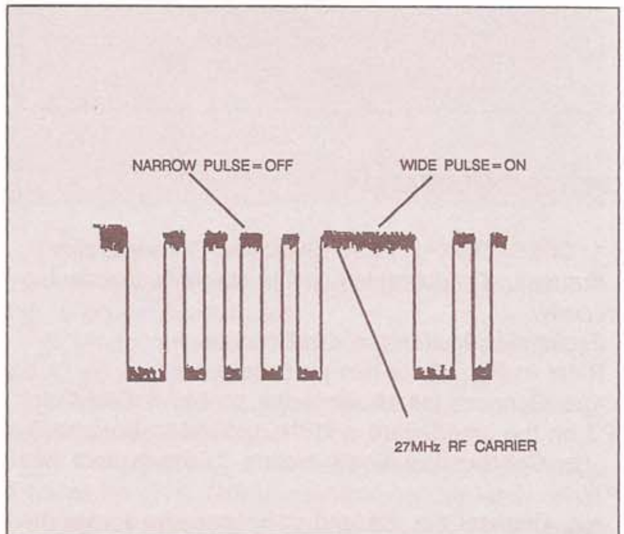


FIG. 27

Fig. 28 shows a schematic diagram of this stage. It consists of a crystal-controlled variation of a Pierce oscillator circuit. This circuit is formed by transistor Q17, crystal Y1, and related components. Oscillator's require

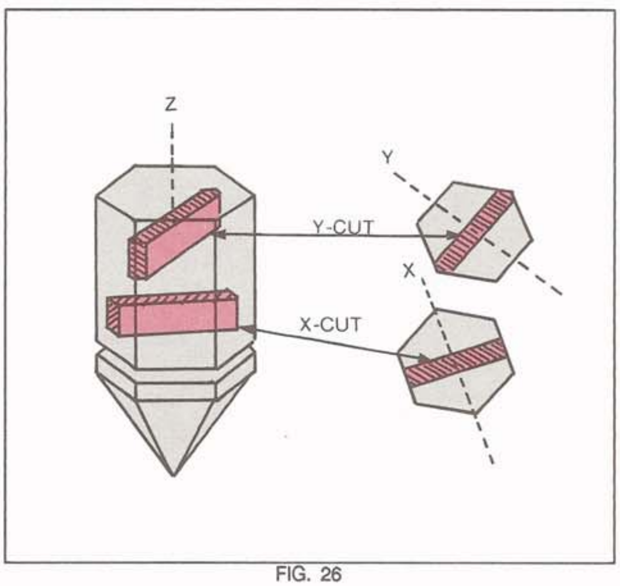


FIG. 26

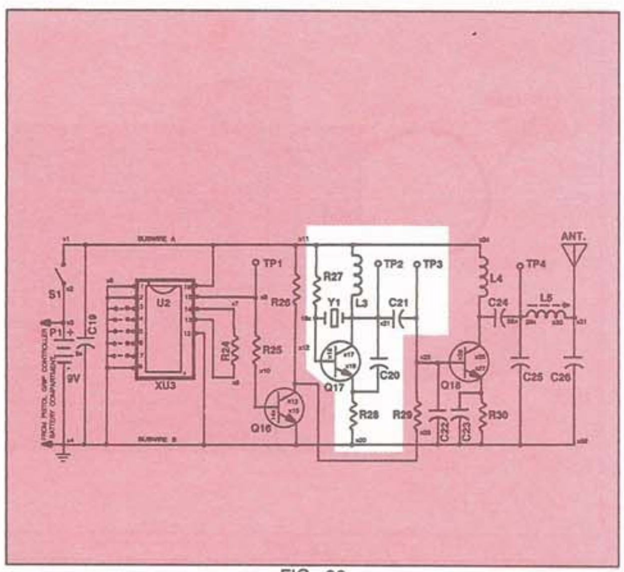


FIG. 28

two quantities to sustain oscillation; in-phase feedback from the output to the input, and amplification of the frequency signal at which the oscillator is designed to operate.

The advantage of Pierce Crystal oscillators are their simplicity. The crystal actually forms the feedback path from the output (collector of Q17) to the input (base of Q17). Together with capacitor C20 and inductor L3, the crystal acts as a very narrow band-pass filtering network. This network allows only signals that fall within the designed frequency range to pass from the output back to the input. These signals are constantly re-amplified by the transistor. Signals outside of the designated frequency band are ATTENUATED (made smaller and smaller) by the filtering action. As was noted above, the pass-band of the filter network is very narrow. In reality, it is limited to a width of 1 Hertz (the operating frequency of the oscillator).

CIRCUIT CONSTRUCTION

PARTS LIST
__R27 Resistor, 120KΩ
__R28 Resistor, 100Ω
__C20 Capacitor, disc 47pf
__C21 Capacitor, disc 47pf
__Q17 Transistor,
__L3 Inductor, 2.2 μh
__Y1 Crystal, 27.145 MHz

__1. The components described in the Parts List comprise the RF Oscillator Stage. Identify these components and set them aside.

__2. Using bare wire connect the following pins together.

__a. Pins 17 and 21

__b. Pins 22 and 26

__3. Solder the following resistors into the circuit.

__a. R27, 120KΩ

__b. R28, 100Ω

__4. Solder the following ceramic disc capacitors into the circuit.

__a. C20, 47pf

__b. C21, 47pf

__5. Tin the leads of transistor Q17 and then solder it into the circuit, observing proper lead positioning (See Fig. 29).

__6. Solder crystal Y1 into the circuit. NOTE: This can be connected in either direction, however, keep the leads short.

__7. Solder Inductor L3 into the circuit.

__8. This completes the construction portion of the Rf Oscillator Stage. Confirm your component placement, wiring and solder connections.

__9. Have your instructor initial your Knowledge Transfer Guide.

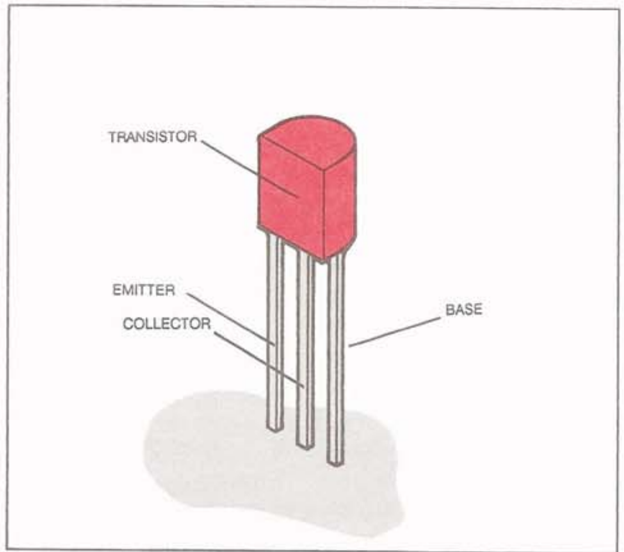


FIG. 29

CIRCUIT EXPLORATION

__1. OPERATIONAL TEST

Purpose: To determine if the stage is functioning properly.

Equipment: Oscilloscope

Refer to Fig. 30 for this test procedure.

__a. Connect the scope probe to Test Point TP2 and the ground lead to Buswire B.

__b. Connect a jumper wire across the S1 slide-switch position.

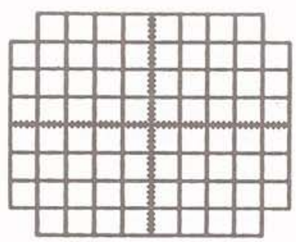
__c. Adjust the scope controls so that the waveform appears steady on the display.

__d. Draw the waveform as it appears on the scope display.

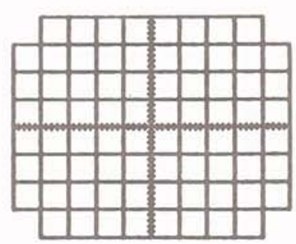
__e. Connect the scope probe to Test Point TP3.

__f. Do not adjust the scope controls.

__g. Draw the waveform as it appears on the scope display.



TP2



TP3

__h. Remove the jumper wire from the S1 slide-switch position.

__2. MODULATION DEMONSTRATION

Purpose: To demonstrate how the IC Encoder modulates the RF oscillator by substituting an AF generator for it.

Equipment: Oscilloscope, AF Generator

Refer to Fig. 30 for this test.

__a. **CAREFULLY** remove IC U2 from the IC test socket assembly.

__b. Set the AF Generator for a 200Hz squarewave at minimum output.

__c. Connect the generator lead to pin 9 (TP1) on the breadboard and its ground lead to Buswire B.

__d. Reconnect the jumper wire across the slide-switch position.

__e. Draw the waveform as it appears on the scope display.

__f. SLOWLY increase the generator's output frequency until two squarewave cycles appear on the scope display. *If the signal is not present, or is severly distorted, take the reading at the emitter of transistor Q17*

__g. Draw the waveform as it appears on the scope display.

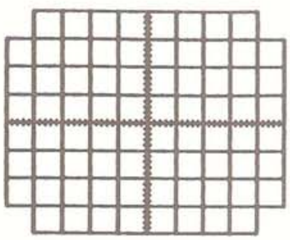
NOTICE the similarity between the second waveform and the one recorded in step 1g. The generator is modulating the transmitter.

__h. Remove the jumper wire from the slide-switch position.

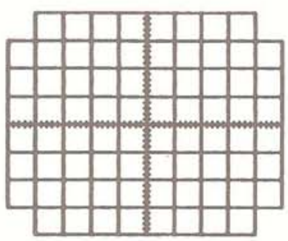
__i. Remove the test equipment leads from the circuit.

__j. **CAREFULLY** replace IC U2 in the IC test socket assembly.

__3. This completes the Circuit Exploration for this stage. Have your instructor initial your Knowledge Transfer Guide.



200 Hz



XXXHz

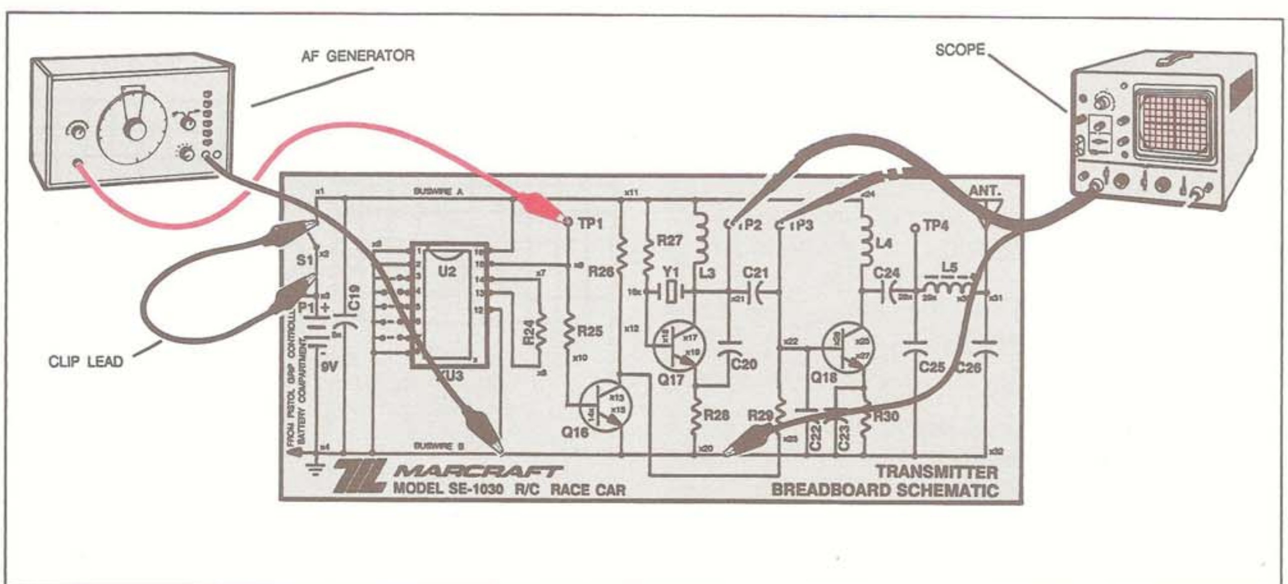


FIG. 30

OUTPUT AMPLIFIER STAGE

Discussion

The final sage of the transmitter is the Output Amplifier Stage. This stage accepts the Encoded/Modulated signal from the previous circuits and amplifies it for application to the antenna for transmission. The circuitry used in this stage is configured as a signal-biased Class-C transistor power amplifier. Class-C amplifiers are the most efficient of all the amplifier classes. No power is used in the circuit to set a constant bias point. Instead, the input signal itself is used to turn on the transistor and make it conduct. Therefore, nearly all of the power applied to the circuit can be translated into signal power for transmission. A typical Class-C amplifier can reach an efficiency rating of over 80%. This makes Class-C amplifiers very popular in radio frequency applications.

Fig. 31 shows the schematic diagram of this stage. It consists of the Class-C amplifier, formed around transistor Q18, and a pi filter network, consisting of variable inductor L5 and capacitors C25 and C26.

The encoded/modulated information signal is applied to the base of transistor Q18. The transistor is biased into conduction by the positive portions of the signal. The transistor will turn ON when the level of the base voltage reaches a point 0.7 volts above that of the emitter. The signal must also overcome the voltage created at the emitter by C23/R30. The amplified information signal is produced in sinusoidal form at Q18's collector. The combination of inductor L4 and capacitor C24 form a resonant circuit that prevents the signal distortion that would occur from driving a resistive load under Class-C conditions. This accounts for the sinusoidal nature of the output signal.

The adjustable pi-network acts to block harmonic frequencies from entering the antenna (E101) and also to match the output impedance of the transistor to that of the load (antenna) for maximum power transfer. The adjustable inductor allows the network to be tuned for maximum signal output to the antenna. Only frequencies within the 27 MHz band can pass to the antenna.

CIRCUIT CONSTRUCTION

PARTS LIST

__R30 Resistor, 100Ω
__C22,24 Capacitor, ceramic disc 47pf
__C23 Capacitor, ceramic disc 0.01μf ("103")
__C25 Capacitor, ceramic disc 150pf
__C26 Capacitor, ceramic disc 39pf
__L4 Inductor, 2.2μh
__L5 Inductor, variable
__Q 18 Transistor, NPN

__1. The components described in the Parts List make up the Output Amplifier Stage. Identify these components and set them aside.

__2. Using bare wire, connect and solder jumper wires between the following points.

__a. Pins 28 and 29 on the breadboard.

__b. Pins 30 and 31 on the breadboard.

__3. Solder adjustable coil L5 into the circuit, as depicted in Fig. 32.

__4. Cut an 18" (45.7cm) length of insulated wire and solder it to pin 31. This will act as the antenna.

__5. Solder Resistor R30 between pin 27 on the breadboard and Buswire B.

__6. Solder inductor L4 into place between pins 24 and 25 on the breadboard.

__7. Solder the following capacitors into the circuit.

__a. C22,24 ceramic disc 47pf

__b. C23, ceramic disc 0.01μf

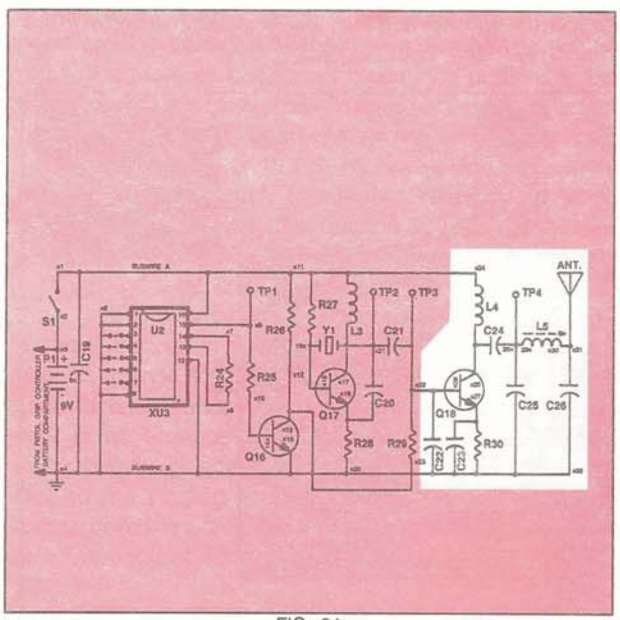


FIG. 31

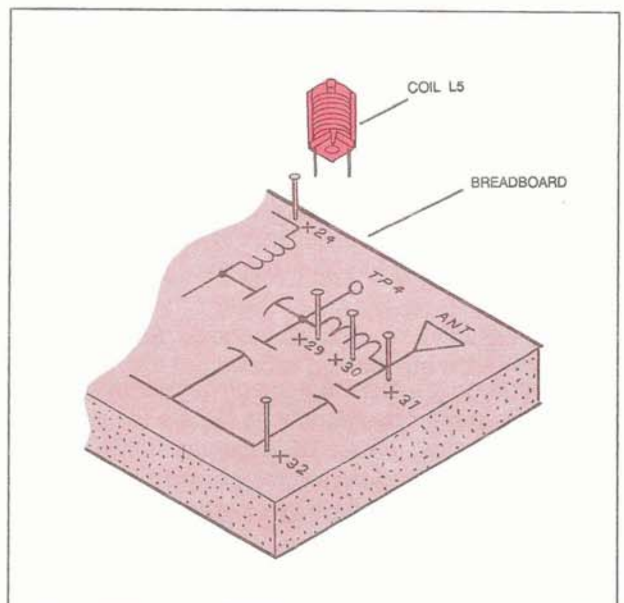


FIG. 32

__c. C25, ceramic disc 150pf
__d. C26, ceramic disc 39pf
__8. Tin the leads of transistor Q18 and solder it into the circuit. See Fig. 33 for proper lead positioning.

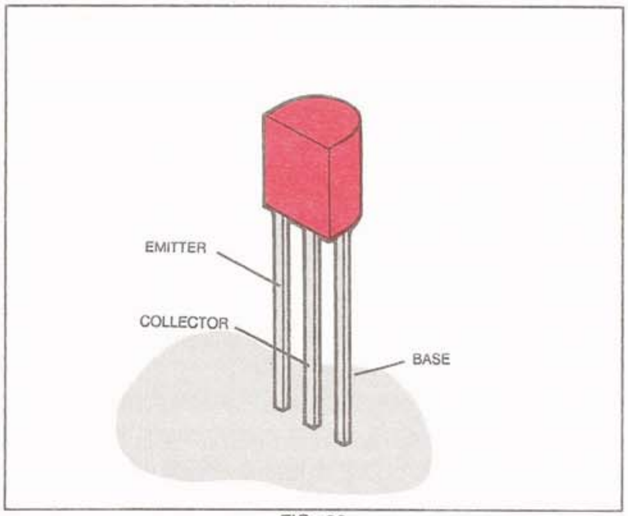


FIG. 33

__9. This completes the construction of this stage and the transmitter. confirm your component placement, wiring, and solder connections.
__10. Have your instructor initial your Knowledge Transfer Guide.

CIRCUIT EXPLORATION

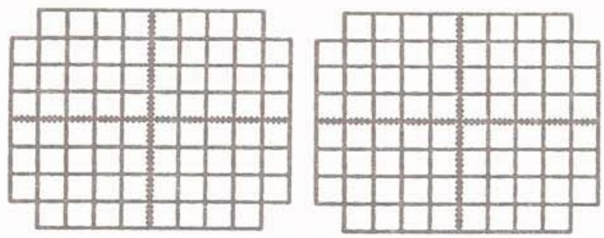
__1. OPERATIONAL TEST
Purpose: To determine if this stage is functioning properly.
Equipment: Multimeter, Oscilloscope
Refer to Fig. 34 for these test procedures.
__a. Set the multimeter (NON-DIGITAL) to the lowest ac voltage range.
__b. Connect one meter lead to Buswire B and wrap the antenna wire tightly around the other lead several times. DO NOT connect the lead directly to the antenna connection.
__c. Connect a jumper wire across the slide switch position.
__d. Observe the meter. Is there a voltage reading present? If so, record its value below.

____

The presence of a voltage reading indicates your transmitter is producing RF energy. If there is no reading, adjust variable inductor L5. If there is still no reading, wrap the meter lead more tightly around the antenna, Refer to the TROUBLESHOOTING section on page 60.

__e. Observing the meter, adjust L5 until maximum output level is obtained on the meter. Adjusting L5 provides greater antenna coupling, resulting in maximum RF output.
__f. Remove the jumper wire from the slide switch .
__g. Remove the meter connections from the circuit.

__2. AMPLIFICATION DEMONSTRATION
Purpose: To demonstrate how the amplifier circuit processes the output signal for transmission.
Equipment: Oscilloscope
__a. Connect the scope probe to Test Point TP3 and the ground lead to Buswire B.
__b. Connect a jumper wire across the slide switch.
__c. Adjust the scope controls so that two complete cycles of the signal are shown on the scope's display at about 4cm p-p.
__d. Draw the waveform as it appears on your scope.
__e. Move the scope probe to Test Point TP4.
__f. Readjust the scope controls if neccessary.
__g. Draw the waveform from the scope display.



d. g.

__h. Remove the jumper from the slide switch
__i. Remove the scope's leads from the circuit.
__3. This completes the Circuit Exploration for this stage. This also completes the Breadboard Assembly portion for the transmitter. Have your instructor initial your Knowledge Transfer Guide.

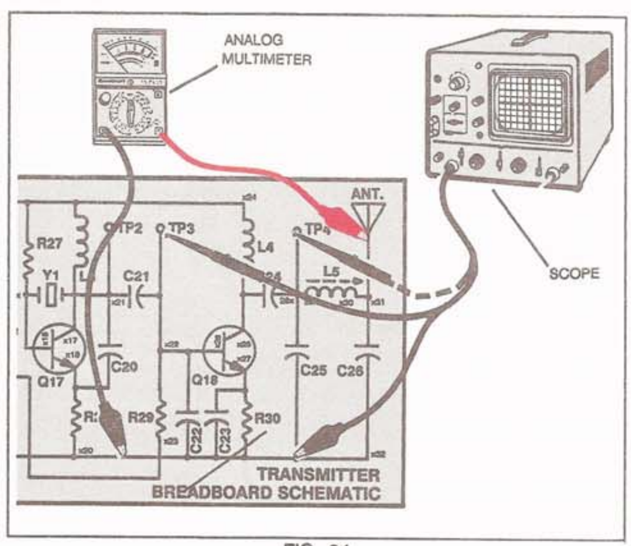


FIG. 34

RECEIVER

DETECTOR STAGE

Discussion

This stage consists of a SUPERREGENERATIVE DETECTOR that functions as the receiver for the transmitted control signal. The stage is designed and tuned to select (or pick out) only signals introduced to the antenna in the 27MHz range (the range of the carrier produced by the transmitter), while rejecting all others. Once received by the stage, the signal is then DETECTED before being amplified by the next stage. This is the process by which the original intelligence information (the pulse train) is removed from the carrier.

This type of detector provides the highest SENSITIVITY of all detector types. Sensitivity is a rating of how selective the receiver is in picking out the desired frequencies, compared to how well it rejects undesired signals. The high sensitivity results from this circuits use of an AC QUENCH VOLTAGE. The quench voltage operates at approximately 250KHz. A quench voltage is used in the detector to alternately vary its sensitivity, and thereby, prevent prolonged oscillations. The quenching frequency is the number of times per second the circuit goes in and out of oscillation. The detector goes into oscillation on each positive peak of the quench voltage and is cut off on each negative swing. By cycling the detector ON and OFF in this manner, the circuit is permitted to regenerate. The result is excellent sensitivity.

Fig. 35 shows the schematic diagram of this stage. It consists of transistor Q1, a parallel-resonant tuned circuit formed by L1 and C2, and related components. The parallel-resonant circuit provides a HIGH IMPEDANCE (resistance to ac current flow) at its resonant frequency (27MHz) and a LOW IMPEDANCE at frequncies outside its resonant passband. The resonant frequency point can be changed slightly by adjusting the setting of L1. Frequencies outside of resonance present at the antenna (E1) are prevented from entering the detector because of the low impedance of the tuned LC circuit.

The collector circuit of Q1 will have pulses of current present at the quench frequency. When there is no 27MHz signal present, the quench voltage establishes a value of AVERAGE CURRENT in the collector circuit.

When the 27MHz signal is received at the antenna, the signal is capacitively coupled to the detector stage through capacitor C1. The amplitude of the quench pulses change to reflect the presence of the signal. This, in turn, causes the average collector current to vary in accordance with the duration of the received signal pulses. Hence, the information signal is detected. Due to the pulsing action of the quench voltage, the output from the detector resembles a squarewave signal at a frquency of 100-500 Hz.

The quenching frequency is established by resistor R1 and capacitor C4. Resistors R2 and R3 establish the quiescent operating (bias) point of Q1.

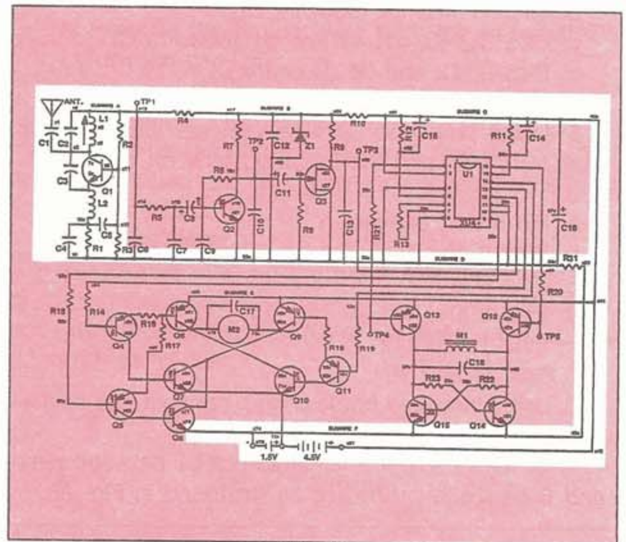


FIG. 35

CIRCUIT CONSTRUCTION

PARTS LIST
- __R1 Resistor, 270Ω
- __R2 Resistor, 5.6KΩ
- __R3 Resistor, 5.6KΩ
- __R4 Resistor, 2.7KΩ
- __R10 Resistor, 100Ω
- __R31 Resistor, 100Ω
- __C1 Capacitor, disc 10pf
- __C2 Capacitor, disc 25pf
- __C3 Capacitor, disc 47pf
- __C4 Capacitor, Mylar 0.0047μf ("472")
- __C5 Capacitor, disc 150pf
- __Q1 Transistor, NPN
- __L1 Coil, variable
- __L2 Coil, RF choke 3.3μh
- __A1 Car chassis assembly
- __MP9 Breadboard pin (48)
- __MP11 Breadboard base, receiver
- __MP13 Breadboard schematic, receiver

__1. The components listed in the Parts List above are necessary to build the first stage of your receiver. Identify these components and set them aside.

__2. Attach the receiver breadboard schematic to the breadboard base by peeling the protective paper off the back of the schematic. Starting at one end, carefully position the schematic onto the base.

__3. Insert forty-six (46) breadboard pins into the breadboard with one positioned through each numbered "X" from 1 to 43 (upper half) of the schematic and pins 61, 74, 75 and 79.

__4. Connect and solder bare wire between the following pins to form the Buswires for the receiver.

__a. Pins 2 and 13 (Buswire A)

__b. Pins 17 and 24 (Buswire B)

__c. Pins 31, 40, 41, 42 and 61 (Buswire C)

__d. Pins 4, 22 and 38 (Buswire D)

__e. Pins 43, 74 and 79 (Buswire F)

__5. Using bare hookup wire, connect and solder a jumper wire between the following pins on the breadboard.

__a. Pin 5 and Buswire A

__b. Pins 6 and 7 on the breadboard

__c. Pins 3 and 7

__d. Pins 8 and 11

__e. Pins 11 and 12

__f. Pins 74 and 75

__6. Using insulated hookup wire, connect and solder a jumper wire between pins 39 and 43.

__7. Carefully solder adjustable coil L1 between pins 5 and 6 on the breadboard, as illustrated in Fig. 36.

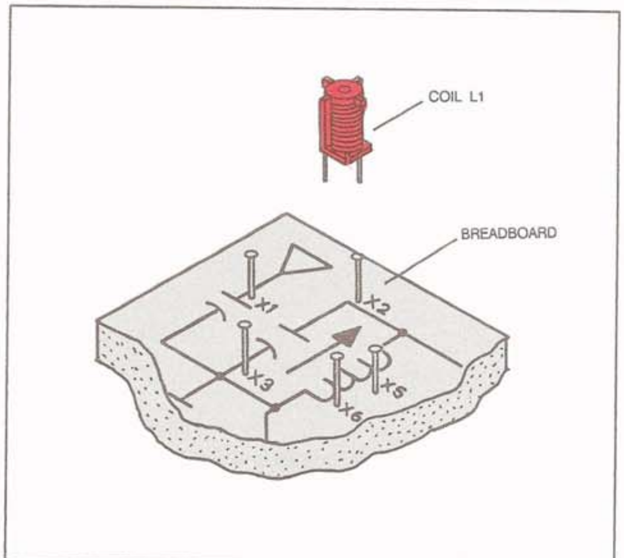


FIG. 36

__8. Solder the following resistors into the circuit.

__a. R1, 270Ω

__b. R2, 5.6KΩ

__c. R3, 5.6KΩ

__9. Solder the following capacitors into the circuit.

__a. C1, 10pf

__b. C2, 25pf

__c. C3, 47pf

__d. C4, 0.0047μf

__e. C5, 150pf

__10. Cut an 18" (45.7cm) length of hookup wire. Connect and solder one end to the free end of C1 (breadboard pin #1).THIS WILL ACT AS AN ANTENNA.

__11. Tin the leads of transistor Q1 and solder it into the circuit. Observe proper lead positioning, as illustrated in Fig. 37, and use a heatsink while soldering.

__12. Solder choke L2 into the circuit.

__13. In order to accomodate the circuit's need for a power supply, install the following components as instructed.

__a. Solder resistor R4 (2.7KΩ) between pins 13 and 17 on the breadboard.

__b. Solder resistor R10 (100Ω) between pins 24 and 31 on the breadboard.

__c. Solder resistor R31(100Ω) between pins 38 and 39 on the breadboard.

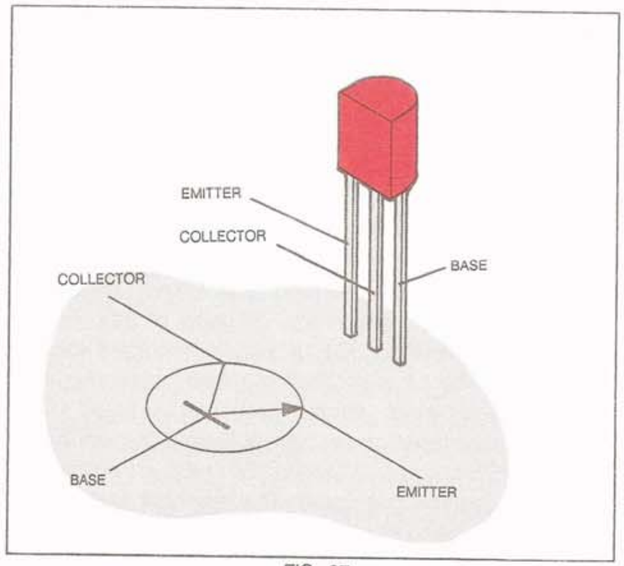


FIG. 37

__14. Lay the car's chassis assembly upside-down along the front edge of the breadboard (with the front of the car pointing to the right). THE CAR SHOULD BE POSITIONED IN THIS MANNER FOR ALL TESTS INVOLVING THE RECEIVER BREADBOARD.

__a. Connect and solder the GREY (+) lead from the slide switch in the car's chassis to pin 61 on the breadboard.

__b. Connect the YELLOW (-) lead to pin 75 on the breadboard.

__15. This completes the construction of this stage. Confirm your component placement, wiring and solder connections.

__16. Have your instructor initial your Knowledge Transfer Guide.

CIRCUIT EXPLORATION

__1. OPERATIONAL TEST

Purpose: To observe the waveform of the control signal at the output of the detector.

Equipment: Oscilloscope

Refer to Fig. 38 for this test.

__a. Connect the scope probe to Test Point TP1 and the ground lead to Buswire D.

__b. Place the transmitter near the receiver.

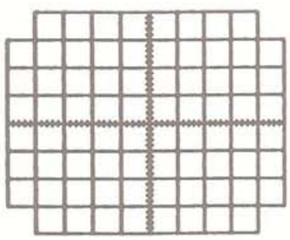
__c. Install the jumper wire across the TRANSMITTER'S S1 slide-switch position. Turn the transmitter ON.

__d. Using the ON/OFF switch located on the car body, turn the receiver ON.

__e. Adjust the scope controls so that two complete square waves or pulses appear at about 4cm p-p.

__f. Adjust coil L1 until the signal on the scope's display reaches maximum amplitude.

__g. Draw the waveform as it appears on the display.



__h. Remove the jumper wire from the transmitter.

__i. Turn the car OFF.

__2. RESONANT FREQUENCY CALCULATION

Purpose: To calculte the resonant frequency of the receiver's tuned circuit, given the capacitance and inductance values.

Equipment: None

__a. Calculate the approximate resonant frequency of the parallel tuned circuit using the following formula, and given the capacitance (C) of C2 and the inductance (L) of L1 as follows:

$$C = 25\text{pf}$$

$$L = 1.3765\mu\text{h}$$

$$F = {}^{1}/_{6.28\sqrt{LC}}$$

____

____

____

____

F = __________ MHz

Your answer should be the same as the one given in ANSWERS on page 67.

__3. This completes the Circuit Exploration for this stage. Have your instructor initial your Knowledge Transfer Guide.

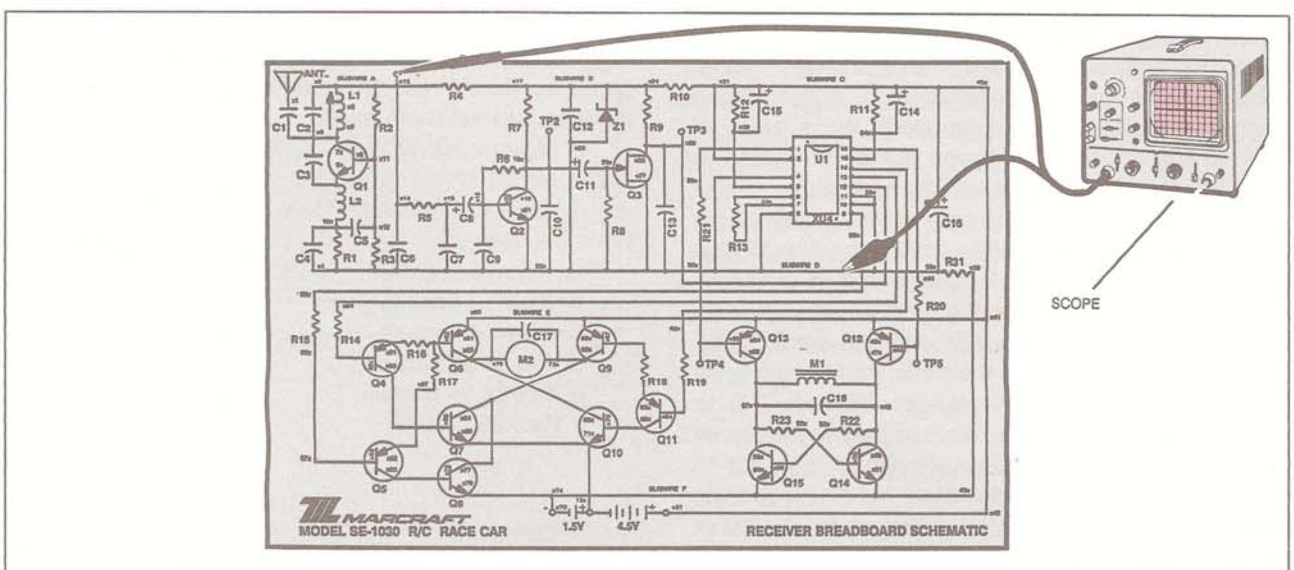


FIG. 38

AF AMPLIFIER STAGE

Discussion

The function of this stage is to amplify the AF signal from the detector to proper levels for driving the decoder stage. The schematic diagram of this stage is shown in Fig. 39.

The AF amplifier consists of two cascaded transistor amplifiers (Q2 and Q3) and associated components. The squarewave signal from the detector, referred to as the control signal, is coupled through a low-pass filter (R5 and C7) and a frequncy sensitive voltage divider (C8 and C9) to the base of Q2.

Transistor Q2 is operated in Class-A mode. This class of amplifier conducts current even when no input signal is applied. The BIASING circuitry configured around the transistor determines its no-input (quiescent) operating point. Since the amplifier is on constantly, Class-A is much less power efficient than the Class-C amplifier described in the transmitter section. The advantage of this type of amplifier is that the output signal can swing both POSITIVE AND NEGATIVE with respect to the quiescent point. Therefore, the signal can be amplified and passed through the amplifier with a minimum of distortion. The quiescent dc voltage level is stripped from the signal by the coupling capacitor (C11) in the signal path between the amplifier stages. Only the ac signal can pass through this capacitor to the next stage.

The output of the first amplifier is fed into the input (cascaded) of the second amplifier. The second amplifier stage is constructed around a special type of transistor called a FIELD EFFECT TRANSISTOR (FET). In operation, the FET is similar the more familiar bi-polar transistor. Differences in construction give it advantages over the bi-polar transistor in some applications. FETs have extremely high input impedance characteristics and very low noise output capability. This makes them useful where distortion must be minimized.

This FET amplifier is operated in (zero-bias) mode. In this mode, it will act as an ON/OFF switch whose quiescent condition is ON (saturated). When an input signal is applied, the FET drops out of saturation to produce pulses for input to the decoder stage.

Resistor R6 provides ac degenerative feedback from the collector of Q2, in order to control the overall gain of the stage. This type of feedback (out of phase) is commonly used to control the gain of amplifiers to some desired level. Resistors R4 and R10 are DECOUPLING resistors that isolate the three stages from each other (in conjuntion with capacitors C8 and C11) to prevent unwanted feedback between the stages. Zener diode Z1 acts as a simple shunt voltage regulator to maintain a constant voltage level to the amplifiers. Capacitor C12 acts as a filter capacitor for the zener regulator in this stage.

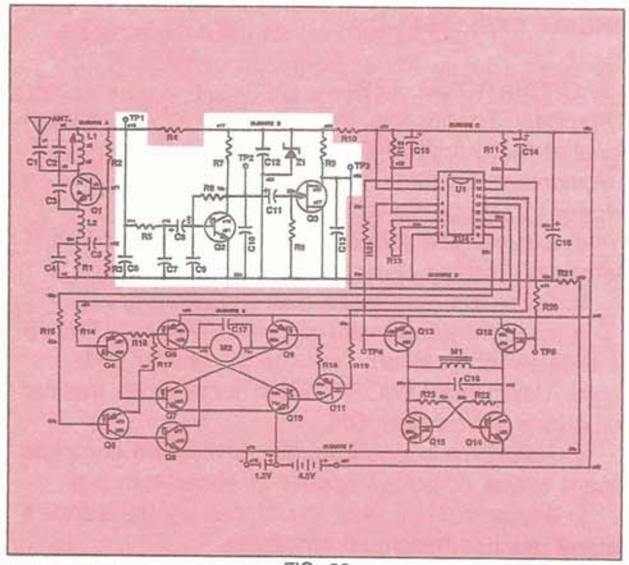


FIG. 39

CIRCUIT CONSTRUCTION

PARTS LIST

_R5 Resistor, 1KΩ
_R6 Resistor, 330KΩ
_R7 Resistor, 10KΩ
_R8 Resistor, 680KΩ
_R9 Resistor, 10KΩ
_C6 Capacitor, 0.01μf *mylar* ("103")
_C7 Capacitor, 0.005μf ("502")
_C8 Capacitor, electrolytic, 2.2μf 50v
_C9 Capacitor, 0.005μf ("502")
_C10 Capacitor, 0.005μf ("502")
_C11 Capacitor, electrolytic, 2.2μf 50v
_C12 Capacitor, electrolytic, 100μf 10v
_Q2 Transistor, NPN
_Q3 Transistor, N-channel FET
_Z1 Zener diode, BZX790 2V4

_1. The components shown in the above Parts List comprise the AF amplifier stage. Identify these components and set them aside.

_2. Using insulated wire, connect a jumper wire between pin 23 on the bread board and Buswire D.

_3. Using bare wire, connect and solder jumper wires between the following points on the breadboard.

_a. Pins 13 and 14
_b. Pins 16 and 20
_c. Pins 18 and 19
_d. Pin 21 to Buswire D
_e. Pin 27 to Buswire D
_f. Pins 25 and 28

__4. Solder the following resistors into the circuit.
__a. R5, 1KΩ
__b. R6, 330KΩ
__c. R7, 10KΩ
__d. R8, 680KΩ
__e. R9, 10KΩ

__5. Solder the following capacitors into the circuit. Be certain to observe proper polarity when installing the electrolytic capacitors.
__a. C6, 0.01μf *mylar* ("103")
__b. C7, 0.005μf ("502")
__c. C8, electrolytic, 2.2μf
__d. C9, 0.005μf ("502")
__e. C10, 0.005μf ("502")
__f. C11, electrolytic, 2.2μf
__g. C12, electrolytic, 100μf ("+" to Buswire B)

__6. Solder zener diode Z1 into the circuit, observing polarity. The banded end indicates the cathode lead and corresponds to the crooked line in the symbol.

__7. Tin the leads of the following transistors and solder them into the circuit, observing proper lead positioning (See Fig. 40 for lead identification information about the FET transistor).
__a. Q2,
__b. Q3,

__8. This completes the construction portion of this stage. Confirm your component placement, wiring and solder connections.

__9. Have your instructor initial your Knowledge Transfer Guide.

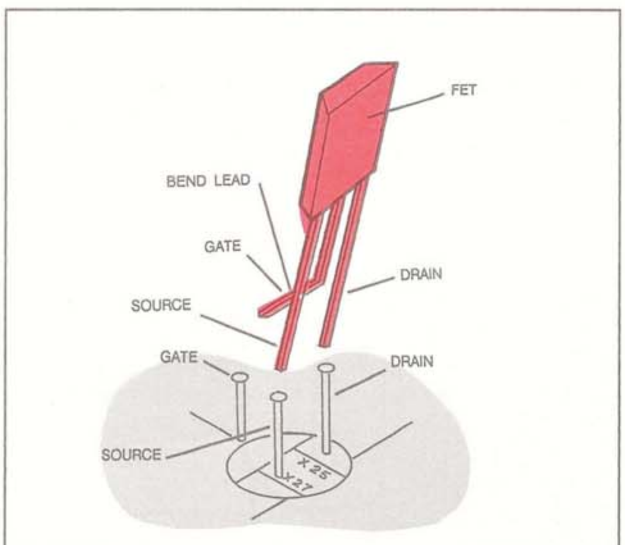
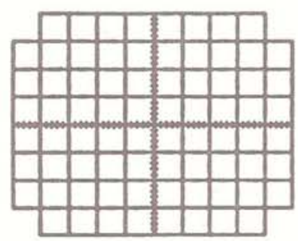


FIG. 40

CIRCUIT EXPLORATION

__1. OPERATIONAL TEST
Purpose: To determine if this stage is functioning properly.
Equipment: AF signal generator, Oscilloscope
__a. Connect the generator leads to Test Point TP1 and Buswire D.
__b. Connect the scope probe to Test Point TP3 and the ground lead to Buswire D. Set the scope controls for 2 ms/cm and 1 V/cm.
__c. Turn the receiver ON. DO NOT turn the transmitter on.
__d. Set the generator's output for 400Hz squarewave at minimum amplitude.
__e. Adjust the generator's output until the signal appears on the scope display. This should require only a small amount of adjustment. If the signal fails to appear, refer to **TROUBLESHOOTING** on page 60.
__f. Record the appearance of the signal from the scope display.
__g. Disconnect the generator from the circuit. The display should disappear. Turn the receiver OFF



__2. VOLTAGE GAIN MEASUREMENT
Purpose: To determine the voltage gain of the AF amplifier stages. This is accomplished by measuring the signal voltages at Test Points TP1 and TP2 and then comparing them to the input signal voltage applied to the stage.
Equipment: AF signal generator, multimeter
Refer to Fig. 41 for this test.
__a. Connect the multimeter measuring (positive) lead to pin 15 on the breadboard and its reference (negative) lead to Buswire D.
__b. Set the multimeter to an acV range capable of measuring 6V.
__c. Connect the signal generator leads to Test Point TP1 and Buswire D.
__d. Adjust the signal generator for a 400Hz squarewave output at minimum amplitude.
__e. Turn the receiver ON.

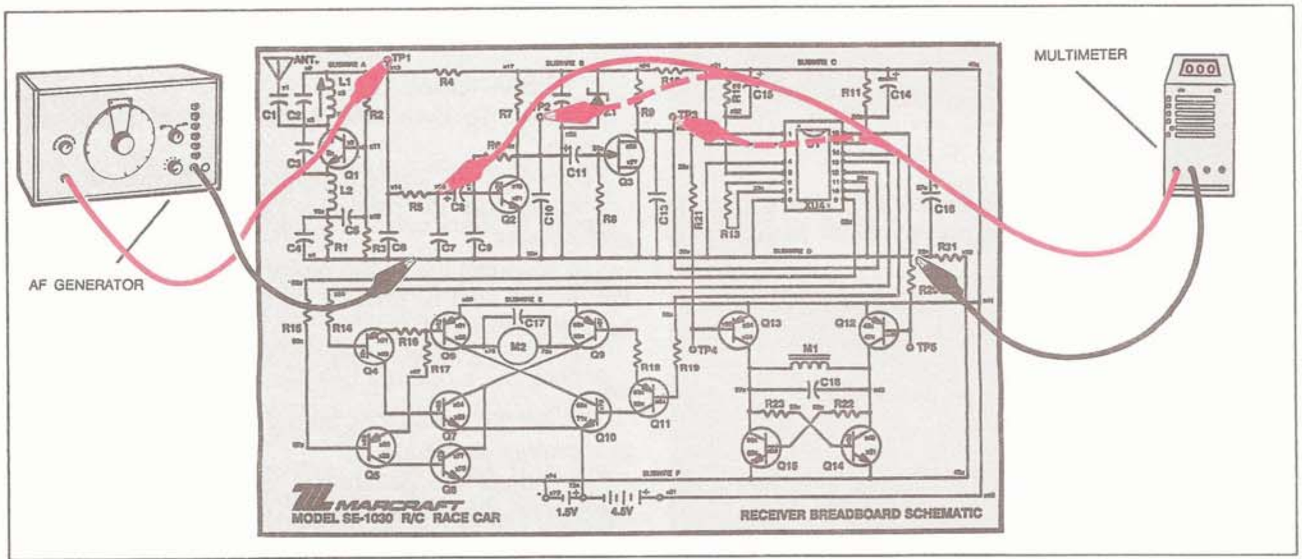


FIG. 41

__f. Slowly increase the generator's output level until a 1.0V reading is obtained.

__g. Move the meter's measuring lead to Test Point TP2 and record the reading below.

Vtp2 = ___

__h. Move the meter's measuring lead to Test Point TP3 and record the reading below.

Vtp3 = ___

__i. Calculate the voltage gain (A) of each stage by dividing the output voltage by the input voltage.

$A2 = {}^{Vtp2}/_{1.0}$

A2 = ___

$A3 = {}^{Vtp3}/_{Vtp2}$

A3 = ___

__j. Turn the receiver OFF.

__k. Remove the signal generator's leads from the circuit. Leave the meter connected to the circuit for the next section of the Circuit Exploration.

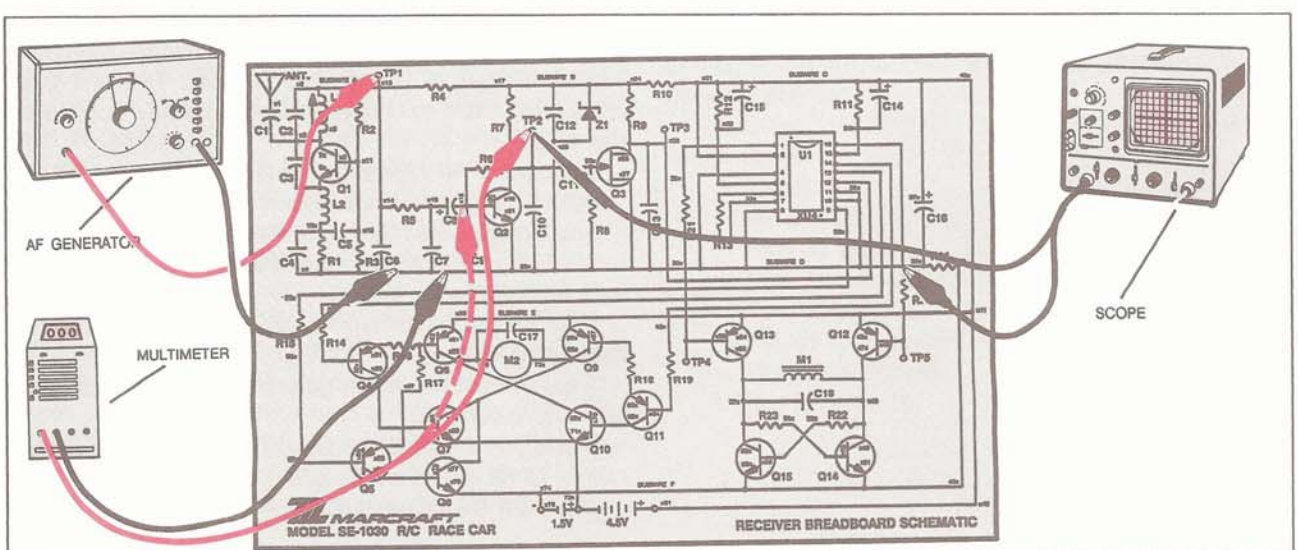


FIG. 42

__3. CLASS A AMPLIFIER TEST

Purpose: To demonstrate the biasing scheme for a Class A amplifier as described in the Circuit Discussion section.

Equipment: AF signal generator, multimeter, oscilloscope

Refer to Fig. 42 for this test.

__a. Set the multimeter to a dcV range suitable for measuring a 2V signal.

__b. Move the measuring lead of the meter to Test Point TP2.

__c. Turn the receiver ON.

__d. Read the meter and record the value below.

Vce = ___________

__e. Move the meter's measuring lead to pin 16 on the breadboard (the base lead of Q2).

__f. Read the meter and record its value below.

Vbe = _________

__g. Set the AF generator for a 400Hz squarewave output at minimum output amplitude.

__h. Connect the generator to TP1 and Buswire D.

__i. Connect the scope probe to TP2 and its ground lead to Buswire D.

__j. Increase the generator's output until a 1V p-p signal is present on the display.

__k. Read and record the dc value shown by the meter.

Vbe = _________

Notice that the voltage has remained nearly the same as in Step 3f.

__l. Move the meter's measuring lead to Test Point TP2.

__m. Read and record the dc value from the meter.

Vce = _________

Notice that the collector voltage has remained about the same as in Step 3d. This shows that the transistor is biased into conduction at all times, regardless of an input signal.

__n. Turn the car OFF.

__4. This completes the Circuit Exploration for this stage. Have your instructor initial your Knowledge Transfer Guide.

DECODER/DEMODULATOR STAGE

Discussion

The function of this stage is to accept the encoded, pulse width modulated signal from the AF Amplifier and convert it into individual dc control signals to govern the operation of the car's drive and steering motors. This function is largely enbodied in a single IC Decoder circuit. This IC is designed to be the compliment of the IC Encoder chip used in the transmitter. Fig. 43 shows the schematic diagram for this stage. It consists of IC U1 and related components. When the transmitter sends a pulse train containing a coded pulse, the receiver accepts the transmitted signal, demodulates it, and applies a re-generated pulse train to the Decoder IC's data input pin.

The START pulses, which the transmitter places at the beginning of each pulse train, cause a timing circuit inside the Decoder IC to synchronize with the incoming pulses (See Fig. 44). After counting each of the START pulses, the IC begins sampling the width of each of the information pulses and storing their values in the form of high and low voltages. These values are held in a special HOLDING register inside the IC. The output of each section of the register corresponds to one of the IC's output pins. In other words, if the third information pulse in the pulse train had a short duration, then output pin D3 would pulse to a low voltage level. In addition, D3 would pulse to this low voltage level each time a pulse train containing a short D3 pulse was received. The same situation holds true for each of the information pulses and its corresponding output pin.

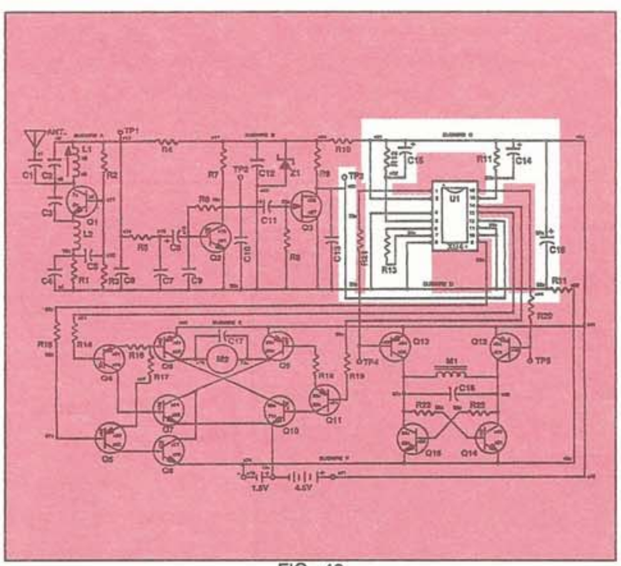


FIG. 43

The operation of the IC's internal circuitry is governed by two external R/C timing circuits. These are R11/C14 (T1) and R12/C15 (T2). Power for the IC's internal circuitry is delivered through pin #2 and circuit ground is supplied at pin #8. An external programming resistor (R13) is used to govern the operation of the Decoder's internal oscillator.

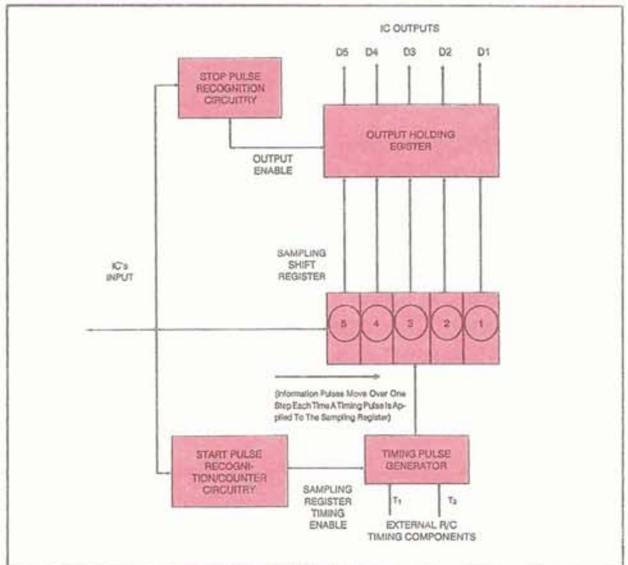


FIG. 44

Capacitor C13 provides signal filtering between the output of the AF Amplifier stage and the data input of the Encoder IC. Capacitor C16 provides power supply filtering for the four 1.5V batteries.

CIRCUIT CONSTRUCTION

PARTS LIST

- __R11 Resistor, 3.3KΩ
- __R12 Resistor, 10KΩ
- __R13 Resistor, 470KΩ
- __C13 Capacitor, 0.001μf ("102")
- __C14 Capacitor, electrolytic, 1μf 50V
- __C15 Capacitor, electrolytic, 10μf 25V
- __C16 Capacitor, electrolytic, 220μf 10V
- __W1 Hookup wire, bare
- __W2 Hookup wire, insulated
- __XU4 16-pin IC socket
- __U1 IC receiver FRC-02R
- __MP9 Breadboard pin (5)
- __MP10 Test socket assembly board

__1. The components shown in the Parts List above are necessary to construct the IC Decoder stage of your receiver. Identify these components and set them aside.

__2. Solder the 16-pin IC socket onto the Test socket assembly board.

__3. Insert breadboard pins in locations 44, 62 and 94 on the breadboard.

__4. Using insulated hookup wire, solder jumper wires to the solder pads associated with the following pins of the IC test socket assembly. Cut the wires to the approximate lengths indicated by the schematic diagram. DO NOT solder the other ends of the wires to their corresponding points on the breadboard at this time.

__a. Pin 12 of the test socket assembly to pin 28 on the breadboard.

__b. Pin 15 of the test socket assembly to pin 34 on the breadboard.

__c. Pin 5 of the test socket assembly to pin 32 on the breadboard.

__d. Pin 7 of the test socket assembly to pin 33 on the breadboard.

__e. Pin 2 of the test socket assembly to Buswire C.

__f. Pin 4 of the test socket assembly to Buswire D.

__5. Using insulated hookup wire, solder jumper wires to the solder pads of the IC test socket assembly which correspond to the following output pins of the Decoder IC. Cut the wires to the approximate lengths as indicated by the schematic diagram. DO NOT solder the free ends of the wires to their designated pins on the breadboard at this time.

__a. D2 (pin 1) to pin 29

__b. D3 (pin 16) to pin 44

__c. D4 (pin 14) to pin 62

__d. D5 (pin 13) to pin 94

__e. D6 (pin 9) to pin 36

__6. Using bare hookup wire, solder jumper wires to pins 8,10 and 11 of the IC test socket assembly. Cut the wires to the approximate length indicated by the schematic diagram. DO NOT solder the wires to Buswire D at this time.

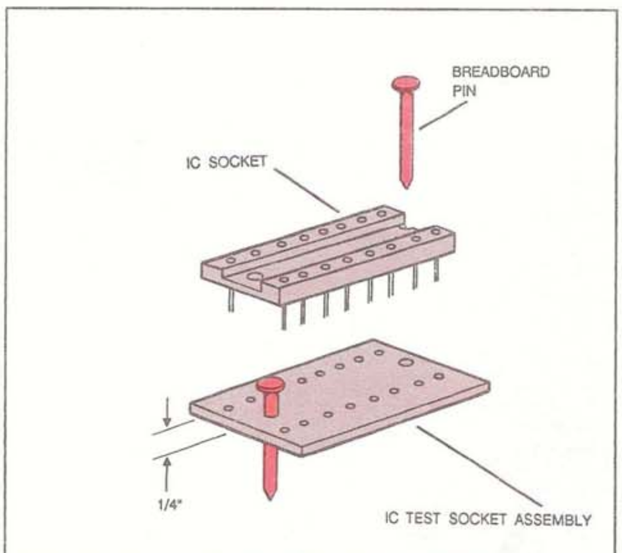


FIG. 45

__7. Mount the IC test socket assembly on the breadboard, as depicted in Fig. 45. DO NOT mount the IC in the socket at this time.

__a. Insert two breadboard pins into the designated holes in the IC Test Socket Assembly. Insert these pins from the NON-FOIL side of the board. The top of each pin should extend 1/4" (5mm) above the board.

__b. Solder the two pins on the FOIL side of the Test Socket's board.

__8. Solder the free ends of the wires listed in steps 4 through 6 to their designated points in the circuit.

__9. Using bare hookup wire, solder jumper wires between the following points on the breadboard.

__a. Pin 35 and Buswire D.

__b. Pin 37 and Buswire C.

__10. Connect and solder the following resistors into the circuit.

__a. R11, 3.3KΩ

__b. R12, 10KΩ

__c. R13, 470KΩ

__11. Connect and solder the following capacitors into the circuit. Make sure to observe proper polarity when installing electrolytic capacitors.

__a. C13, 0.001μf ("102")

__b. C14, 1μf electrolytic

__c. C15, 10μf electrolytic

__d. C16, 220μf electrolytic

__12. Install the IC (U1) in the test socket assembly. Make certain to align the IC with pin #1 adjacent with the pin #1 position on the assembly. Take care to avoid bending any of the IC's pins under. Use proper IC handling techniques.

__13. This completes the construction of this stage. Confirm your component placement, wiring and solder connections.

__14. Have your instructor initial your knowledge transfer guide.

CIRCUIT EXPLORATION

__1. OPERATIONAL TEST

Purpose: To determine if this stage is functioning properly.

Equipment: Oscilloscope

Refer to Fig. 46 for this test.

__a. Connect the scope's ground lead to Buswire D.

__b. Turn the receiver ON using the slide switch in the car body.

__c. Adjust the scope controls so that you can read and record the voltage CONDITIONS at the following pins of the IC. Simply record whether the pin is in a High, Low, or Pulsing condition.

__1. Pin 1 (D2) _____
__2. Pin 16 (D3) _____
__3. Pin 14 (D4) _____
__4. Pin 13 (D5) _____
__5. Pin 9 (D6) _____

__d. Place the transmitter breadboard near the receiver, so that their antenna wires are about 6" (15cm) apart.

__e. Turn the transmitter ON by connecting a jumper across the S1 slide-switch position. Be sure the battery is still connected.

__f. Re-read and record the voltage conditions at the output pins of the IC.

__1. Pin 1 (D2) _____
__2. Pin 16 (D3) _____
__3. Pin 14 (D4) _____
__4. Pin 13 (D5) _____
__5. Pin 9 (D6) _____

__g. Use a jumper wire to short each of the Encoder IC's input pins (D2-D5 ON THE TRANSMITTER breadboard) to ground (Buswire B), one at a time, as directed in the following table. Record the conditions generated at the Decoder IC's output pins (D2-D6 ON THE RECEIVER breadboard) for each input pin shorted to ground.

__h. Turn the transmitter OFF by removing the jumper wire from the S1 slide-switch position.

__i. Turn the receiver OFF.

__j. CAREFULLY remove IC U1 from the Test Socket Assembly.

__k. This concludes the Circuit Exploration for this stage. Have your instructor initial your Knowledge Transfer Guide.

ENCODER INPUT PIN	DECODER OUTPUT PINS				
	D2(pin 1)	D3(pin 16)	D4(pin 14)	D5(pin 13)	D6(pin 9)
D2(pin 3)					
D3(pin 4)					
D4(pin 5)					
D5(pin 6)					
D6(pin 7)					

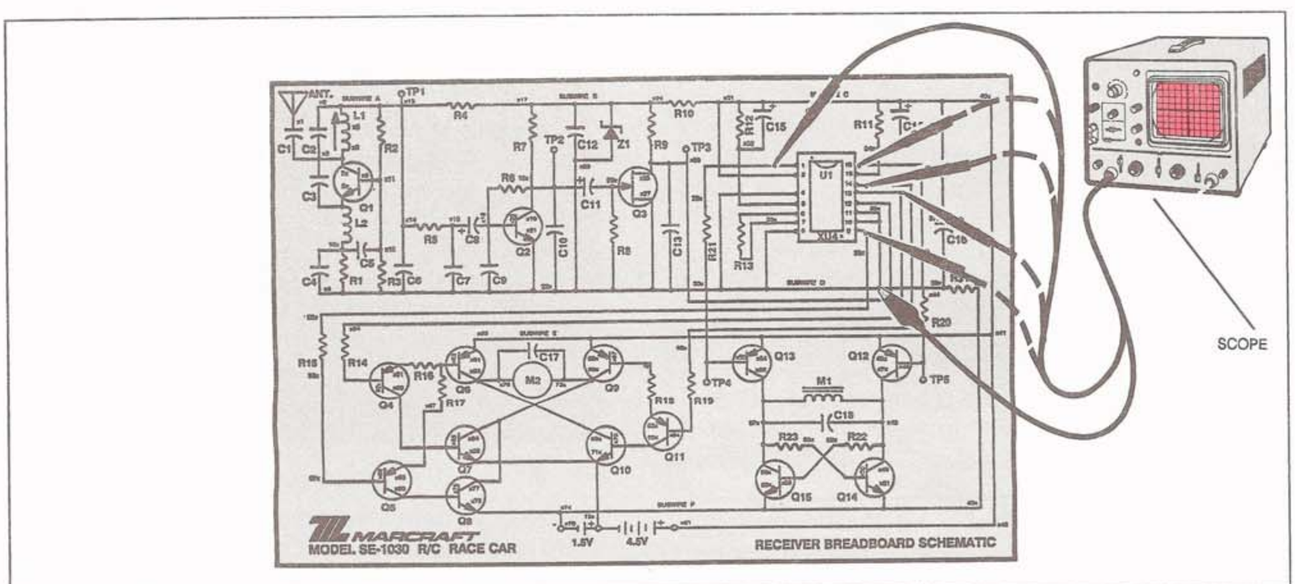


FIG. 46

STEERING ACTUATOR AMPLIFIER/ CONTROLLER STAGE

Discussion

The function of this stage is to control the operation of the car's steering mechanism. This is accomplished by using two of the output signals from the Decoder/Demodulator (D2 and D3) to control the direction of current flow through the inductive steering actuator, which in turn, positions the car's mechanical steering arm. The stage is also considered an amplifier (or DRIVER) stage since it is responsible for delivering enough current to the actuator to operate it. A common characteristic of IC devices is that they often lack the current handling capabilities to drive heavy loads such as motors and other inductors. Therefore, its common to use DRIVER TRANSISTORS to control load devices rather than having the IC control it directly.

The car's steering actuator is an electro-mechanical, solenoid-like device designed to provide limited turning ability. The actuator consists of a large PERMANENT MAGNET (one that maintains its magnetic properties at all times) bent into a ring, an electromagnet, and a motion limiting spring. These components are illustrated in Fig. 47. The magnet produces invisible magnetic force lines called FLUX LINES that run from the NORTH end (POLE) of the magnet to its SOUTH pole and form a magnetic field around the magnet that possesses both force and direction (POLARITY).

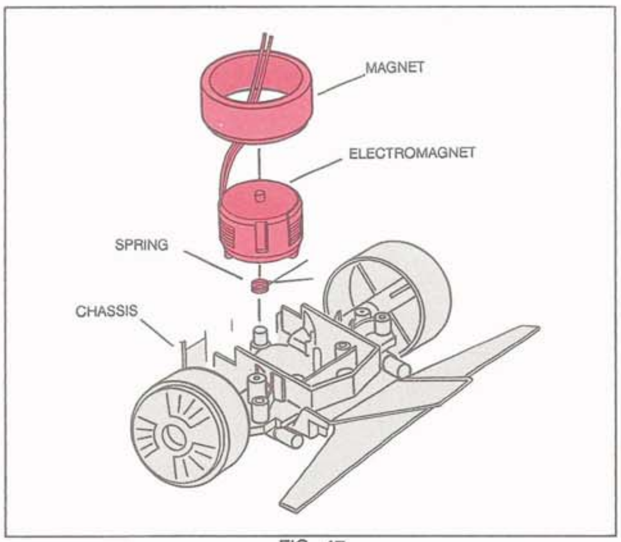


FIG. 47

A magnetic field can also be generated by passing an electrical current through a conductor. The current generates flux lines at right angles to its direction of flow, as depicted in Fig. 48. The magnetic polarity established by the flux lines depends on the direction in which the current is passed through the conductor. Magnetic fields generated in this manner are referred to as ELECTROMAGNETIC FIELDS and the devices used to generate them are called temporary or ELECTRO magnets (since the magnetic field wears off shortly after the current is removed from the conductor).

The two types of magnetic fields are compatible with each other and, therefore, can interact with each other. Objects with similar magnetic fields tend to REPEL each other while objects having magnetic field with opposite polarities ATTRACT each other.

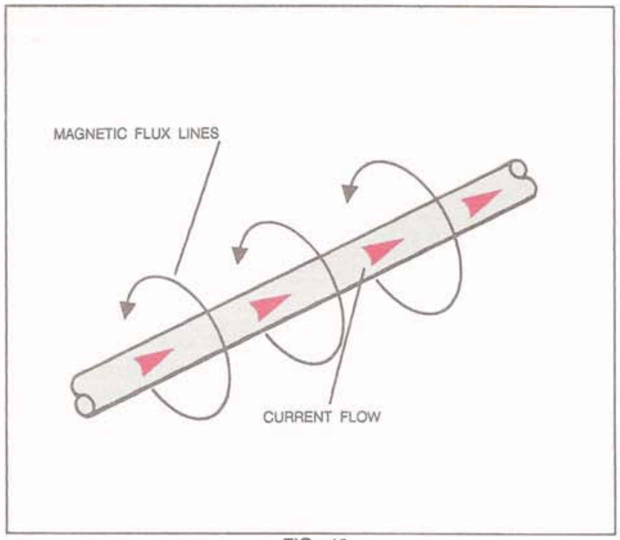


FIG. 48

In the actuator, the electromagnet is free to turn through a limited distance. Steering motion is generated by passing a direct current through the electromagnet. The magnetic field generated by the current flow will be ATTRACTED to either the NORTH or SOUTH pole of the permanent magnet, depending on the polarity of the electromagnetic field. This attraction will cause the actuator to turn, moving the steering linkage, which, controls the position of the wheels.

If the direction of the current in the actuator is reversed; the polarity of the electromagnetic field will reverse, the electromagnet will be attracted to the opposite permanent magnet pole, the actuator will turn in the opposite direction, and the wheels will point in the opposite direction. When no turning signal is applied to the control circuitry, the wheels are held in a staight-ahead position by a retaining spring.

Fig. 49 shows a schematic diagram of the actuator control circuitry. It consists of the actuator (M1), a differential amplifier, and related components.

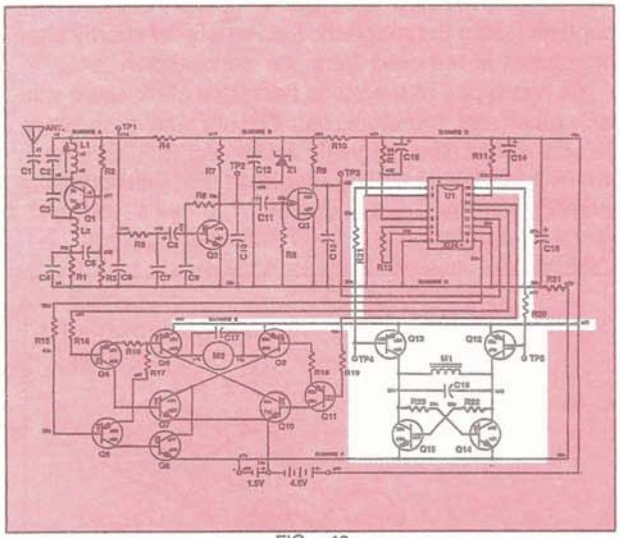


FIG. 49

In the Steering Actuator Amplifier/Controller stage, the current reversal process is accomplished by reversing the RELATIVE voltage polarities at the D2 and D3 inputs of transistors Q12 and Q13. Looking at the arrangement of the differential amplifier as it's drawn, it should not be difficult to realize that the circuit consists of two equally matched sides with the actuator between them.

Recall that the output signals from the Decoder IC were only high voltage levels that momentarily pulse to a low voltage level when activated. In order to make the actuator turn, a difference of potential must be created across it. When no switches have been activated in the transmitter, the output from the Decoder is such that the voltage levels at both bases are high and both transistors (Q12 and Q13) are turned OFF. Because the two halves of the circuit are balanced and because they're both cut off, no current can flow in either half and no voltage difference exists across the actuator.

If the voltage at the Decoder's D2 output pulses to a low level while the output at D3 stays at a high level, as illustrated in Fig. 50(a), transistor Q13 will forward bias and start conducting current. This action will cause the collector of Q13 to approach Vcc. The condition at the collector does two things. First, it is applied to the base of transistor Q14, forward biasing it and, thereby, dropping its collector voltage to near ground potential. Secondly, the high level of voltage causes a difference of potential to exist across the actuator and electron current will flow through the it, from the right side of the circuit to the left side. This will cause the steering mechanism to turn in a given direction.

If the relative polarities are reversed (D2 is high while D3 drops low, part b of Fig. 50), then the opposite transistors are activated and current will flow in the opposite direction through the circuit and the actuator. Therefore, the car will turn in the opposite direction from that stated in the preceding paragraph.

If both D2 and D3 were to drop to a low voltage level at the same time, whichever side had the transistor with the fastest reaction time would overpower the other side and gain control of the circuit. Capacitor C18 acts as a filter to prevent "motor noise", created by the inductive kickback of switching the actuator ON and OFF, from entering the circuit.

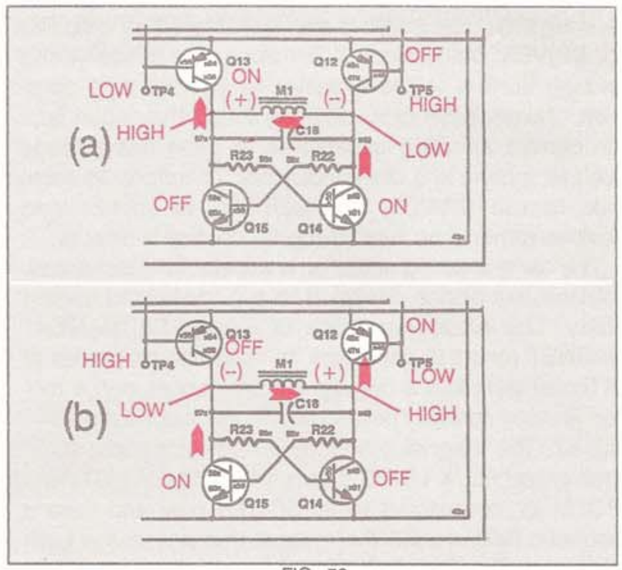


FIG. 50

CIRCUIT CONSTRUCTION

PARTS LIST

- _R20 Resistor, 680Ω
- _R21 Resistor, 680Ω
- _R22 Resistor, 270Ω
- _R23 Resistor, 270Ω
- _C18 Capacitor, disc, 0.02μf ("203")
- _Q12 Transistor, PNP
- _Q13 Transistor, PNP
- _Q14 Transistor, NPN
- _Q15 Transistor, NPN
- _MP9 Breadboard pin (47)

_1. The components described in the Parts List above comprise the Steering Actuator Amplifier/Controller stage. Identify these components and set them aside.

_2. Insert forty-seven (47) breadboard pins into the lower section of the receiver breadboard, with one located at each position indicated by a numbered "X" on the schematic from 45 to 97 (excluding pins 61, 62, 74, 75 and 94).

_3. Using bare hookup wire, connect pins 41 and

80 on the breadboard to form Buswire E in the lower half of the receiver's circuitry.

__4. Using insulated hookup wire, connect and solder the following pins on the breadboard.

__a. Pins 30 and 55

__b. Pins 50 and 53

__5. Using bare hookup wire, connect and solder jumper wires between the following pins on the breadboard.

__a. Pins 52 and 59

__b. Pins 47, 48 and 49

__c. Pins 56, 57 and 58

__d. Pins 45 and 54 to Buswire E

__e. Pins 51 and 60 to Buswire F

__6. Connect and solder the following resistors into the circuit.

__a. R20, 680Ω

__b. R21, 680Ω

__c. R22, 270Ω

__d. R23, 270Ω

__7. Connect and solder capacitor C18 (0.02μf) into the circuit.

__8. Tin the leads of the following transistors and then solder them into the circuit.

__a. Q12

__b. Q13

__c. Q14

__d. Q15

__9. Connect the WHITE and RED steering actuator leads (from the car chassis) to breadboard pins 48 and 57 respectively.

__10. This completes the construction of this stage. Confirm your component placement, wiring and solder connections.

__11. Have your instructor initial your Knowledge Transfer Guide.

CIRCUIT EXPLORATION

__1. OPERATIONAL TEST

Purpose: To determine if this stage is functioning properly.

Equipment: Oscilloscope

Refer to Fig. 51 for this test.

__a. Connect the scope's ground lead to Buswire F.

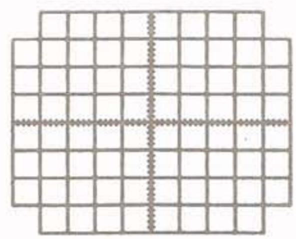
__b. Connect the scope probe to Test Point TP4 and adjust the controls to 10ms/cm and 2$^{V}/_{cm}$. Also, set the scope's ground reference point so that dc voltage levels can be read

__c. Manually position the front wheels of the car so that they are pointing straight ahead.

__d. Turn the receiver ON using the ON/OFF slide-switch in the car's chassis.

__e. Turn the transmitter ON by placing a jumper wire across the S1 slide-switch position on the breadboard.

__f. Draw the waveform from the scope display.



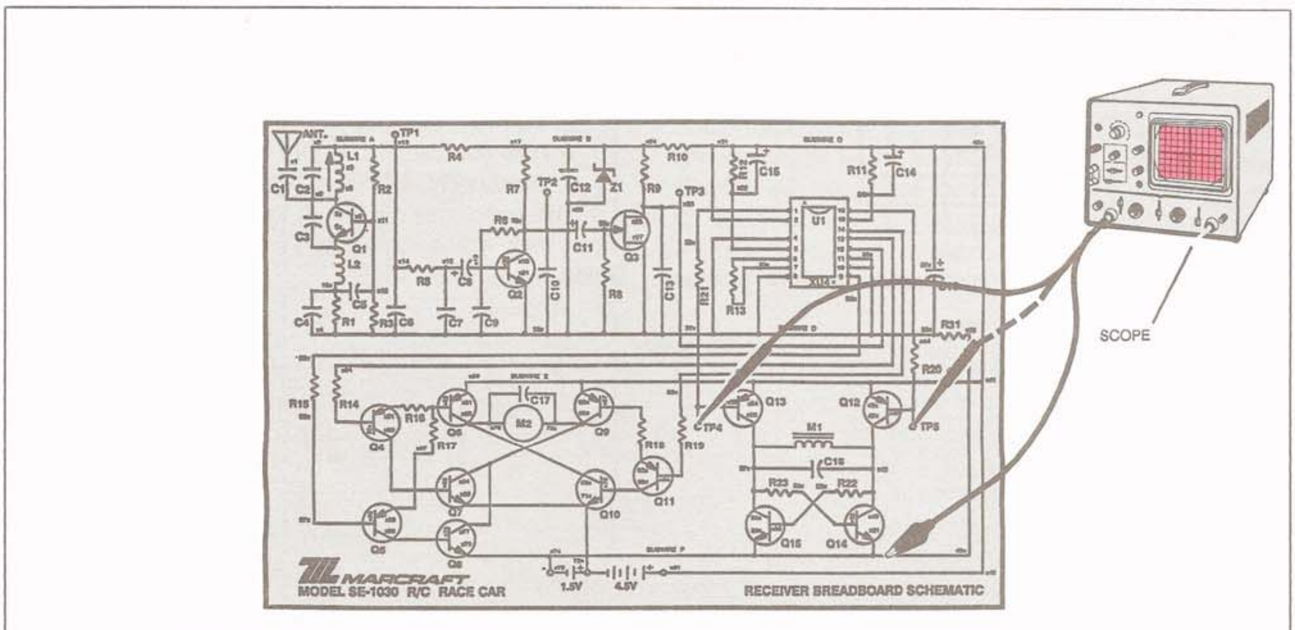
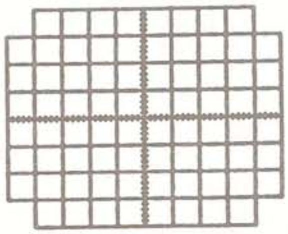


FIG. 51

__g. Use a jumper wire to short pin 3 of the TRANSMITTER'S Encoder IC (U2) to Buswire B on the transmitter breadboard.

__h. Draw the waveform from the scope display.

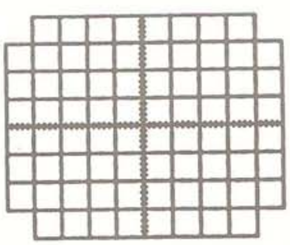


__i. Note the direction in which the wheels on the car turn.

____

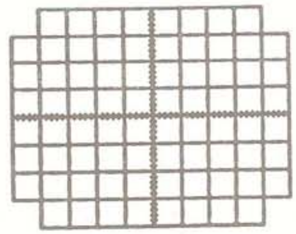
__j. Move the jumper from pin 3 to pin 4 of the TRANSMITTER'S Encoder IC.

__k. Draw the TP4 waveform from the scope display.



__l. Move the scope probe to Test Point TP5.

__m. Draw the waveform from the scope display.

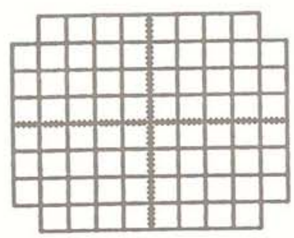


__n. Note the direction in which the car's wheels turn on the line below.

____

__o. Remove the jumper from pin 4 of the transmitter's Encoder IC.

__p. Draw the waveform from the scope display.



__q. Turn the car OFF.

__r. Turn the transmitter OFF

__s. Disconnect the scope leads from the circuit.

__2. This concludes the Circuit Exploration for this stage. Have your instructor initial your Knowledge Transfer Guide.

DRIVE MOTOR AMPLIFIER/ CONTROLLER STAGE

Discussion

The purpose of this stage is very similar to that of the Steering Actuator Amplifier/Controller stage. It must accept decoded control signals from the Decoder/Demodulator stage and produce sufficient current in the proper direction to operate the car's drive motor in the desired direction. It is somewhat different than the steering actuator stage in that it controls a dc motor. In addition, the drive motor control circuitry also provides a special TURBO action, which makes the car run at a faster speed when requested by the hand-held controller (transmitter).

A direct current (dc) motor is used for the drive motor in this project. The operation of a dc motor is based on the magnetic principle that *like magnetic* (or electromagnetic) *fields repel each other* and *unlike fields attract each other*. This is illustrated in Fig. 52. In part (a) of the figure, the field created around the conductor (by the current flowing in it) is of the same polarity as the field at the bottom of the pole pieces (because both of their fields are moving in the same directions, as indicated by the arrow tips) and opposing the polarity of the top pole piece. This creates a rotational force called TORQUE in the conductor, forcing it UP. If the current in the conductor is reversed as depicted in part (b) of the figure, the direction of the flux lines around the conductor is also reversed and the torque is produced in the opposite direction. The induced torque forces the conductor to rotate in the DOWNWARD direction. This is the underlying principle of motor action.

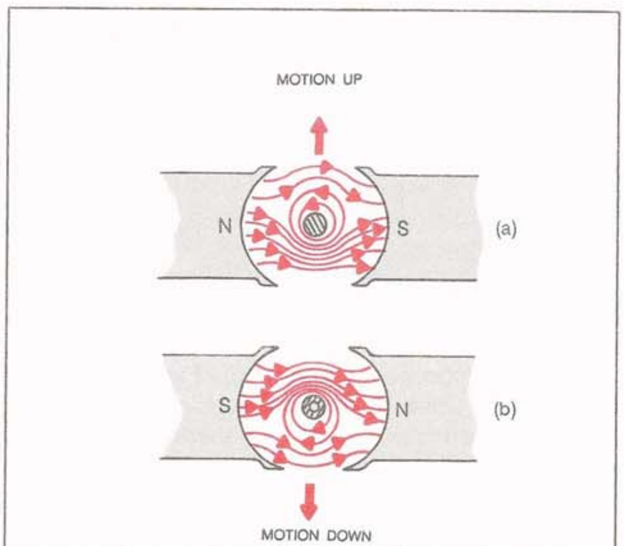


FIG. 52

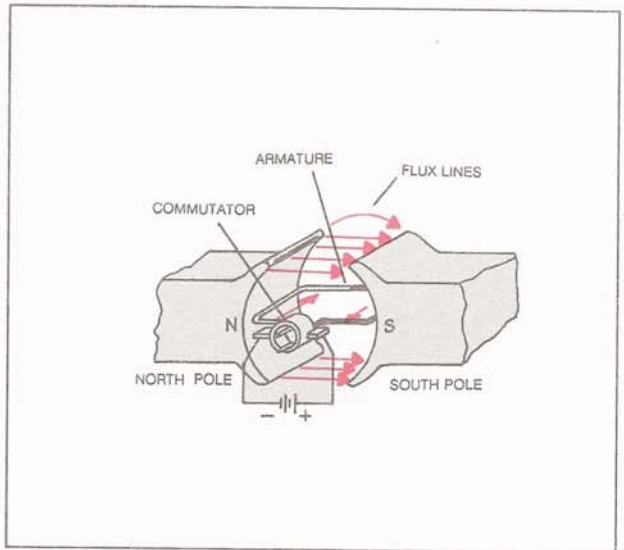


FIG. 53

The essential parts of a simple dc motor are depicted in Fig. 53. A loop of wire acting as an ARMATURE (bearings not shown) is designed to rotate in the field of magnetic flux lines created by a pair of permanent magnets (FIELD POLES). The ends of the loop are connected to a commutator-brush assembly that allows the battery to apply current to the armature while it rotates. The COMMUTATORS are electrical contact points on the rotating armature. The BRUSHES are the fixed electrical contacts that ride on the turning shaft of the armature and make contact with the bars of the commutator. The flux created by the armature current creates a torque and the armature begins to rotate. It might seem that the armature would stop when it rotated 90 degrees from its indicated starting position (because of the break in the commutator). However, the armature's INERTIA (built-up force) causes it to continue to rotate past the break and causes both brushes to contact the other commutator contact.

This action will cause the armature to continue to rotate through the other half of the field since the direction of current in the armature has been changed over. Current still flows into the LEFT-HAND brush and out of the RIGHT-HAND brush. In order to reverse the motor's direction of rotation, the polarity of the voltage applied to the brushes must be reversed.

The circuitry for this stage is depicted in schematic form in Fig. 54. It is similar to the Steering Actuator circuitry in that it basically consists of a differential amplifier. In contrast to the steering circuit, the IC Decoder chip does not drive the differential amplifier directly. Instead, another pair of driver transistors (Q4 and Q11) are used to control the differential amplifier.

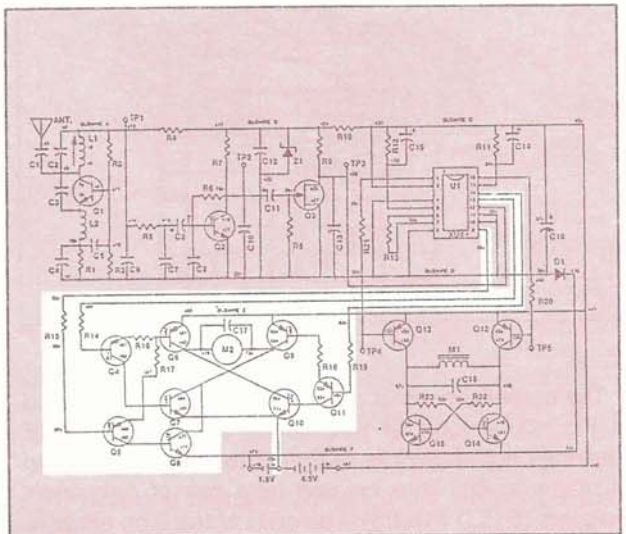


FIG. 54

During normal operation of the car, this stage funtions using only 4.5 volts (3 batteries). When TURBO speed is selected on the hand-held controller/transmitter, the turbo portion of the circuit (Q5 and Q8) shifts the car's full 6 volt supply to the circuit, causing the motor to run faster.

This Drive Motor Amplifier/Controller circuit can be functionally divided into three sub-sections; the FORWARD circuitry (consisting of transistors Q4, Q6, and Q7), the REVERSE circuitry (consisting of transistors Q9, Q10, and Q11), and the TURBO circuitry (consisting of transistors Q5 and Q8). The operation of the circuit is as follows.

If the Decoder IC pulses one of the direction control points to a low level of voltage, the transistors on that side of the circuit (as its drawn) are turned ON and a low resistance path for current flow is established through the motor.

When the forward direction is selected at the transmitter, the Decoder IC's D5 pin is pulsed to a low voltage level. This voltage level turns ON PNP transistor Q4. In turn, Q4 turns ON both PNP transistor Q6 and NPN transistor Q7. Therefore, a path for current flow is established from the emitter to the collector of Q7, through motor M2 from right-to-left, and from the collector to the emitter of Q6 (See Fig. 55). Transistors Q9-Q11 are all in an OFF condition during this time.

When the reverse direction is selected, D4 pulses low, transistors Q9 through Q11 are turned on, and the direction of current flow through the motor is reversed. This causes the drive motor and wheels to turn the opposite direction.

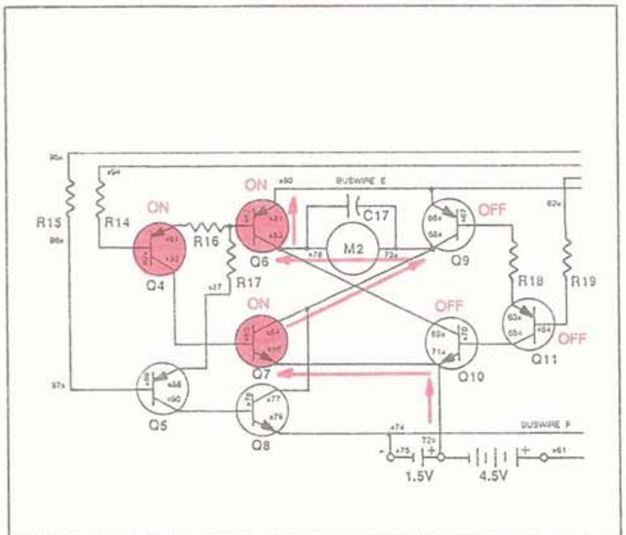


FIG. 55

If the transmitter is placed in the turbo position, D6 is activated and transistors Q5, Q6, and Q8 are turned ON. The circuit operation is identical to that described for forward motion except that the voltage (and therefeore the current) applied to the motor is higher. This causes the motor to turn faster.

CIRCUIT CONSTRUCTION

PARTS LIST

- __R14 Resistor, 1.8KΩ
- __R15 Resistor, 1.8KΩ
- __R16 Resistor, 100Ω
- __R17 Resistor, 100Ω
- __R18 Resistor, 100Ω
- __R19 Resistor, 1.8KΩ
- __Q4 Transistor, PNP
- __Q5 Transistor, PNP
- __Q6 Transistor, PNP
- __Q7 Transistor, NPN
- __Q8 Transistor, NPN
- __Q9 Transistor, PNP
- __Q10 Transistor, NPN
- __Q11 Transistor, PNP

__1. The components shown in the Parts List above comprise the Drive Motor Amplifier/Controller stage. Identify these components and set them aside. This is the final stage of construction.

__2. Connect and solder the ORANGE wire from the battery pack in the car's chassis to pin 72 on the breadboard.

__3. Using bare wire, connect and solder jumper wires between the following points.

__a. Pins 66 and 81 to Buswire E

__b. Pins 89, 96 and 97

__c. Pins 78 and 90

__d. Pins 68 and 84

__e. Pins 77 and 84

__f. Pins 85 and 93

__g. Pins 65 and 70

__h. Pins 68 and 73

__i. Pins 76 and 83

__4. Using insulated wire, connect and solder jumper wires between the following pins on the breadboard.

__a. Pin 71 and 72

__b. Pin 71 and 86

__c. Pin 69 and 83

__d. Pin 87 and 88

__e. Pin 36 and 95

__5. Solder the following resistors into the circuit.

__a. R14, 1.8KΩ

__b. R15, 1.8KΩ

__c. R16, 100Ω

__d. R17, 100Ω

__e. R18, 100Ω

__f. R19, 1.8KΩ

__6. Capacitor C17 (0.047μf) has already been installed across the drive motor at the factory.

__7. Tin the leads of the following transistors and solder them into the circuit. Observe proper lead positioning.

__a. Q4

__b. Q5

__c. Q6

__d. Q7

__e. Q8

__f. Q9

__g. Q10

__h. Q11

__8. Connect the BLACK and WHITE Drive motor leads from the car's chassis to pins 73 and 76 on the breadboard.

__9. This completes the construction of this stage and of the entire receiver breadboard. Confirm your component placement, wiring and solder connections.

__10. Have your instructor initial your Knowledge Transfer Guide.

CIRCUIT EXPLORATION

__1. OPERATIONAL TEST

Purpose: To determine if this stage is functioning properly.

Equipment: None

__a. Turn the transmitter ON by placing a jumper wire across the S1 slide-switch position.

__b. Turn the receiver ON using the slide-switch in the car's chassis.

__c. Place the transmitter breadboard near the receiver so their antenna wires are about 6" (15cm) apart.

__d. Using a jumper wire, short pin 5 of the IC Encoder (U2 ON THE TRANSMITTER breadboard) to Buswire B OF THE TRANSMITTER. *Note the response of car. If no apparent response is noted, check the transmitter and receiver's battery connections, THEN REFER TO TROUBLESHOOTING on page 60.*

____

__e. Move the jumper wire from pin 5 to pin 6 of the Encoder IC. Note the response of the car.

____

__f. Move the jumper wire from pin 6 to pin 7 of the Encoder IC. Note the response of the car.

____

__g. If the car's rear wheels did not move in the forward direction in steps e and f, reverse the positions of the BLACK and WHITE leads at pins 73 and 76 on the receiver breadboard.

__2. RECEIVER ALIGNMENT

Purpose: To maximize the reception of the transmitted signal.

Equipment: None

__a. Move the transmitter about 3' (1m) away from the receiver.

__b. The drive motor should continue to run. If it does not, use an alignment tool to adjust the slug in coil L1 until the motor runs.

__c. Move the transmitter farther away to determine the maximum transmitting range.

__d. Turn the transmitter OFF. The drive motor should stop running.

__e. Turn the receiver OFF.

__3. This completes the Circuit Exploration for this stage. This also completes the Breadboard Assembly portion of your project. Have your instructor initial your Knowledge Transfer Guide.

SECTION III

In Section III of your Knowledge Transfer Manual, you will be instructed to remove the components from the breadboards you've assembled and transfer them onto printed circuit (PC) boards. The PC boards will be tested and aligned, then mounted into their housings.

Section III is divided into the following sub-sections:

TRANSMITTER PC BOARD ASSEMBLY
TRANSMITTER ADJUSTMENT PROCEDURE
TRANSMITTER HOUSING ASSEMBLY
RECEIVER PC BOARD ASSEMBLY
RECEIVER ADJUSTMENT PROCEDURE
RECEIVER HOUSING ASSEMBLY

To facilitate the mounting of components on your PC boards, the component symbols and their numbers have been silkscreened onto the COMPONENT SIDE (non-foil side) of the boards.

Very carefully remove each component from the breadboards one at a time as they are called for in the assembly instructions. To remove the resistors and capacitors having long leads, cut the leads near the solder connections. To remove the other components having short leads, re-heat the connection, then carefully remove the component from the breadboard pin or buswire, using long-nose pliers. Clean off the solder from the leads so that they will fit through the holes in the PC board.

Unless otherwise instructed, insert all components and wires from the non-foil COMPONENT SIDE of the PC board. To prevent short circuits and lead breakage, mount all components, except the transistors, flush against the PC board surface. After inserting each component, bend the leads slightly on the FOIL SIDE of the board to hold it in place until you are instructed to solder it.

DO NOT solder any lead until instructed to do so. Use a heatsink on the leads of the transistors and diodes while soldering them. All solder connections must have good, clean, well-contoured joints similar to those depicted in the Soldering Instructions Section at the beginning of the manual. Because of the small foil pads, care must be exercised when soldering around them. Use a soldering iron with a small sharp tip.

IT IS RECOMMENDED THAT SAFETY GLASSES BE WORN WHILE SOLDERING AND UNSOLDERING IN ORDER TO AVOID EYE INJURY FROM HOT SOLDER SPLASHES OR FLYING PIECES OF LEAD WIRE.

The project will be assembled stage-by-stage in the same order as the breadboard construction. This will enable you to test each stage after it is assembled, thus, making it easier to isolate problems, should they occur. IF A STAGE DOES NOT FUNCTION PROPERLY IN THE TEST, DO NOT PROCEED TO THE NEXT STAGE UNTIL YOU HAVE CORRECTED THE PROBLEM.

TRANSMITTER PC BOARD ASSEMBLY

IC SIGNAL ENCODER STAGE

CIRCUIT CONSTRUCTION

Refer to Fig. 56 and assemble the first stage of your transmitter as follows.

__1. Insert resistor R24 (1MΩ) through the holes indicated on the PC board, standing it on end, as illustrated in Fig. 57. Insert the lead nearest the body through the hole marked with a circle. After insertion, bend the leads slightly to hold the resistor in place until requested to solder.

__2. Insert capacitor C19 (0.02μf- "203") in the PC board.

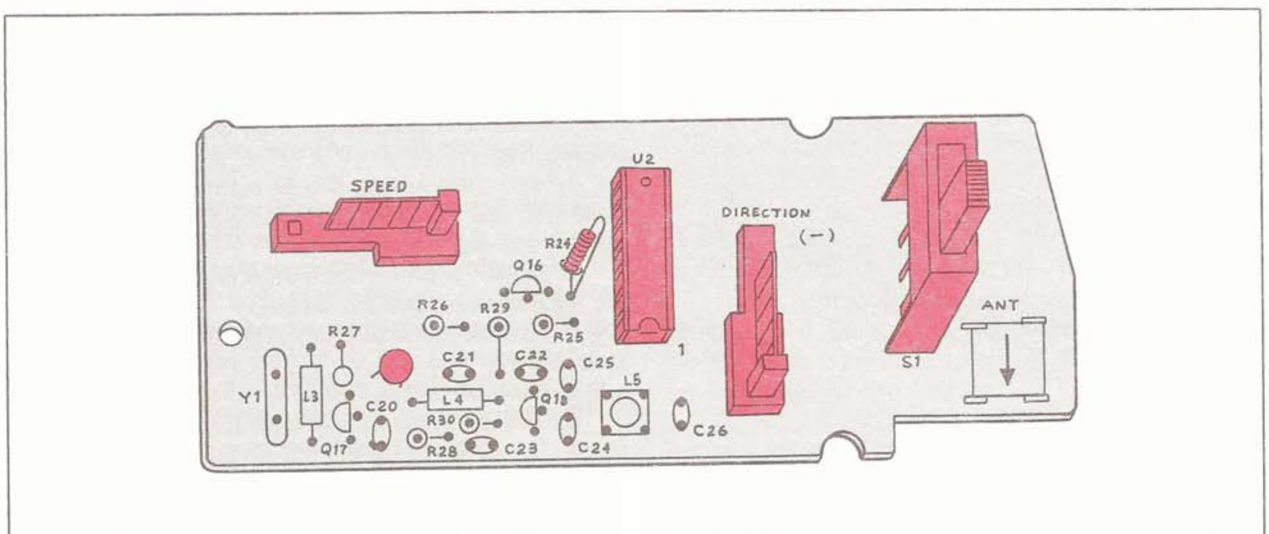


FIG. 56

__3. Solder all leads to the PC board. Be certain solder does not flow over adjacent open holes. The solder joints should look similar to those shown in the SOLDERING INSTRUCTIONS section. Next, clip off excess lead length flush against the solder joints.

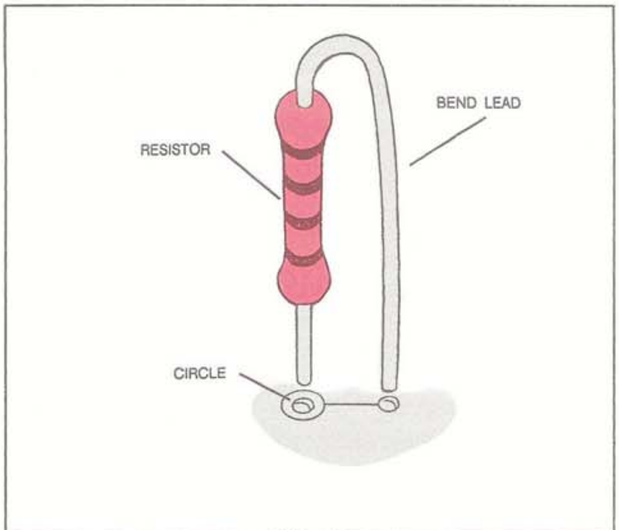


FIG. 57

__4. Install the 16-pin IC socket (XU1) as follows. CAUTION: USE CARE TO AVOID BENDING THE LEADS WHEN INSERTING THIS PART.

__a. Position the socket over the PC board area marked "U2". Find the #1 pin location (using the SMALL NOTCH technique described earlier for finding pin #1) then align it with the pin "1" marking on the PC board (See Fig. 58).

__b. Align the socket leads with the corresponding PC board holes, then CAREFULLY insert the socket so that it is flush against the PC board. Make certain that no socket pins are bent under the socket.

__c. On the FOIL SIDE of the PC board, bend several leads from both rows of pins to hold the socket in place.

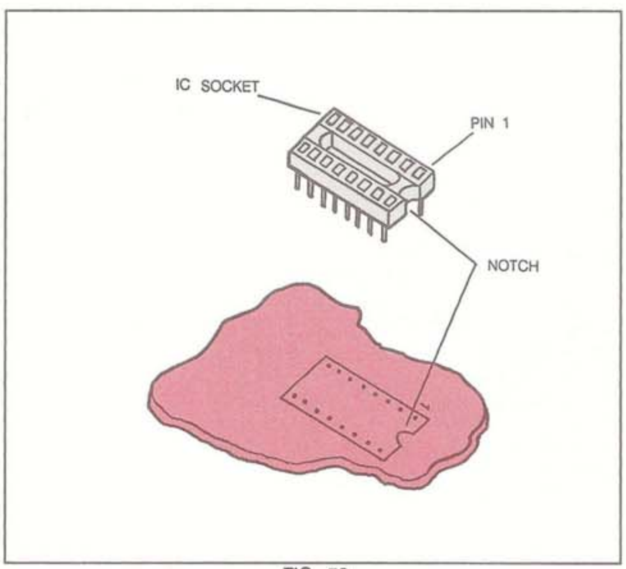


FIG. 58

__d. Confirm that the socket is flush against the PC board with all 16 leads extending through the FOIL SIDE of the board.

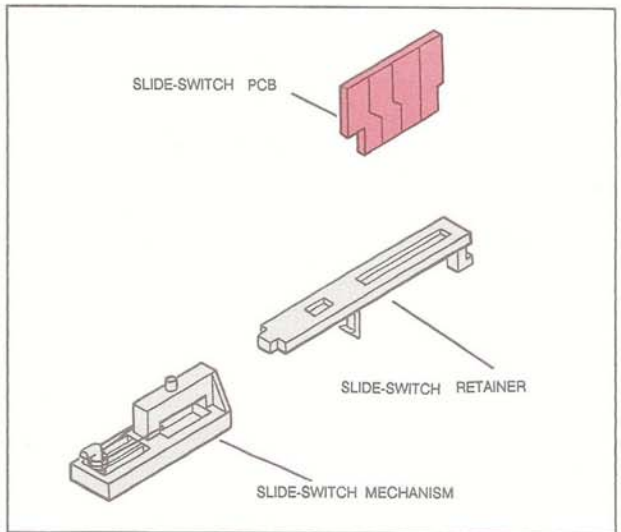


FIG. 59

__e. CAREFULLY solder the 16 pins to the PC board, then clip off any excess lead length. DO NOT install the IC at this time.

__5. Install the slide-switch (S1) on the component side of the PC board, then solder.

__6. Snap the plastic Drive and Steering switch contact board retainers into the COMPONENT SIDE of the PC board, as illustrated in Fig. 59.

__7. Position the Drive and Steering Switch Contact Boards into the retainers and solder them in place. The retainers are keyed to hamper reverse installation of the boards.

__8. Slide the spring-loaded Drive and Steering Switch contacts onto the plastic retainers.

__9. Solder the two battery leads from the pistol-grip controller to the PC board, as illustrated in Fig. 60. Solder the RED lead to the solder pad marked with a (+) and the BLACK lead to the (-) point.

__10. Following the precautions outlined in the IC HANDLING section, install the Encoder IC (U2, FRC-01T) in the socket as follows.

__a. WITHOUT TOUCHING THE PINS, carefully insert the IC into the socket with pin #1 properly aligned.

__11. This completes construction of this stage. Referring to Fig. 56, confirm that all components and leads have been inserted in the proper holes, that all solder joints are of good quality, and that they are not bridging together or across foil traces.

__12. Have your instructor initial your Knowledge Transfer Guide.

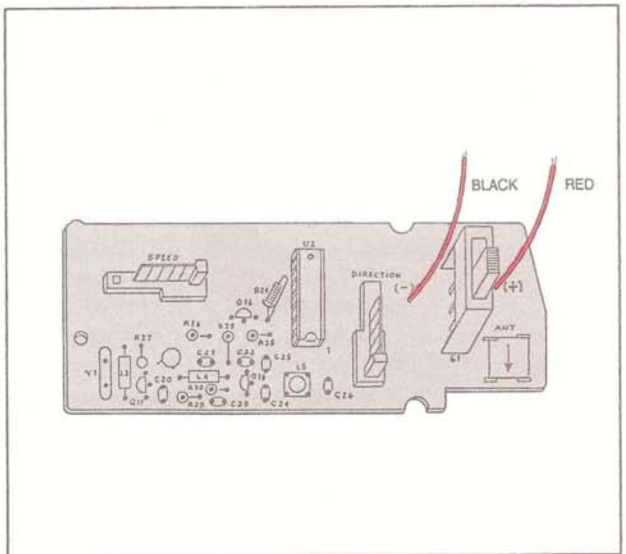


FIG. 60

CIRCUIT TEST

In this procedure you will test the IC Encoder stage of your transmitter to determine if it is functioning prroperly. The test will require an oscilloscope.

Refer to Fig. 61 for this test.

__1. Place a fresh 9-volt battery in the pistol grip as directed by the diagram in the housing.

__2. Connect the scope probe to Test Point TP1 on the FOIL SIDE of the PC board and the ground lead to the (-) side of the battery.

__3. Move the ON/OFF switch to the ON position.

__4. Adjust the scope controls so that a complete squarewave pulse packet appears at about 4cm p-p. IF THERE IS NO DISPLAY, RE-CHECK THE SCOPE CONNECTIONS, COMPONENT PLACEMENT, THEN REFER TO **TROUBLESHOOTING** on page 60.

__5. While observing the scope display, SLOWLY move the spring-loaded Drive Switch contact back and forth. The pulse widths of three of the pulses in the pulse packet should change.

__6. While observing the scope display, SLOWLY move the spring-loaded Steering Switch contact back and forth. The pulse widths of two of the pulses should change.

__7. Remove the battery and scope leads.

__8. This completes the test. Have your instructor initial your Knowledge Transfer Guide.

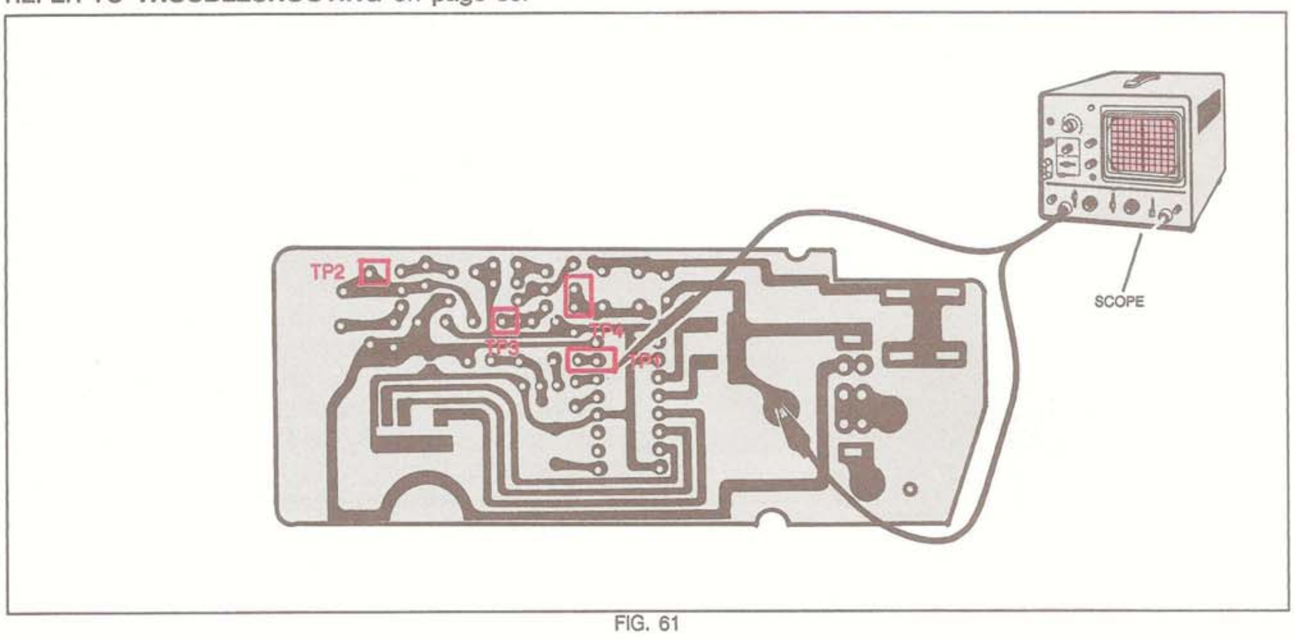


FIG. 61

MODULATOR STAGE

CIRCUIT CONSTRUCTION

Refer to Fig. 62 and assemble the stage as follows.

__1. Insert the following resistors.

__a. R25, 10KΩ

__b. R26, 4.7ΩK

__c. R29, 22KΩ

__2. Insert transistor Q16, aligning the FLAT side of its body with the FLAT portion of the symbol on the PC board.

__3. Solder all leads, using a heatsink on the transistor leads. Clip off excess lead length.

__4. This completes construction of the Modulator stage. Confirm that all components and leads have been inserted properly and that all solder joints are of good quality. Check for solder bridges between foil traces and solder pads.

__5. Have your instructor initial your Knowledge Transfer Guide.

CIRCUIT TEST

In this procedure you will verify that the modulator stage is functioning properly. You will require an oscilloscpe.

__1. Place the 9-volt battery in the pistol grip as described in the battery compartment.

__2. Attach the scope probe to Test Point TP3 on the FOIL SIDE of the PC board and the ground lead to the (-) terminal of the battery (See Fig. 63).

__3. Move the ON/OFF switch to the ON position.

__4. Adjust the scope controls to get on complete pulse packet on the display. IF NO DISPLAY IS FOUND, re-check the scope connections and your component placement. Then refer to **TROUBLESHOOTING**.

__5. While observing the scope display, SLOWLY move the Drive and Steering slide switches back and forth. The pulse widths of the information pulses in the pulse packet should change.

__6. Remove the battery and scope leads.

__7. This completes the test. Have your instructor initial your Knowledge Transfer Guide.

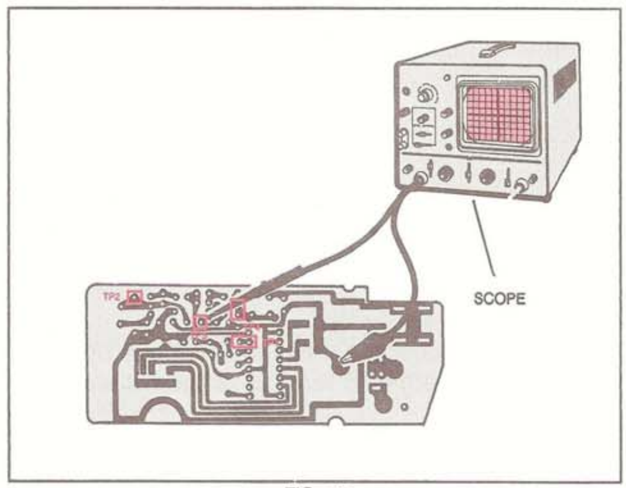


FIG. 63

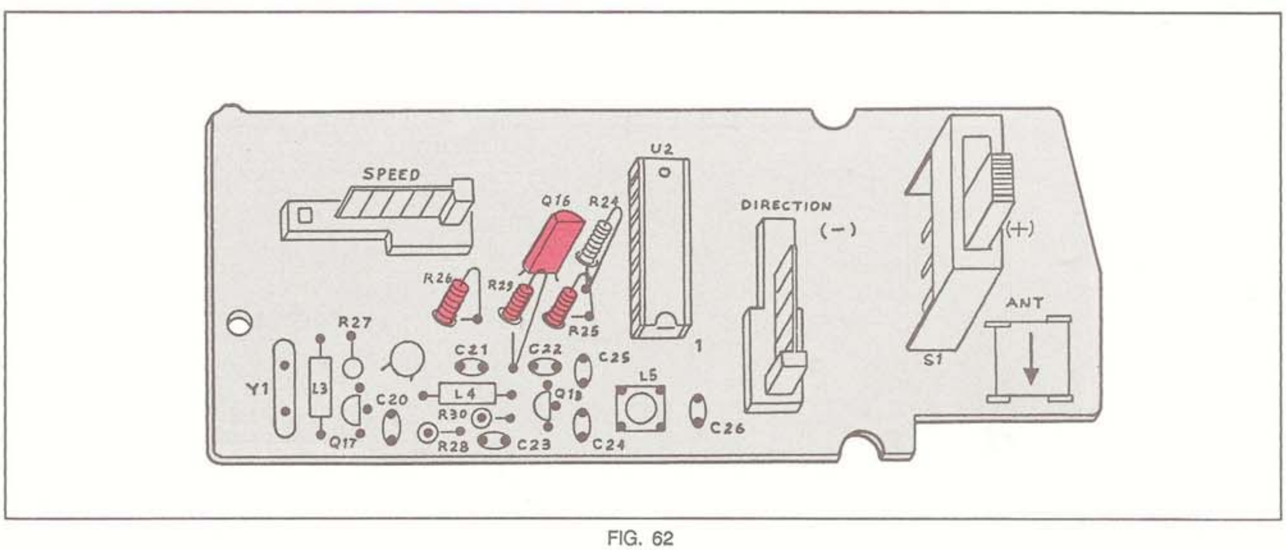


FIG. 62

RF OSCILLATOR STAGE

CIRCUIT CONSTRUCTION

Refer to Fig. 64 and assemble this stage as follows.

__1. Insert the following resistors.

__a. R27, 120KΩ

__b. R28, 100Ω

__2. Insert the following capacitors.

__a. C20, 47pf

__b. C21, 47pf

__3. Insert coil L3 (2.2μh).

__4. Insert crystal Y1. This component may be mounted in either direction.

__5. Insert transistor Q17 aligning the FLAT side of the symbol with the FLAT side of the transistor body.

__6. Solder all leads, using a heatsink on the transistor leads. Clip off excess lead lengths.

__7. This completes construction of the RF Oscillator stage. Confirm that all components and leads have been inserted properly and that all solder joints are of good quality. Check for solder bridges and slashes.

__8. Have your instructor initial your Knowledge Transfer Guide.

CIRCUIT TEST

In this procedure you will test the RF Oscillator Stage to determine if it is operating properly. You will need an oscilloscope and an AF generator.

__1. Place the battery in the battery compartment of the pistol grip controller.

__2. Connect the scope probe to Test Point TP3 and the ground lead to the (-) terminal of the battery (See Fig. 65).

__3. Carefully remove IC U2 from the socket and set it aside.

__4. Set the AF generator for a 200Hz squarewave output at minimum level.

__5. Connect one lead of the AF generator to Test Point TP1 and the ground lead to the (-) terminal of the battery pack.

__6. Move the ON/OFF slide-switch (S1) to the ON position.

__7. Adjust the scope controls to observe the waveform. Vary the generator's input frequency and look for signs of the high frequency carrier's presence on the squarewave. IF THE CARRIER IS NOT PRESENT, verify the connections of your test equipment and then REFER TO **TROUBLESHOOTING** on page 60.

__8. Remove the battery and the AF generator and scope leads from the circuit.

__9. This completes the test. Have your instructor initial your Knowledge Transfer Guide.

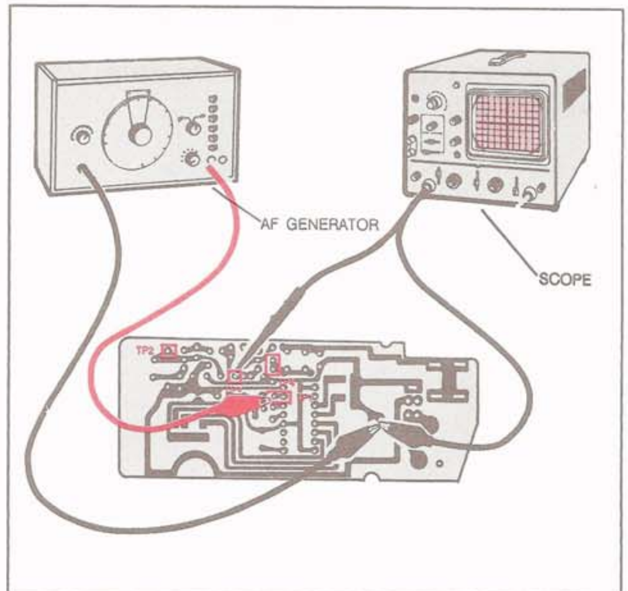


FIG. 65

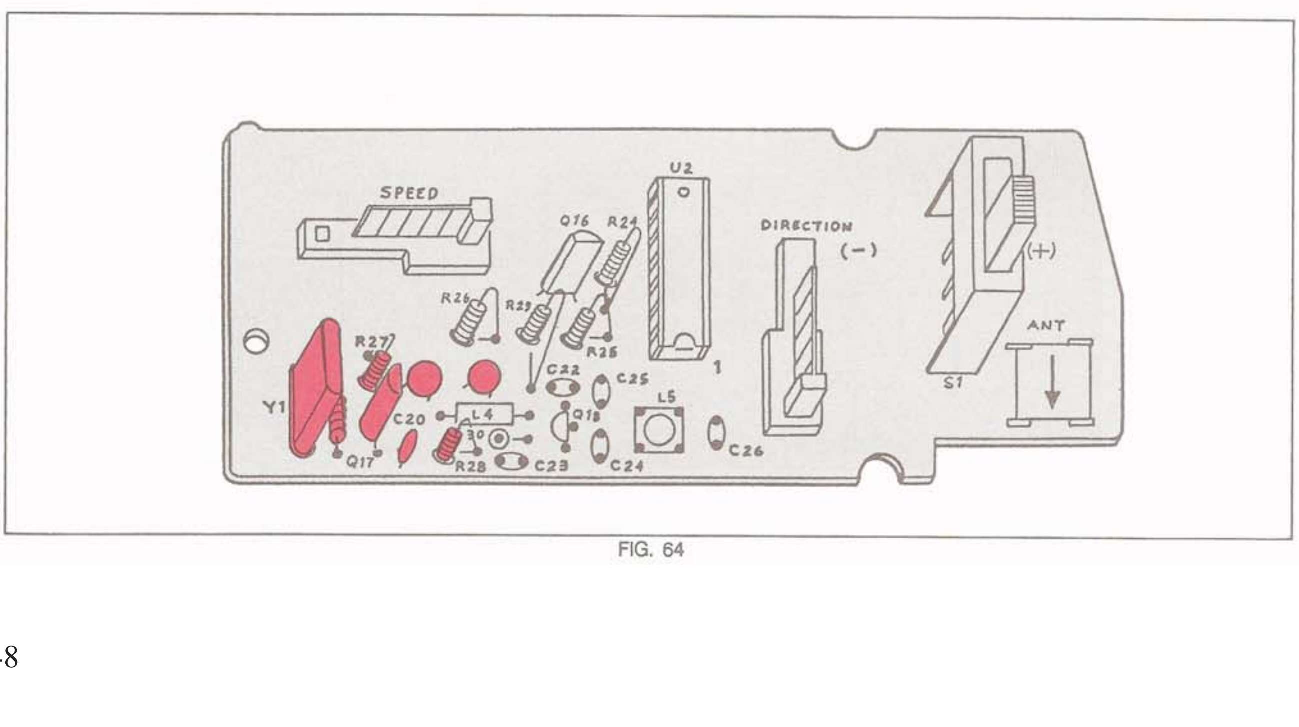


FIG. 64

OUTPUT AMPLIFIER STAGE

CIRCUIT CONSTRUCTION

Refer to Fig. 66 and assemble this stage as follows.

__1. Insert resistor R30 (100Ω) into the holes on the PC board.

__2. Insert the following disc capacitors.

__a. C22, 47pf

__b. C23, 0.01μf *disc* ("103")

__c. C24, 47pf

__d. C25, 150pf

__e. C26, 39pf

__3. Insert coil L4 (2.2μh).

__4. Insert variable coil L5 (11.5 T)

__5. Insert transistor Q18 aligning the FLAT side of the transistor with the FLAT side of the symbol.

__6. Solder all leads , using a heatsink on the transistor leads. Clip off excess lead lengths.

__7. Mount the antenna holder to the COMPONENT SIDE of the PC board, as illustrated in Fig. 66. Make certain that the threaded hole is oriented in the same direction as the one depicted in the figure. Then solder the antenna holder's four tabs in place.

__8. Solder the insulated wire antenna from the bread-board to the FOIL pad of the antenna holder. This will serve as an antenna for the Circuit Test that follows.

__9. This completes construction of the Output Amplifier Stage and your transmitter's PC board. Confirm that all components and leads have been inserted correctly. Check all solder joints for good quality and for signs of solder splash.

__10. Have your instructor initial your Knowledge Transfer Guide.

CIRCUIT TEST

In this test you will test the Output Amplifier Stage and the entire transmitter to determine if it is functioning properly. You will need a NON-DIGITAL multimeter.

__1. Reseat IC U2 in its socket on the printed board.

__2. Place the battery in the battery compartment of the pistol-grip controller.

__3. Set the multimeter to the lowest ac voltage range (0.5V maximum). DO NOT use a digital meter.

__4. Wrap one meter lead several times around with the antenna wire. Connect the other lead to the (-) terminal of the battery.

__5. Move the ON/OFF slide switch to the ON position. You should obtain a meter reading, indicating that your transmitter is producing RF energy. IF THERE IS NO READING, FIRST ADJUST L5, THEN CHECK YOUR METER CONNECTIONS, AND FINALLY, REFER TO **TROUBLESHOOTING** on page 60.

__6. DO NOT remove the battery, meter leads, or the temporary antenna.

__7. This completes the test. Have your instructor initial your Knowledge Transfer Guide.

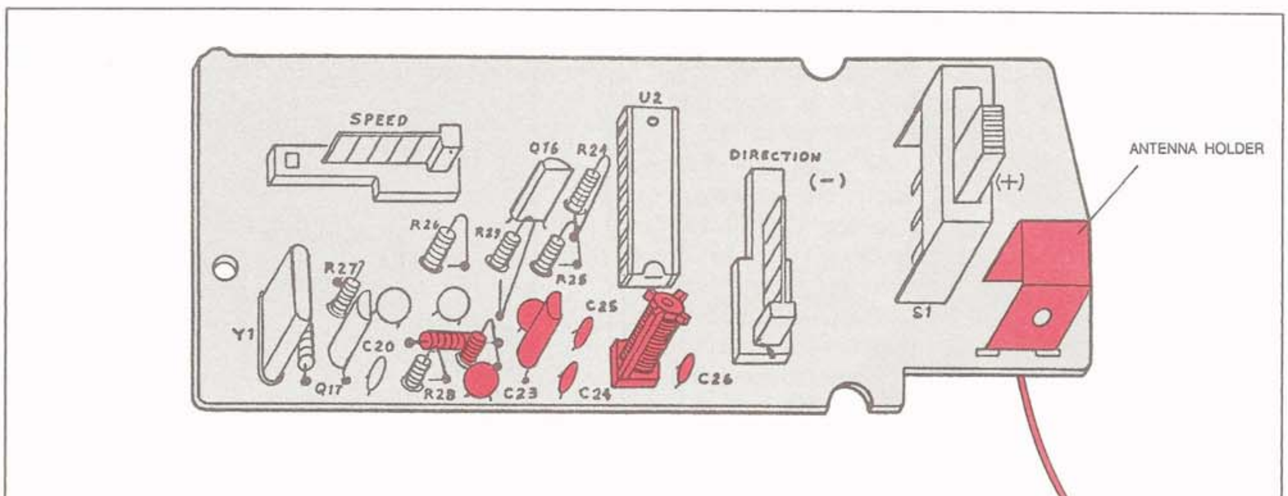


FIG. 66

TRANSMITTER ADJUSTMENT PROCEDURE

In this procedure you will adjust coil L5 for maximum RF output. A NON-DIGITAL multimeter is required.

__1. Using an alignment tool, adjust the slug in coil L5 for a maximum meter reading. Turn the slug back one full turn. (This may decrease the output slightly).

__2. Disconnect the meter leads and remove the temporary antenna and battery from the transmitter.

__3. This completes the Adjustment Procedure. Have your instructor initial your Knowledge Transfer Guide.

TRANSMITTER HOUSING ASSEMBLY

Refer to Fig. 67 through 70 for this procedure.

__1. Place the condition indicator panel over the ON/OFF switch as illustrated in Fig. 67.

__2. Install the controller's speed control trigger on the elevated mounting post, as depicted in the figure.

__3. Position the transmitter's PC board over the mounting posts on the right half of the transmitter housing (See Fig. 68).

__4. Make certain that the posts on the Drive and Steering slide switches align with the slots in the Trigger and Steering Wheel mechanisms.

__5. Join the left half of the transmitter's body to the right half, using three (3) H1 self-tapping screws (3.0Øx8mm), as depicted in Fig. 69.

__6. Finish securing the two halves of the body together by installing two (2) H1 self-tapping screws under the battery compartment cover.

__7. Screw the telescoping antenna into the top of the transmitter body.

__8. Slide the battery compartment cover into place as described in Fig. 70.

__9. This completes the Housing Assembly and also the construction of the transmitter. Have your instructor initial your Knowledge Transfer Guide.

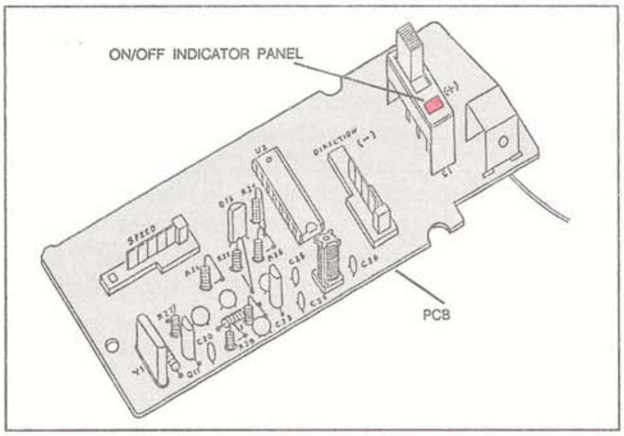


FIG. 67

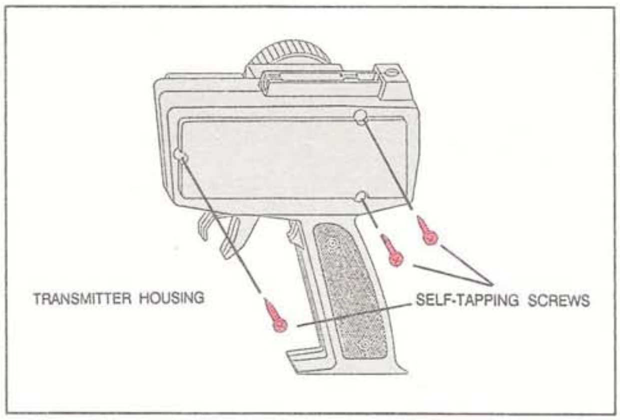


FIG. 69

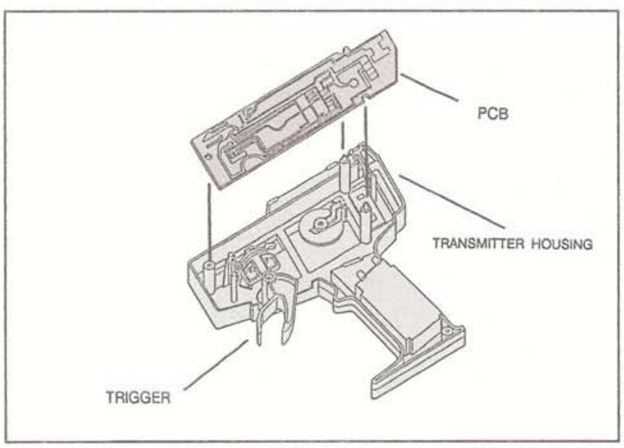


FIG. 68

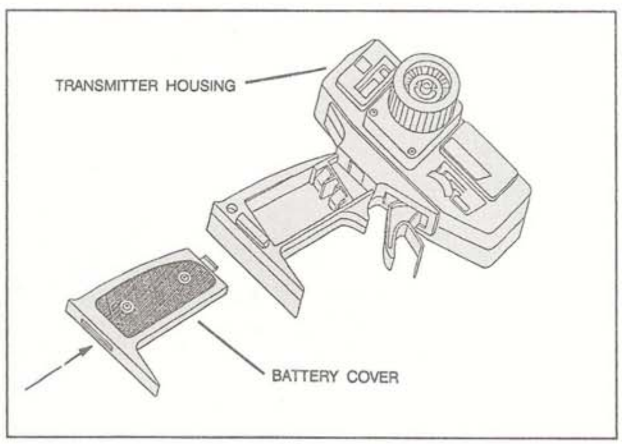


FIG. 70

RECEIVER PC BOARD ASSEMBLY

DETECTOR STAGE

CIRCUIT CONSTRUCTION

Refer to Fig. 71 and assemble this stage as follows.

__1. Insert the following resistors into the PC board, standing them on end.

__a. R1, 270Ω
__b. R2, 5.6KΩ
__c. R3, 5.6KΩ
__d. R4, 2.7KΩ
__e. R10, 100Ω
__f. R31, 100Ω

__2. Insert the following capacitors into the circuit.

__a. C1, 10pf
__b. C2, 25pf
__c. C3, 47pf
__d. C4, 0.0047μf ("472")
__e. C5 150pf

__3. Solder all leads, then clip off excess lead lengths.

__4. Insert transistor Q1 into the PC board, matching the flat side of the transistor's body with the flat side of the symbol.

__5. Solder all leads, using a heatsink on the transistor and diode leads. Clip off all excess lead lengths.

__6. Insert coils L1 and L2 into the circuit board.

__7. Solder all leads, clip any excess lead lengths.

__8. Solder the temporary insulated wire antenna (E1) to point-ANT on the PC board (See Fig. 72).

__9. Cut the length of the ORANGE, GREY, and YELLOW wires coming from the car's battery pack to a length of 4". Take care to insure that the leads are NOT TOO SHORT.

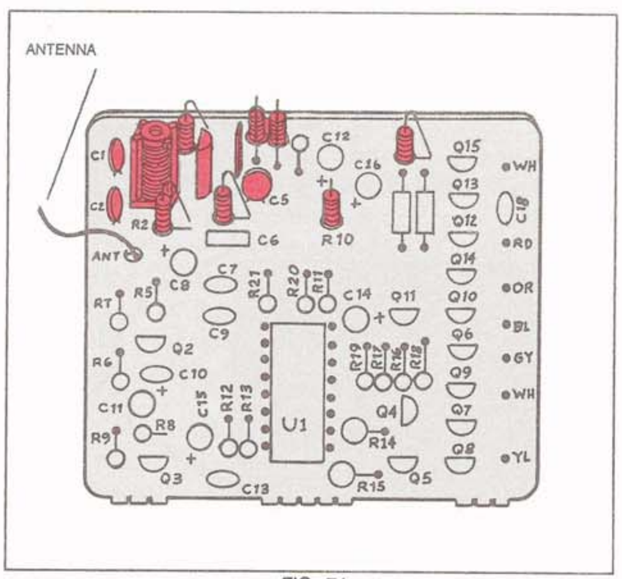


FIG. 71

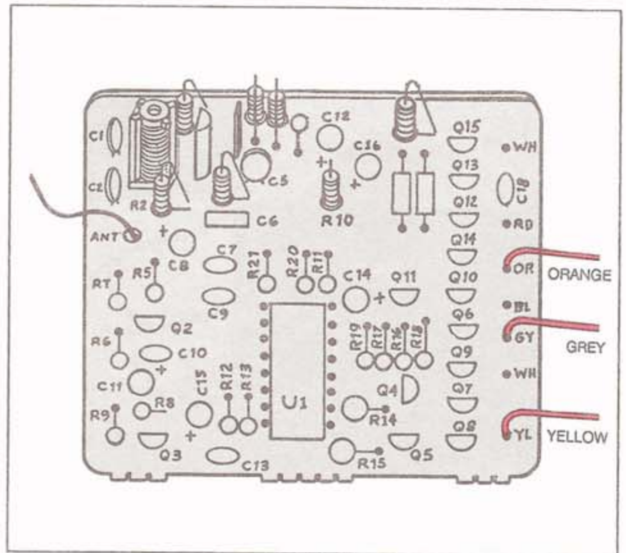


FIG. 72

__10. Solder the three leads from Step-10 to the PC board, in the locations illustrated in Fig. 72.

__11. This completes the construction of this stage. Confirm your component placement and soldering.

__12. Have your instructor initial your Knowledge Transfer Guide.

CIRCUIT TEST

In this procedure you will test the Detector Stage to determine if it is functioning properly. The test will require an oscilloscope. *Be sure that all other transmitters in the vicinity are off during the test.*

__1. Place a 9-volt battery in the transmitter.

__2. Place the transmitter so that its antenna is about 6" (15cm) from the receiver's temporary antenna.

__3. Connect the scope probe to Test Point TP1 on the FOIL SIDE of the PC board and the ground lead to the (-) side (YELLOW LEAD) of the battery pack, as illustrated in Fig. 73.

__4. Turn the transmitter ON.

__5. Turn the car ON. Adjust the scope controls until two cycles of the waveform are visible on the display.

__6. While watching the scope display, turn the transmitter OFF and back ON. An intelligent waveform should appear on the scope display when the transmitter is ON. IF NOT use an alignment tool to adjust the slug in coil L1. If the waveform still does not appear, confirm your component placement, then refer to **TROUBLESHOOTING** on page 60.

__7. Move the transmitter about 3' (1m) from the receiver. If the waveform disappears, adjust L1

__8. Turn the car and transmitter OFF.

__9. This completes the test. Have your instructor initial your Knowledge Transfer Guide.

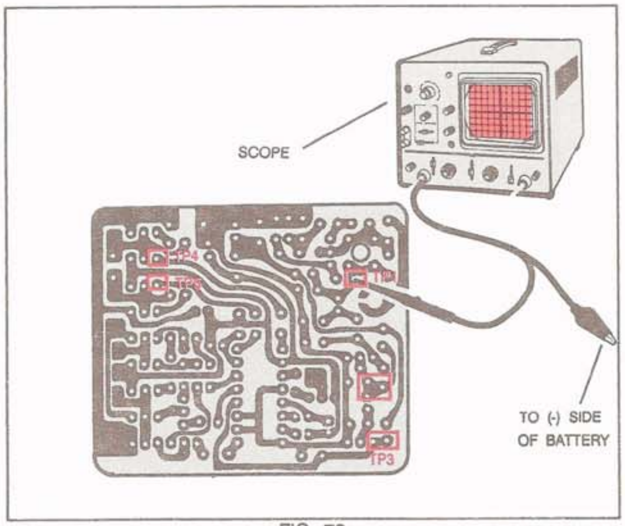


FIG. 73

AF AMPLIFIER STAGE

CIRCUIT CONSTRUCTION

Refer to Fig. 74 and assemble this stage as follows.

__1. Insert the following resistors.

__a. R5, 1KΩ

__b. R6, 330KΩ

__c. R7, 10KΩ

__d. R8, 680KΩ

__e. R9, 10KΩ

__2. Insert the disc capacitors.

__**a. C6, 0.01μf *mylar* ("103")**

__**b. C7, 0.005μf disc ("502")**

__**c. C9, 0.005μf disc ("502")**

__**d. C10, 0.005μf disc ("502")**

__3. Solder all leads and then clip off any excess lead lengths.

__4. Insert the following electrolytic capacitors, observing polarity.

__a. C8, 2.2μf

__b. C11, 2.2μf

__c. C12, 100μf

__5. Solder all leads and then clip off any excess lead lengths.

__6. Insert the following transistors, positioning them properly.

__a. Q2

__b. Q3

__7. Install zener diode (Z1) with the banded end through the hole marked with a "K".

__8. Solder all leads using a heatsink on the transistors and zener diode.

__9. This completes the construction of this stage. Confirm your component placement and soldering, using Fig. 74 as a reference.

CIRCUIT TEST

In this test you will verify that the AF amplifier is functioning properly. You will need an oscilloscope.

__1. Connect the scope probe to Test Point TP3 on the FOIL SIDE of the PC board and the ground lead to the (-) side of the battery pack as depicted Fig. 75.

__2. Turn the car and transmitter ON.

__3. Adjust the scope controls until two full pulse packets are displayed on the scope display.

__4. Actuate the transmitter's Drive and Steering control mechanisms while observing the scope display. You should be able to observe the variations in the widths of the information pulses. IF NOT, confirm your component placement and soldering, then refer to **TROUBLESHOOTING** on page 60.

__5. Turn the transmitter and car OFF.

__6. This completes the test. Have your instructor initial your Knowledge Transfer Guide.

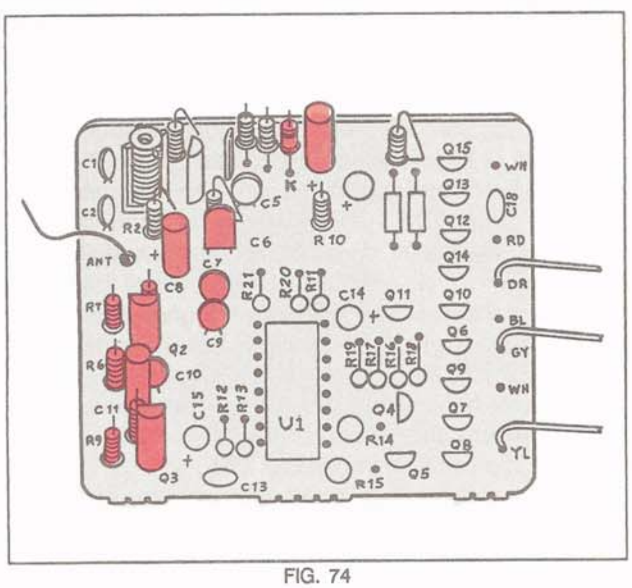


FIG. 74

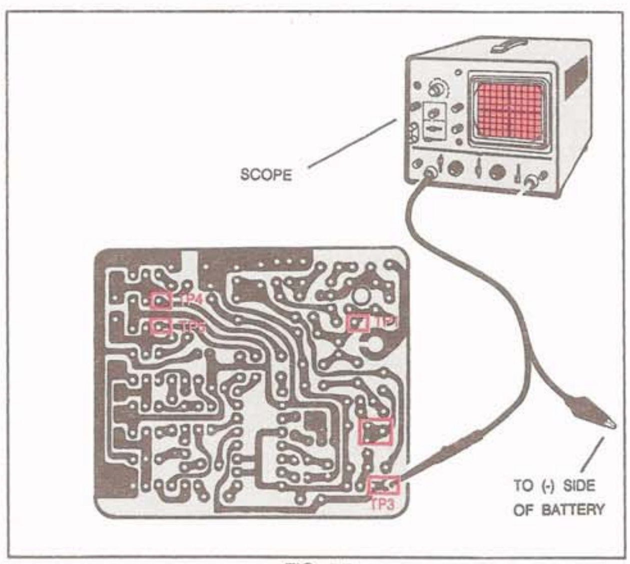


FIG. 75

DECODER/DEMODULATOR STAGE

CIRCUIT CONSTRUCTION

Refer to Fig. 76 and assemble this stage as follows.

__1. Insert the following resistors.

__a. R11, 3.3KΩ

__b. R12, 10KΩ

__c. R13, 470KΩ

__2. Insert disc capacitor C13 (0.001μf - "102") on the PC board.

__3. Insert the following electrolytic capacitors, observing polarity.

__a. C14, 1μf

__b. C15, 10μf

__c. C16, 220μf

__4. Solder all leads, then clip off any excess lead lengths.

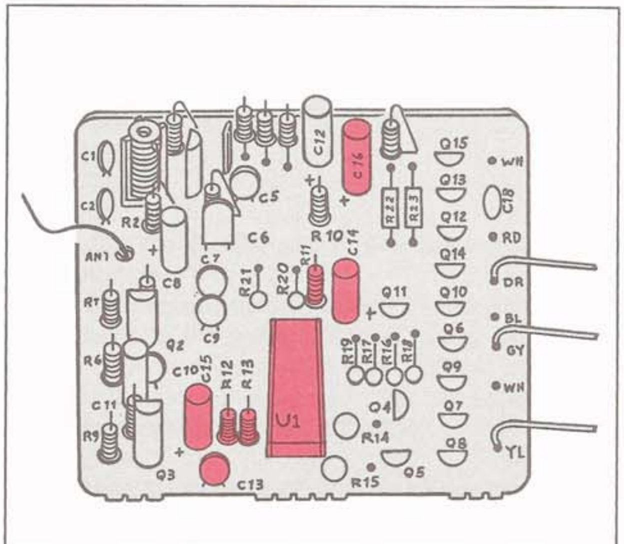


FIG. 76

__5. Install the 16-pin IC socket (XU2) as follows. CAUTION: USE CARE TO AVOID BENDING THE LEADS WHEN INSERTING THIS PART.

__a. Position the socket over the PC board area marked "U1". Align the #1 pin of the socket with the hole marked "1" on the PC board (See Fig. 77).

__b. Carefully insert the socket leads so that it is flush against the PC board. Make certain that no socket pins are bent under the socket.

__c. On the FOIL SIDE of the PC board, bend several of the leads from both rows of pins to hold the socket in place.

__d. Confirm that the socket is flush against the PC board with all 16 pins extending through the FOIL SIDE of the board.

__e. CAREFULLY solder the 16 pins to the PC board, then clip off any excess lead length.

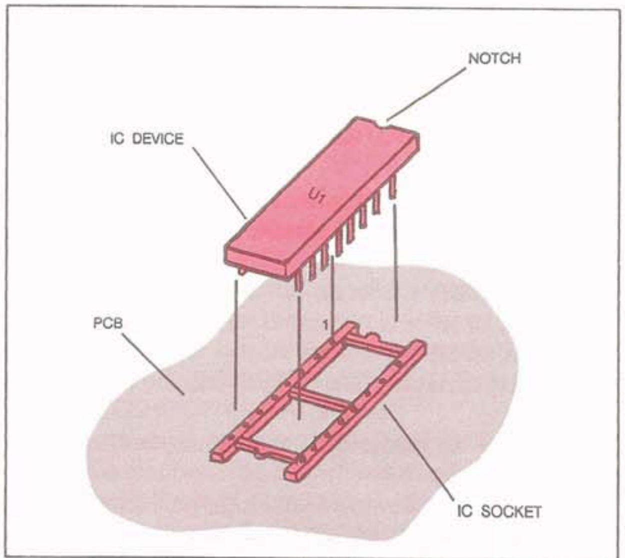


FIG. 77

__3. Following the precautions given in the IC HANDLING section, install the IC Decoder (U1, FRC-02R) in the socket. Make sure to align pin #1 of the IC with pin #1 of the socket.

__4. This concludes the construction of this stage. Confirm that all components and leads have been inserted properly, using Fig. 76 as a reference.

__5. Have your instructor initial your Knowledge Transfer Guide.

CIRCUIT TEST

In this procedure you will verify that the IC Decoder Stage is functioning properly. You will need an oscilloscope for this test.

__1. Turn the car and transmitter ON.

__2. Connect the ground of the scope to the (-) side of the battery pack.

__3. Repeatedly actuate the Drive and Steering mechanisms on the transmitter.

__4. While observing the scope display, use the scope probe to check for pulses at pins 1,16,14,13, and 9 of the Decoder IC. PULSES SHOULD APPEAR AT EACH INDIVIDUAL PIN as its control mechanism is actuated in the transmitter. IF NOT, confirm your component placement, then refer to **TROUBLESHOOTING**.

__5. Turn the car and the transmitter OFF.

__6. This concludes the circuit test for the Decoder/Demodulator stage. Have your instructor initial your Knowledge Transfer Guide.

STEERING ACTUATOR AMPLIFIER/ CONTROLLER STAGE

CIRCUIT CONSTRUCTION

Refer to Fig. 78 and assemble this stage as follows.

__1. Insert the following resistors.

__a. R20, 680Ω

__b. R21, 680Ω

__c. R22, 270Ω

__d. R23, 270Ω

__2. Insert capacitor C18 (0.02µf) into the printed circuit board.

__3. Solder all leads, then clip off any excess lead length.

__4. Insert the following transistors, positioning them properly.

__a. Q12

__b. Q13

__c. Q14

__d. Q15

__5. Solder all leads using a heatsink.

__6. Cut the RED and WHITE Steering Actuator leads to a length of 4".

__7. Connect and solder the Actuator's leads to the points specified in Fig. 79.

__8. This completes the construction of this stage. Use Fig. 78 to verify your component placement and solder connections.

__9. Have your instructor initial your Knowledge Transfer Guide.

CIRCUIT TEST

In this procedure you will verify that the Steering Actuator's control circuitry and mechanisms are working properly.

__1. Turn the car and the transmitter ON.

__2. SLOWLY rotate the steering wheel on the transmitter to the LEFT. The front wheels of the car should also turn to the LEFT. IF the wheels DO NOT turn, refer to **TROUBLESHOOTING** on page 60.

__3. SLOWLY rotate the steering wheel to the RIGHT. The front wheels on the car should also turn RIGHT.

__4. Turn the car and transmitter OFF.

__5. This concludes the test of the transmitter and receiver steering system. Have your instructor initial your Knowledge Transfer Guide.

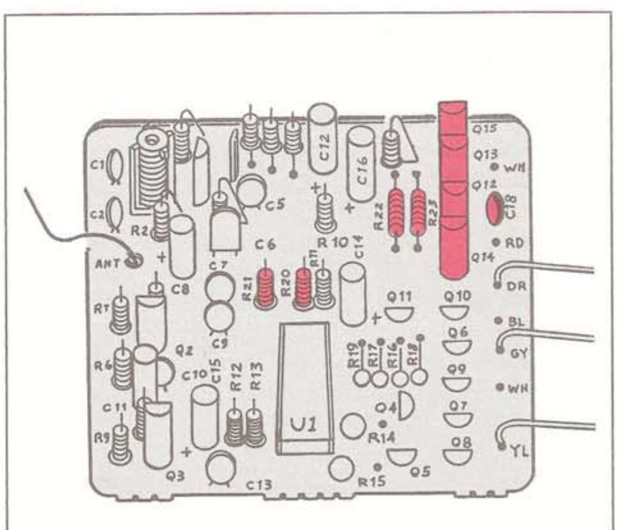


FIG. 78

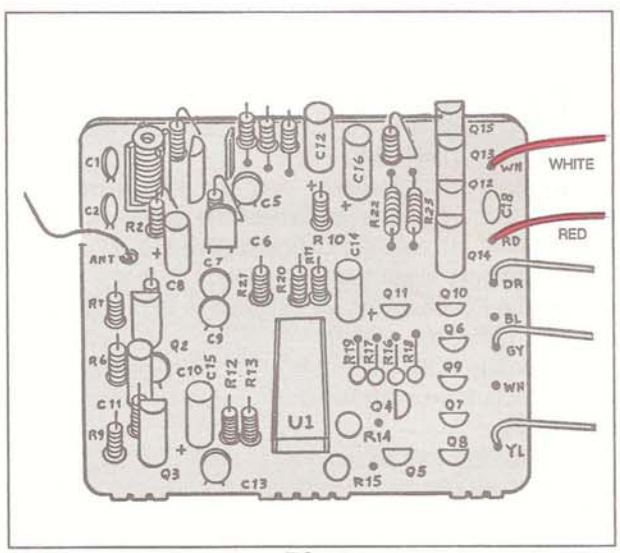


FIG. 79

DRIVE MOTOR AMPLIFIER/ CONTROLLER STAGE

CIRCUIT CONSTRUCTION

Refer to Fig. 80 and assemble the final stage of your receiver as follows.

__1. Insert the following resistors.

__a. R14, 1.8KΩ

__b. R15, 1.8KΩ

__c. R16, 100Ω

__d. R17, 100Ω

__e. R18, 100Ω

__f. R19, 1.8KΩ

__2. Solder all leads, then clip off any excess lead length.

__3. Install the following transistors, observing proper positioning.

__a. Q4

__b. Q5

__c. Q6

__d. Q7

__e. Q8

__f. Q9

__g. Q10

__h. Q11

__4. Cut the BLACK and WHITE Drive Motor leads to a length of 4".

__5. Connect and solder the BLACK and WHITE Drive Motor leads to the points specified in Fig. 81.

__6. This completes construction of this stage and of the entire receiver PC board. Use Fig. 80 to confirm your component placement and check your solder connections.

__7. Have your instructor initial your Knowledge Transfer Guide.

CIRCUIT TEST

In this procedure you will verify the operation of the Drive Motor Amplifier/Controller Stage and the entire receiver.

__1. Turn the car and the transmitter ON.

__2. Pull the trigger on the transmitter back to the "LOW" position. The rear wheels should turn in the FORWARD direction. IF THE WHEELS DO NOT TURN, refer to **TROUBLESHOOTING** on page 60.

__3. Continue to pull the trigger back until the TURBO position is reached. The rear wheels should turn noticably faster in the forward direction.

__4. Force the trigger forward until the REVERSE position is reached. At this point, the rear wheels should turn in a reverse direction.

__5. If the wheels do not turn in the correct direction, reverse the positions of the Black and White wires at the printed circuit board.

__6. Turn the car and transmitter OFF.

__7. This completes the test of your receiver.

__8. Have your instructor initial your Knowledge Transfer Guide.

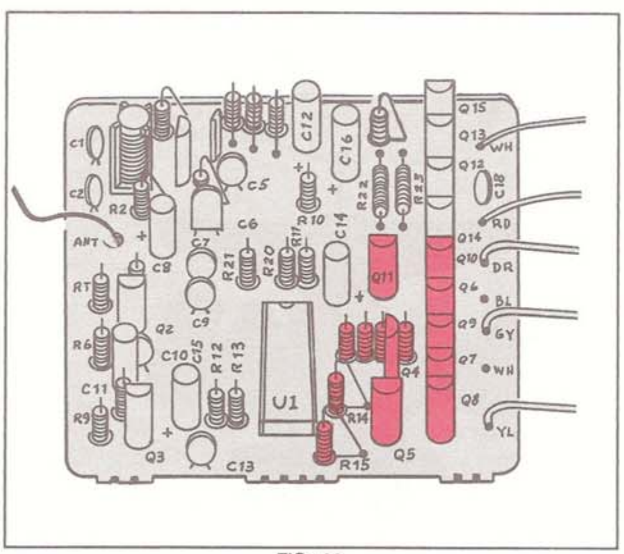


FIG. 80

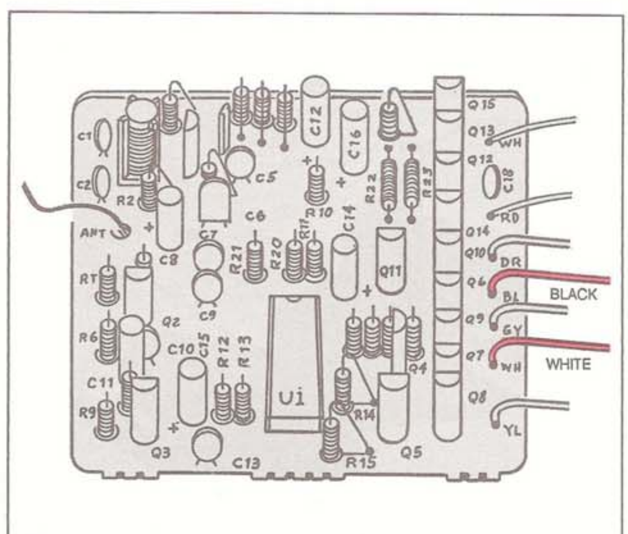


FIG. 81

RECEIVER ADJUSTMENT PROCEDURE

In this procedure you will adjust coil L1 to tune the receiver to the transmitter's crystal frequency. Be sure that all other transmitters in the vicinity are OFF.

__1. Turn the car and transmitter ON.

__2. Position the transmitter about 3' (1m) from the receiver.

__3. Pull the trigger on the transmitter. The drive motor should run.

__4. Using an alignment tool, adjust coil L1 to the point where the car just stops running. Then adjust the slug back to a point about half way between Running and Not-running.

__5. Move the transmitter about 20' (6m) from the receiver.

__6. If the drive motor stops, repeat Step 4.

__7. Release the trigger. The drive motor should stop running.

__8. Turn the car and transmitter OFF.

__9. This completes the Adjustment Procedure for your receiver. Have your instructor initial your Knowledge Transfer Guide.

RECEIVER HOUSING ASSEMBLY

Refer to Figures 82 through 85 for this procedure.

__1. Mount the PC board (component side down) to the chassis as depicted in Fig. 82. Secure the PC board and the whip antenna by inserting an H1 self-tapping screw (3.0øx8mm) through the loop in the antenna, the hole in the PC board, and into the mounting post

__2. Install the PC board compartment cover, using an H1 self-tapping screw, as illustrated in Fig. 83.

__3. Using 1 - 3.0øx8 self-tapping screw, secure the car's air scoop to the rear deck of the car body. Align the scoop's two circular tabs with their corresponding holes in the body of the car.

__4. Thread the antenna through the hole on the right side of the car body. Position the catch on the rear of the body with the slot in the chassis (directly behind the PC board cover), as shown in Fig. 84.

__5. Gently fit the body and chassis together and secure them by inserting (1) H1 self-tapping screw through the mounting hole in the front of the chassis (See Fig. 85).

__6. Attach the decals to the car body, if you wish to do so. Install the four tires on the hubs.

__7. This completes the Receiver's Housing Assembly and the entire project. Have your instructor initial your Knowledge Transfer Guide.

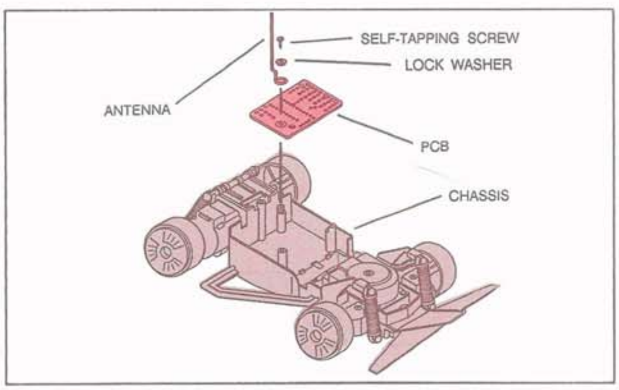


FIG. 82

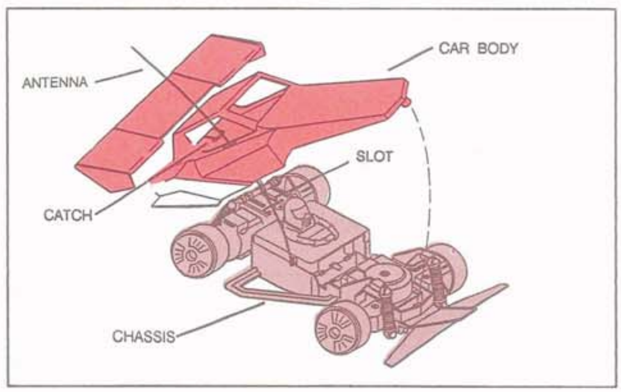


FIG. 84

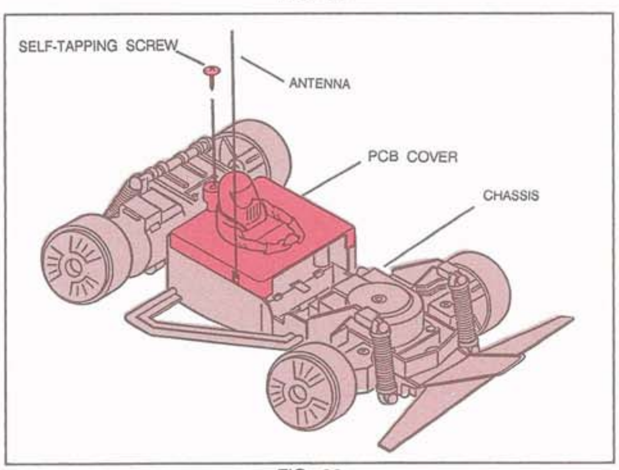


FIG. 83

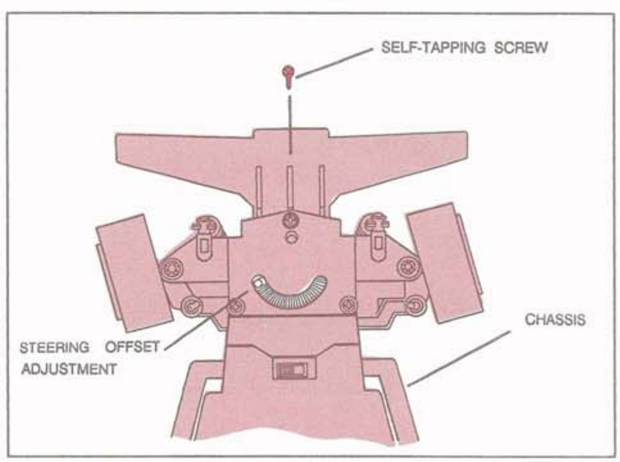


FIG. 85

OPERATING PROCEDURE

For optimum performance from your R/C car, follow these simple instructions.

__1. Insert fresh batteries into the battery compartments of the car and transmitter, observing proper polarity.

__2. Turn the car and the transmitter ON.

__3. Operate the car by pulling on the transmitter's trigger and rotating the steering wheel. The car will turn in response to the steering wheel. Release the trigger and the car will stop. Pushing the trigger away will cause the car to run in reverse.

__4. If the car fails to travel in a straight path when the transmitter's steering wheel is NOT being turned, adjust the steering actuator's retaining spring by moving the white plastic lever under the front of the chassis. The normal direction of travel can be offset to the (R) right or (L) left by varying degrees (refer to Fig. 85).

__5. The operation of the drive motor can be altered between HIGH and LOW ranges by adjusting the small switch on the rear of the drive motor housing. Simply select the (H) or (L) setting for the switch.

__6. When finished operating the car, place the power switch on both the car and the transmitter to "OFF".

__7. If the car will be unused for a period of time, remove the batteries. This will prevent damage to the car from corrosion of the batteries.

NOTICE: MODIFICATION TO THE TRANSMITTER OR RECEIVER, OR CHANGING THE TRANSMITTING FREQUENCY IS IN VIOLATION OF APPLICABLE FCC REGULATIONS.

SECTION IV

KNOWLEDGE TRANSFER REVIEW

The Knowledge Transfer Review will test your understanding of the material covered in the Circuit Discussions of Section II. When you have completed the questions, have your instructor grade this exam and enter your score in the Knowledge Transfer Guide.

Multiple choice: Answer the following questions by circling the correct answer.

1. An encoder is a device that:
   a. accepts a single input and encodes it into several output signals.
   b. accepts many inputs and encodes them into a single output signal.
   c. encodes an RF pulse train with information.
   d. encodes a squarewave with sine wave information.

2. Cascaded amplifiers
   a. operate side-by-side with each other.
   b. ceate feedback for each other.
   c. operate one after the other in the signal path.
   d. create oscillations to be amplified.

3. To change the direction of rotation in a dc motor you must:
   a. change the direction of current through the motor.
   b. change the charge across the motor's capacitor.
   c. change the polarity of the magnets in the motor.
   d. all of the above.

4. Magnetic flux lines are:
   a. force lines that have energy and direction.
   b. force lines that have energy but no direction.
   c. force lines that have direction but no energy.
   d. imaginary lines of force.

5. Capacitors are placed across dc motors to:
   a. to help the motor get started when first turned ON.
   b. to prevent inductive kickback in the circuit.
   c. to control the speed of the motor.
   d. to stop the motor when its charge is removed.

6. Transmissions where one piece of information is transmitted after the other along a single communiction path is referred to as:
   a. serial transmission.
   b. asynchronous transmission.
   c. standard transmission.
   d. RF transmission.

7. An IC is composed of:
   a. thousands of small resistors.
   b. thousands of carbon circuits.
   c. thousands of semiconductor circuits.
   d. thousands of small silicon switches.

8. Torque can be defined as:
   a. a stretching force.
   b. an electrical push or pull.
   c. a turning force.
   d. an electrical chare that builds over time.

9. A common shortcoming of ICs is:
   a. their inability to produce high output voltages.
   b. their inability to produce sufficient output currents.
   c. their inability to operate at low frequencies.
   d. their inability to operate at high frequencies.

10. The purpose of adding START pulses to a transmission is:
    a. to synchronize the transmitter and receiver.
    b. to synchronize the decoder circuitry to the incoming pulse stream.
    c. to synchronize the encoder and decoder with each other.
    d. to synchronize the modulator and detector with each other.

11. An Asynchronous transmission is:
    a. where the transmitter and receiver circuitry must be synchronized each time information is transmitted.
    b. where many pieces of information are sent using a single clock pulse.
    c. where two unconnected clock circuits are used to synchronize the transmitting and receiving circuitry.
    d. where no synchronization is required by the transmitting and receiving circuitry.

12. What special care should be taken when working with IC devices?
    a. avoid touching its pins.
    b. avoid applying excessive heat to the IC.
    c. avoid static build-up around the IC.
    d. all of the above.

13. A decoder is a device that:
    a. accepts a single input and decodes it into several output signals
    b. accepts many input signals and decodes them into a single output signal.
    c. decodes information from an RF pulse train.
    d. decodes a squarewave from sinewave information.

14. Rotating the transmitter's steering wheel:
    a. changes the amplitude of one of the pulses.
    b. changes one of the pulses into a sinewave.
    c. changes the frequency of one of the pulses.
    d. changes the width of one of the pulses.

15. Another name for detection is:
a. differentiation.
b. demodulation.
c. decoupling.
d. both (a) and (b)

16. In a Class-A amplifier:
a. the amplifier is always partially ON.
b. the amplifier is turned ON only when an input signal is applied.
c. the amplifier is never allowed to be ON.
d. the amplifier decreases the size of the output signal.

17. In a Class-C amplifier:
a. the amplifier is always partially ON.
b. the amplifier is turned ON only when an input signal is applied.
c. the amplifier is never allowed to be ON.
d. the amplifier decreases the size of the output signal.

18. The frequency of the transmitter's output is controlled by the:
a. bandpass filter.
b. resonant circuit.
c. crystal.
d. both (a) and (b).

19. The purpose of the pi-filter network at the output of the transmitter is:
a. to match the impedance of the output amplifier to that of the antenna.
b. to remove noise from the receiver.
c. to block harmonic frequencies from entering the antenna.
d. both (a) and (c).

20. The number of times per second the detector circuit goes in and out of oscillation is called the:
a. impedance.
b. resonant frequency.
c. quenching frequency.
d. tuned frequency.

21. The frequency of a crystal is determined by:
a. voltage input.
b. temperature.
c. dimensions of a quartz slab.
d. both (b) and (c).

22. Objects having opposing magnetic fields tend to:
a. repel each other.
b. attract each other.
c. produce electrical current flow between themselves.
d. discharge electrical energy.

23. A dc motor works on the principle that a current-carrying conductor in a magnetic field will tend to move:
a. at right angles to the direction of the field.
b. parallel to the direction of the field.
c. 180 degrees to the direction of the field.
d. to Bakersfield.

24. In transistor switching circuits the transistors are:
a. operated in Class-A
b. operated in Class-B
c. operated in Class-C
d. operated in Class-D

25. Oscillators are:
a. circuits that generate pulse packets.
b. circuits that generate constantly re-occurring waveforms.
c. squarewave output pulses.
d. harmonic waveforms.

26. What is the value of a disc capacitor labeled "503"?
a. $0.0005\mu f$
b. $50{,}000\mu f$
c. 500pf
d. $0.05\mu f$

27. What precaution should be taken when soldering semiconductors like transistors and diodes?
a. use a soldering gun instead of the pencil style iron.
b. use a heatsink.
c. use a solderwick to remove some of the heat build up.
d. use an antistatic strap to ground yourself.

28. The type of detector with the highest sensitivity is the:
a. regenerative.
b. RF oscillator.
c. superhetrodyne.
d. superregenerative.

29. What application is being performed by components that prevent unwanted oscillations from passing between stages?
a. decoupling.
b. degenerative feedback.
c. regenerative feedback.
d. low-pass filtering.

30. The frequency band of the transmitter's carrier is:
a. UHF
b. VHF
c. FM
d. none of the above.

SECTION V

TROUBLESHOOTING

If any stage of your project fails to function properly, first confirm the items in the CHECK LIST below.

CHECK LIST

1. **BATTERIES**. Test all batteries.
2. **SOLDER CONNECTIONS.** Be sure there are no cold solder joints. Also check for solder slash or bridges.
3. **LEAD DRESS**. Check to see if any component leads are touching each other.
4. **COMPONENT PLACEMENT**. Confirm that all components are in their proper positions, and that the transistors and diodes are inserted properly. Also check the polarity ("+" position) of the electrolytic capacitors.
5. **WIRES**. Look for broken leads.

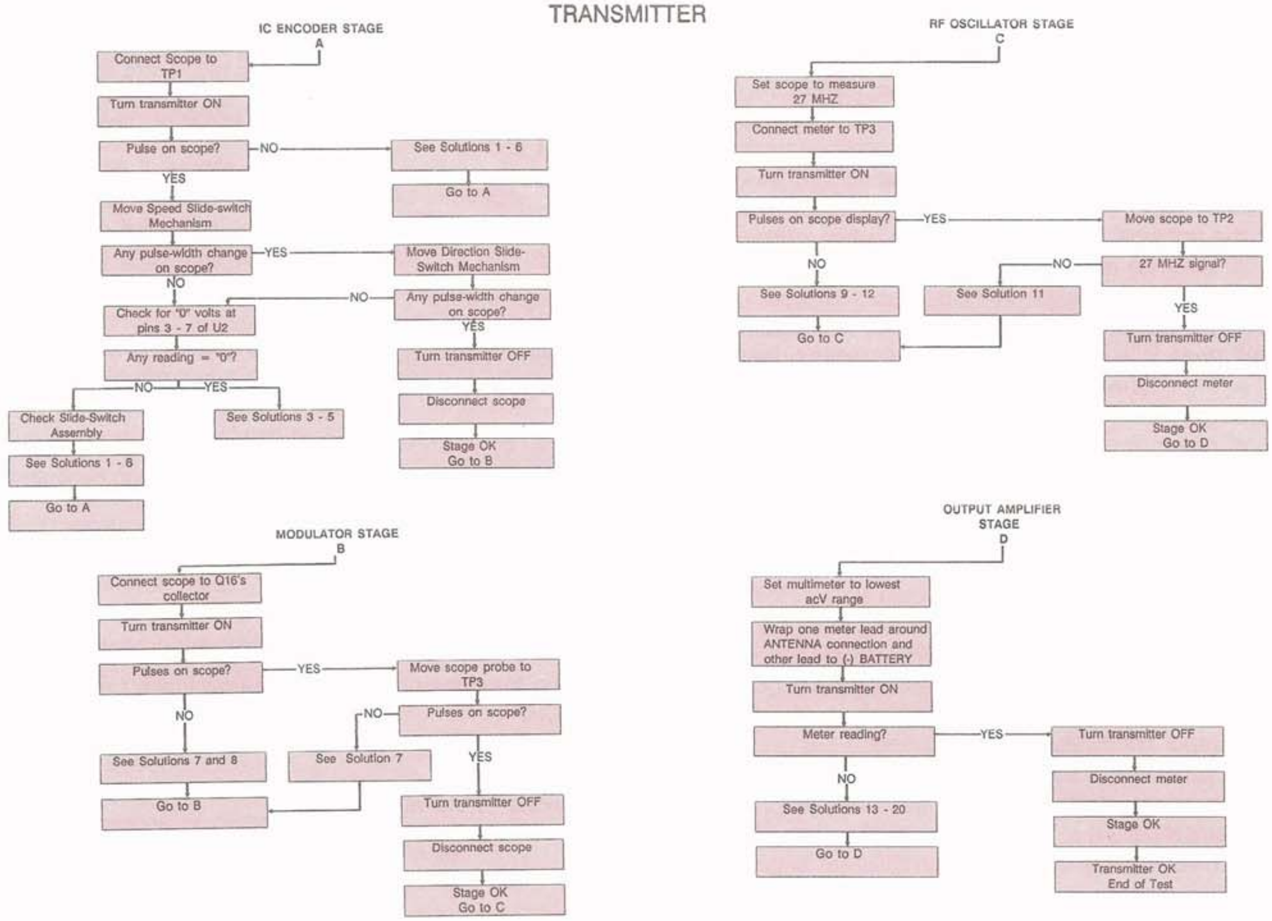
If the five items above do not reveal the problem, then proceed to the PROBLEM DIAGNOSTIC FLOW CHARTS.

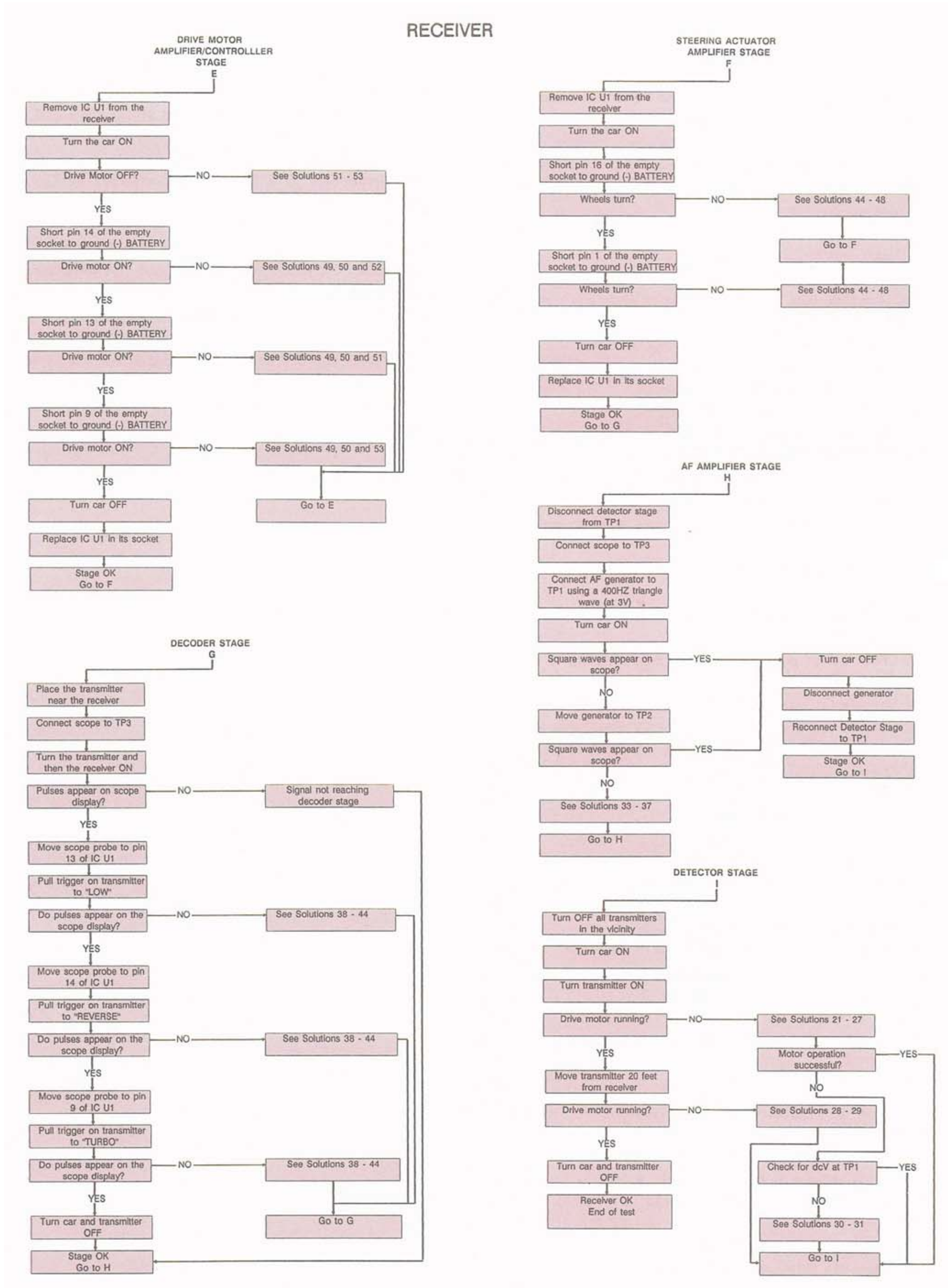
PROBLEM DIAGNOSTIC FLOW CHARTS

INSTRUCTIONS

1. The flow charts are divided into the nine circuit construction phases, covering the transmitter and receiver. Begin the diagnostic procedure at the stage that is inoperative. For example: If the AF Amplifier Stage that you just completed fails to function properly, and the check list does not reveal the problem, then begin at F in the flow charts.
2. If any component fails the out-of-circuit test, replace it with a new part of the same value and specifications. Use only factory replacement for the transistors and coils.
3. To isolate the problem, follow the solutions specified in the flow charts (See Solutions on Page 62).
4. If requested to check a capacitor or resistor for "proper value", simply make a visual inspection of the markings to be sure the proper component is inserted.
5. To measure transistor voltages, refer to TABLE 1.
6. To test transistors out-of-circuit, refer to Fig. 89.
7. To test diodes, refer to Fig. 90.
8. Connect test equipment ground leads to the (-) side of the battery (in the transmitter) or battery pack (in the receiver) unless otherwise instructed.
9. Disconnect the power prior to removing a component from the circuit.
10. Use fresh batteries.

TRANSMITTER



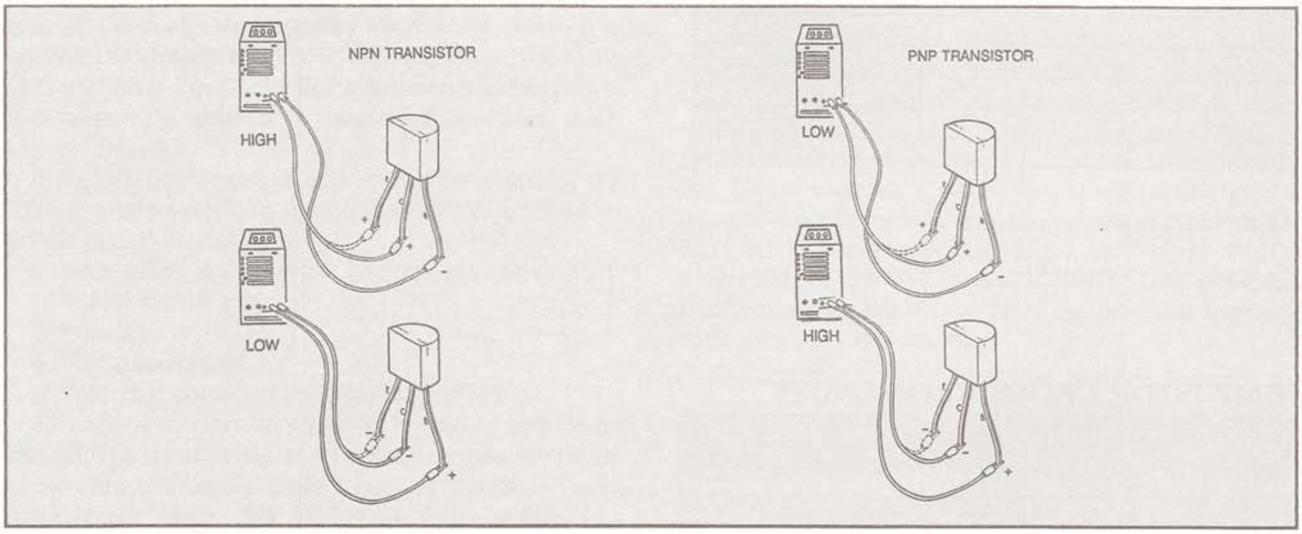

RECEIVER
DRIVE MOTOR AMPLIFIER/CONTROLLLER STAGE
E
Remove IC U1 from the receiver
Turn the car ON
Drive Motor OFF?
NO
See Solutions 51 - 53
YES
Short pin 14 of the empty socket to ground (-) BATTERY
Drive motor ON?
NO
See Solutions 49, 50 and 52
YES
Short pin 13 of the empty socket to ground (-) BATTERY
Drive motor ON?
NO
See Solutions 49, 50 and 51
YES
Short pin 9 of the empty socket to ground (-) BATTERY
Drive motor ON?
NO
See Solutions 49, 50 and 53
YES
Turn car OFF
Go to E
Replace IC U1 in its socket
Stage OK Go to F
STEERING ACTUATOR AMPLIFIER STAGE
F
Remove IC U1 from the receiver
Turn the car ON
Short pin 16 of the empty socket to ground (-) BATTERY
Wheels turn?
NO
See Solutions 44 - 48
Go to F
YES
Short pin 1 of the empty socket to ground (-) BATTERY
Wheels turn?
NO
See Solutions 44 - 48
YES
Turn car OFF
Replace IC U1 in its socket
Stage OK Go to G
AF AMPLIFIER STAGE
H
Disconnect detector stage from TP1
Connect scope to TP3
Connect AF generator to TP1 using a 400HZ triangle wave (at 3V)
Turn car ON
Square waves appear on scope?
YES
Turn car OFF
Disconnect generator
Reconnect Detector Stage to TP1
Stage OK Go to I
NO
Move generator to TP2
Square waves appear on scope?
YES
NO
See Solutions 33 - 37
Go to H
DECODER STAGE
G
Place the transmitter near the receiver
Connect scope to TP3
Turn the transmitter and then the receiver ON
Pulses appear on scope display?
NO
Signal not reaching decoder stage
YES
Move scope probe to pin 13 of IC U1
Pull trigger on transmitter to "LOW"
Do pulses appear on the scope display?
NO
See Solutions 38 - 44
YES
Move scope probe to pin 14 of IC U1
Pull trigger on transmitter to "REVERSE"
Do pulses appear on the scope display?
NO
See Solutions 38 - 44
YES
Move scope probe to pin 9 of IC U1
Pull trigger on transmitter to "TURBO"
Do pulses appear on the scope display?
NO
See Solutions 38 - 44
YES
Turn car and transmitter OFF
Go to G
Stage OK Go to H
DETECTOR STAGE
I
Turn OFF all transmitters in the vicinity
Turn car ON
Turn transmitter ON
Drive motor running?
NO
See Solutions 21 - 27
Motor operation successful?
YES
NO
YES
Move transmitter 20 feet from receiver
Drive motor running?
NO
See Solutions 28 - 29
YES
Turn car and transmitter OFF
Check for dcV at TP1
YES
NO
Receiver OK End of test
See Solutions 30 - 31
Go to I

SOLUTIONS

1. Measure the supply voltage on the PC board (about 9V).
2. Check R24 for proper connection.
3. Remove the IC from the socket to check for bent pins.
4. Use an ohmeter to check the continuity of the socket connections by testing from the inside of each socket pin to its outside terminating point in the circuit.
5. Check for continuity between pins 1,2,8, and 12 and ground.
6. Check C19 for proper value.

Replace U2 by substitution.

7. Check R25, R26, and R29 for proper value and connection.
8. Measure Q16 voltages. If NG, test out-of-circuit.
9. Check R27 and R28 for proper value and connection.
10. Measure the continuity of inductor L3 (See Table 2).
11. Check C20 and C21 for proper value.
12. Measure Q17 voltages. If NG, test out-of-circuit.
13. Check R30 for proper value and connection.
14. Check C22, C23 and C24 for proper value and connection.
15. Measure the continuity of inductor L4 (See Table 2).
16. Measure Q18 voltages. If NG, test out-of-circuit.
17. Check C25 and C26 for proper value and connection.
18. Adjust coil L5.
19. Check coil L5 for proper installation, then measure continuity (See Table 2).
20. Check antenna connection.
21. Adjust coil L1.
22. Check L1 for proper installation, then measure its continuity (See Table 2).
23. Measure Q1 voltages. If NG, test out-of-circuit.
24. Measure the continuity of inductor L2 (See Table 2).
25. Check R1, R2 and R3 for proper value and connection.
26. Check C1, C2, C3, C4 and C5 for proper values and connections.
27. Check antenna connection.
28. Adjust L1.
29. L1 out-of-tolerance, replace.
30. Check for proper voltages at Buswires A and B (about X and Y volts respectively).
31. Check R4 and R10 for proper value and placement.
32. Check R1 for proper placement and value..
33. Check Q2 and Q3 voltages. If NG, test out-of-circuit.
34. Check R5, R6, R7, R8 and R9 for proper value and connection.
35. Check C6, C7, C9, C10 and C12 for proper value and placement.
36. Check C8 and C11 for proper value and polarity.
37. Check Zener diode Z1 for proper polarity and then test out-of-circuit.
38. Remove the IC (U1) from the socket to check for bent pins.
39. Use an ohmeter to check the socket's continuity by checking from the inside of the socket's pin to its external termination point.
40. Replace the IC by substitution.
41. Check R11, R12 and R13 for proper value and connection.
42. Check C13 for proper value and placement.
43. Check C14, C15 and C16 for proper value and polarity.
44. Check R20, R21, R22 and R23 for proper value and connection.
45. Check C18 for proper value and placement.
46. Measure Q12, Q13, Q14 and Q15 voltages. If NG, test out-of-circuit.
47. Check actuator M1 wiring for an open.
48. Measure continuity of the actuator (See Table 2).
49. Check R14, R15, R16, R17, R18 and R19 for proper values and placement.
50. Check C17 for proper value and connection.
51. Measure Q4, Q6 and Q7 voltages. If NG, test out-of-circuit.
52. Measure Q9, Q10 and Q11 voltages. If NG, test out-of-circuit.
53. Measure Q5 and Q8 voltages. If NG, test out-of-circuit.
54. Control signal frequency out of tolerance. Check transmitter battery.



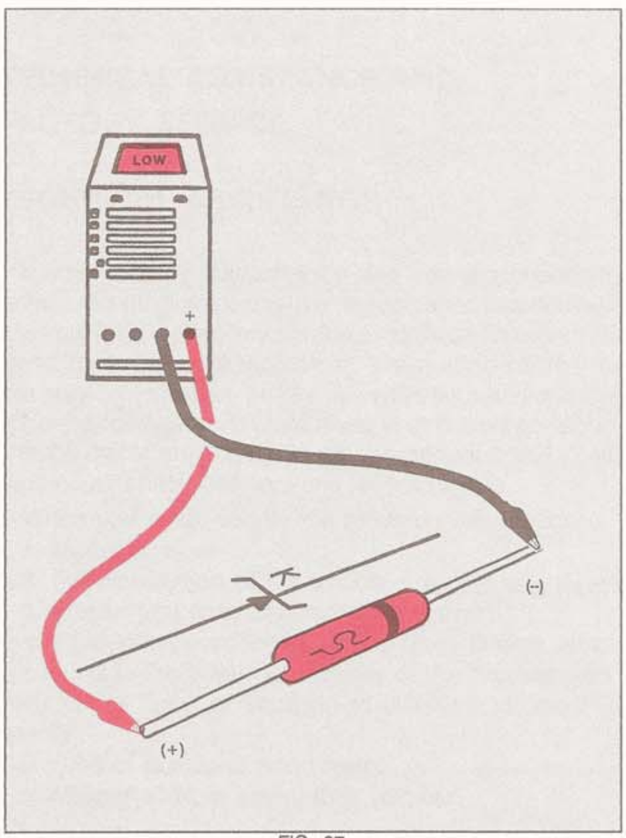


FIG. 87

Transistor	E	C	B	Reference Pt.
Q1	1.85	3.27	2.46	Buswire F
Q2	1.76	2.67	2.44	Buswire F
Q3	1.83	1.80	3.56	Buswire F
Q4	5.92	0.00	6.37	Buswire F
Q5	5.92	0.00	6.37	Buswire F
Q6	6.34	0.02	5.89	Buswire F
Q7	1.58	0.01	0.00	Buswire F
Q8	0.00	0.00	0.00	Buswire F
Q9	6.33	0.02	5.87	Buswire F
Q10	1.56	0.02	0.00	Buswire F
Q11	5.86	0.00	6.33	Buswire F
Q12	6.34	0.00	6.35	Buswire F
Q13	6.34	0.00	6.35	Buswire F
Q14	0.00	0.00	0.00	Buswire F
Q15	0.00	0.00	0.00	Buswire F
Q16	0.00	6.19	0.18	Buswire B
Q17	1.07	9.18	1.38	Buswire B
Q18	2.33	9.08	2.60	Buswire B

MEASUREMENT CONDITIONS

1. Battery Voltages: 1.5, 4.5, 9.0V
2. No input signal to receiver (Xmitter OFF)
3. 100 MΩ meter sensitivity
4. All readings ± 20%
5. Q3 Measurement - Source, Gate, Drain

TABLE 1

Device	Resistance
Drive Motor	1.5Ω
Actuator	22.5Ω
L1	0.5Ω
L2	0.5Ω
L3	0.5Ω
L4	0.5Ω
L5	0.5Ω

TABLE 2

TRANSISTOR CROSS REFERENCES

	TOSHIBA	HITACHI	NEC	MATSUSHITA
2SC3192-O	2SC380-0			
2SC495-P	2SC1815-GR	H945-P	C945-P	C828
2SK156-J1				
2SA733-P	2SA1015-GR		A733-P	
2SB562-C		B562-C	B564	A683
2SD468-C		D468-C	D471	C1383
H8550-C	A950	H8550-C	A952	
H8050-C	C2120	H8050-C	C2001	

or 2SC3193-Y

SPECIFICATIONS

Transmitter

Transmit frequency: 27.145MHz + 0.001%
Radiated output power: 10,000uV/m maximum
Maximum carrier bandwidth: 20KHz
FCC certification as per Part 15,118

Receiver

Receiving Frequency range: 26.9-28.9MHz
Maximum sensitivity: 35dB/m
Control Signal frequency response: 100-500Hz

NOTE: All specifications are nominal and will vary slightly from unit to unit. Specifications subject to change without notice.

REPLACEMENT PARTS

If you should require a replacement part, use the REPLACEMENT PART ORDER FORM packaged with your project. Fill-in all the requested information clearly and be sure to include the PART NO. (found in the Parts List) and your Zip Code. For quality control purposes, please indicate whether the part was damaged, missing, or defective.

If you should misplace your order form, supply the following information to the factory, at the address or phone no. given below.

1. Your name and address (include zip code)
2. Model No. of project
3. Part No.
4. Part description
5. Was part damaged, missing, or defective?

All parts are normally replaced by the factory at no charge. The factory may, at its option, request the return of the defective part or project prior to processing your replacement order. DO NOT RETURN UNLESS REQUESTED.

Factory Address:
MARCRAFT INTERNATIONAL CORP.
Replacement Parts Dept.
100 N. Morain St., Suite 302
Kennewick, WA 99336
(509) 374-1951

TECHNICAL ASSISTANCE AND FACTORY SERVICE

TECHNICAL ASSISTANCE

If your project malfunctions and you are unable to isolate the problem using the Troubleshooting section, you may write the factory service consultant for technical assistance (See address below). There is no charge for this service. However, before you write be sure you have done the following: (1) Confirmed your circuit construction, (2) thoroughly checked all components, and (3) inspected all solder connections for cold joints.

When you write, supply the following information:

1. Model number
2. Full description of the trouble
3. Stages you have satisfactorally tested
4. Production number of your project (3-digit number found in the lower right corner of the Replacement Parts Order Form or stamped in black ink on the PC board).
5. Date of purchase and receipt
6. Mailing address and phone number

FACTORY SERVICE

IN WARRANTY SERVICE

Within one (1) year from the date of purchase you may return your project for repair or adjustment. This service is free of charge within this period provided that the cause of the failure was related to the Marcraft product (i.e. a bad component). If not, you will be charged a $10 fee. This is charged in advance and will be refunded to you upon verification of the source of the problem. DO NOT RETURN YOUR PROJECT WITHOUT PRIOR AUTHORIZATION FROM MARCRAFT. This authorization will take the form of a Return Merchandise Authorization (RMA) number.

Projects that require extensive re-work, that are not assembled in accordance with the instruction manual, that are modified in any way, that show signs of misuse, neglect, or accident, or that indicate the use of acid-core solder will be returned, un-repaired at the owner's expense.

When returning your project, write the RMA number on the outside of the mailing box and enclose your remittance of $10. Remove any batteries from the project and ship it, well-packed, postage paid and insured to:

MARCRAFT INTERNATIONAL CORP.
Service Department
100 N. Morain St., Suite 302
Kennewick, WA 99336

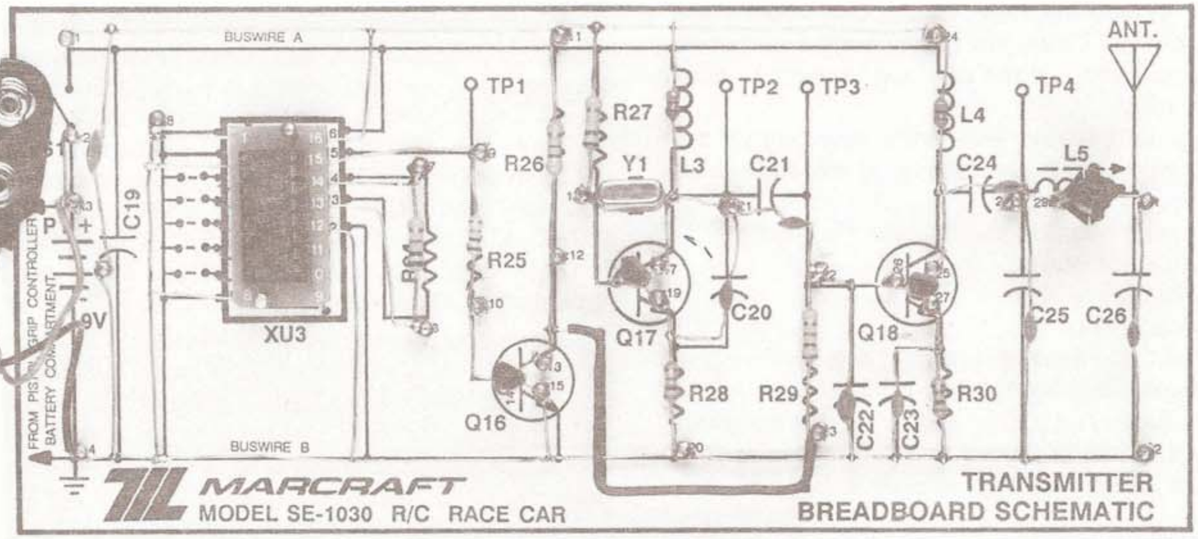
NOTE: Write the RMA number in a conspicuous place on the outside of the box.

OUT OF WARRANTY SERVICE

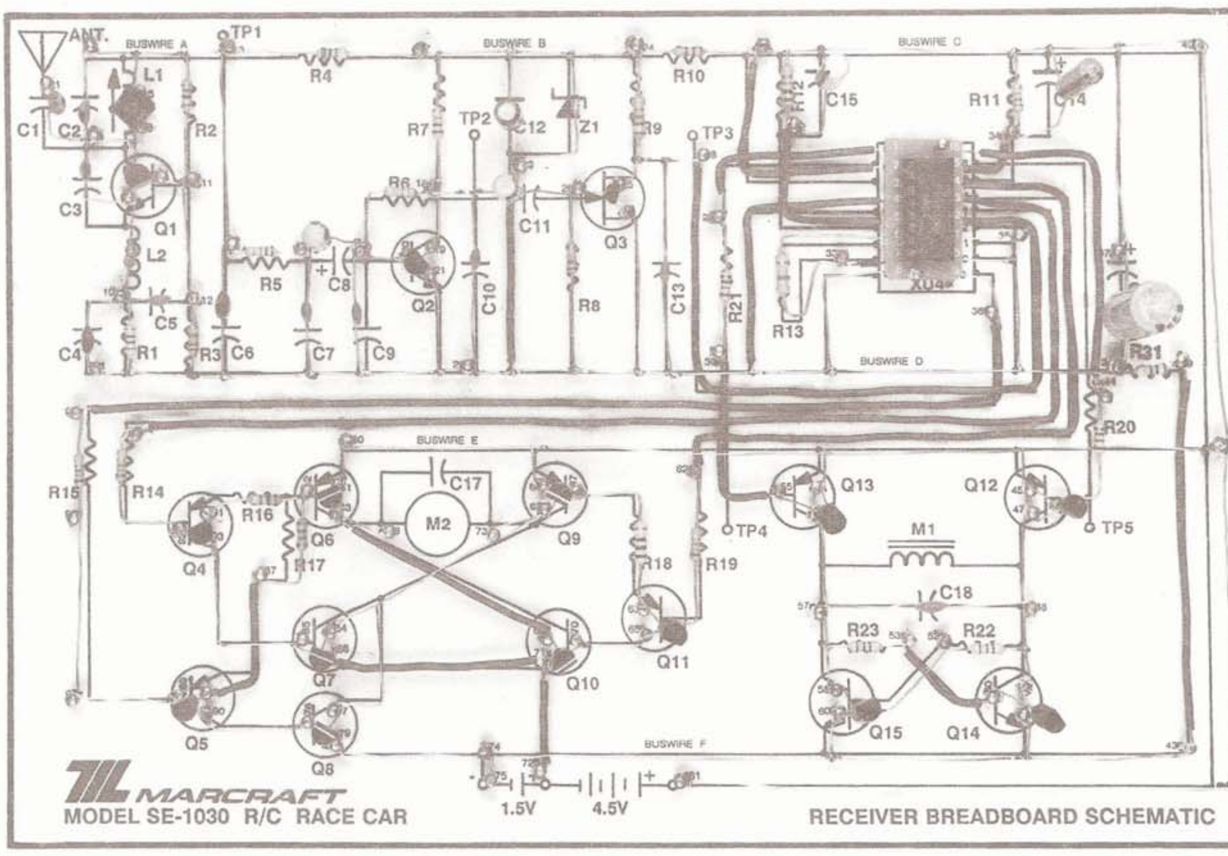
After the one (1) year warranty period has expired, your project may be returned for repair or adjustment, with a service charge of $35 per hour plus parts and postage, payable in advance. DO NOT RETURN THE PROJECT WITHOUT PRIOR AUTHORIZATION FROM MARCRAFT

BREADBOARD WIRING DIAGRAMS

TRANSMITTER



RECEIVER



ANSWERS

1. b
2. c
3. a
4. a
5. b
6. a
7. c
8. c
9. b
10. b
11. a
12. d
13. a
14. d
15. b
16. a
17. b
18. c
19. d
20. c
21. c
22. b
23. a
24. c
25. b
26. d
27. b
28. d
29. a
30. c

TRANSMITTER

Encoder Stage

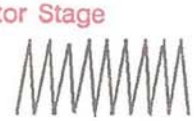
2f. 9cm.
2g. 18ms.
2h. 55.5Hz
2i. 0.8cm
2j. T = 7.4ms F = 135.1Hz
2l. #4 2m. 5,6,7,8

Modulator Stage

1g. 2.16V

RF Oscillator Stage

1g. TP2



8.33MHz

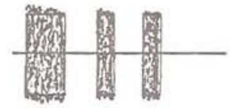
TP3

2g.

RECEIVER

Detector Stage

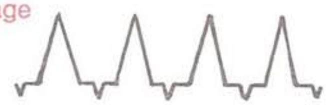
1h.



2a. F = 27.145 MHz

AF Amplifier Stage

1f.



2g. 1.397V
2h. 1.12V
2i. A2 = 1.3, A3 = no gain(duty factor change)
3d. 0.851
3f. 0.584
3k. 0.568
3m. 0.830

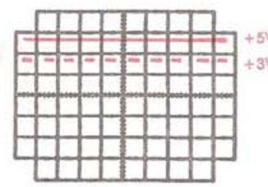
Decoder Stage

1g. L H H H H
H L H H H
H H L H H
H H H L H
H H H H L

Steering Actuator stage

1f. / 1k. / 1o. high

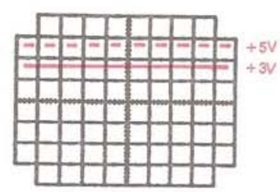
high



1i. Left

1h. / 1l. low

low



1n. Right

Drive Motor Stage

1d. Reverse
1e. Forward
1f. Turbo Forward