The normal operation of a conventional, non-programmable four-bit binary counter stage is as follows: The internal circuitry of the counter always starts at zero. Each input pulse from the source raises the internal count of the counter by one. When this count reaches 15 in a four-bit divider (counting zero, this is 16 total cycles of the input signal), an output pulse occurs.

The programmable divider operates in the same fashion with the exception of the fact that the programmable divider does not necessarily always start counting at zero. It is possible, via external programming inputs, to pre-set the counter to any desired number. This allows the number of cycles of the input frequency for each output pulse to be changed. Therefore, the division ratio of the counter is effectively changeable or programmable. This method of changing the division ratio by presetting the counters to start at a number other than zero, is a method used in the Formula D for programming the channel frequency.

With counters of this nature, it is also possible to decode any particular internal count by means of the four binary outputs available. This means that it is possible to stop the count and provide an output pulse to the next counter at a count less than 15. Doing this requires the use of external gates to sense the condition of the counters. This method is referred to as changing the terminal count, and is used on the Formula D to change the division ratio by 46 between transmit mode and receive mode. This is done by enabling one of two nand gates used to sense the terminal count. Each of these gates is connected to selected binary outputs of the counters. When all inputs to a given nand gate are high, terminal count is sensed and an output pulse appears at the gate output.

This output pulse resets all the counters to the preset value set by the channel selector and also is the counter chain's output to the phase detector.

The terminal count sense gate used in the receive mode is connected to sense a terminal count of 2072. The transmit mode senses a count of 2118. Since the receive mode gate senses an earlier count, it will control the divider when both gates are active. In the transmit mode, the receive mode gate is disabled by bringing one input low. (Connected by D13 to the 9 volt receive bus, which is grounded on transmit.) This allows the transmit mode gate to control the divider.

REFERENCE OSCILLATOR CIRCUIT DESCRIPTION

General Description

The reference oscillator is a crystal controlled stage consisting of Q9, X1 and frequency control circuitry including D14, Q10 and the delta tune control. The normal output of this oscillator is 10.240 MHz on receive and 10.2381 MHz on transmit.

Circuit Description

The oscillator (Q9) is of the common collector variety with the output taken from the emitter. D14 is forward biased in the transmit mode and reverse baised in the receive mode. This results in an increase in capacitance in the transmit mode, which results in a frequency shift to 10.2381 MHz when L11 has been properly adjusted in the transmit mode. The reverse bias on D14 is made variable by the action of the delta tune control and its associated amplifier, Q10. This variation in bias on the cathode of D14 is sufficient to cause approximately 700-800 hertz of frequency shift above and below a center value of 10.240 MHz in the receive mode. The delta tune control is disabled in the transmit mode, as its power source, the 9 volt receive bus is shorted to ground during transmit.

REFERENCE DIVIDER CIRCUIT DESCRIPTION

General

The reference divider consists of I.C.'s 5, 6 and 7, plus one section of I.C. 8. Its purpose is to provide a fixed division ratio of 1,024 to 1 on the output of the reference oscillator, Q9.

Circuit Description

The signal from Q9 emitter is coupled through R607 and C521 to the base of Q24, the reference divider driver. The purpose of this common emitter amplifier is to provide a sufficiently large peak to peak voltage swing to insure that the reference divider input switches fully from logical 1 to logical 0 during each input cycle. The output of Q24 is coupled directly to the "A input" of I.C. 5, a type 7493 four-bit binary counter. This counter performs a division of 16 to 1 on the input signal. In other words, the output of I.C. 5 will have a frequency 1/16 that of the input (640 KHz on receive). The output of I.C. 5 is coupled directly to the input of I.C. 6. This stage is identical to the previous one and performs another division of 16 to 1 on the input signal (40 KHz output). The output of this stage is coupled to I.C. 7, a type 7474 (dual D-type) edge triggered flip-flop. Each half of this I.C. divides by 2. The two sections are connected in series for a total division ratio of 4 to 1. Therefore, the input signal at 40 KHz is divided by 4 to result in an output frequency of 10 KHz. (All frequencies noted are true on receive only. Transmit values are slightly lower, due to reference oscillator frequency shift.)

I.C. 7 actually has two outputs in the form of square waves, 180° out of phase. The ideal input for the phase detector (I.C. 9) is a negative going spike, of fast rise time. To obtain this, both outputs of I.C. 7 are acted upon by a nand gate (part of I.C. 8) in the following manner: Each output of I.C. 7 is coupled to an input of the nand gate. However, one output has a .01 capacitor (C517) across it to ground. This capacitor slows the rise time of the output to which it is connected sufficiently so that the inputs to the nand gate are slightly out of phase. Therefore, for a very short period of time, both inputs are high to the nand gate. During this period, a short negative spike appears at the nand gate output. This is the drive to the reference input of I.C. 9, the phase detector.

OUT-OF-LOCK DETECTOR CIRCUIT DESCRIPTION

General Description

The "out-of-lock detector" section of the synthesizer serves the purpose of providing a disabling voltage to the mixers of the transmitter and receiver to insure against off frequency operation, should phase lock be lost.

The circuit consists of Q18, Q19, D25 and three nand gates which are part of I.C. 8.

Circuit Description

One of the "two-input nand gates" in I.C. 8 has each of its inputs coupled to one output of the phase detector. Please remember that the output of a nand gate is low only during the time when both inputs are high. If either input should go low, the output will go high. The output of this nand gate is capacitively coupled to a half wave shunt detector (D25). The output of this detector is negative going and is used to control the gate of Q19, which is a junction F.E.T. This F.E.T. operates as a depletion mode device. Due to the fact that no external bias is provided, this F.E.T. is saturated unless sufficient negative bias is provided from the detector (D25).

The output at the drain of Q19 is coupled to an inverter formed by connecting both inputs of one section of I.C. 8 together. The output of this inverter is coupled to a third section of I.C. 8, which is used as a nand gate. The other input of this nand gate is connected to a pull-up resistor connected to V.C.C. and one contact of the channel selector switch.

The output of this nand gate is coupled directly to the base of Q18, which functions as an output emitter follower for the out of lock disable circuit.

Normal Operation

A positive going spike will appear on the output of the first nand gate driving the out of lock detector every 100 microseconds. Under phase locked conditions, these output pulses will be very narrow, resulting in a small amount of detected DC at the output of D25. However, should out of lock conditions exist, either the leading or lagging output of the phase detector will have a much wider pulse on its output. Therefore, the positive going spikes at the output of the nand gate will be much wider and the detected DC voltage will be greater in value. Component values in the coupling network between the detector and Q19 are chosen so that when out of lock conditions prevail, sufficient DC voltage is provided to reverse bias Q19. This allows its drain voltage to rise sufficiently to cause an inverter connected to its output to switch to the low output state. This will drive one input of the third nand gate low, which will result in a high voltage on its output. This will raise the base voltage on Q18 and cause it to conduct, creating a positive pull-up voltage (approximately 3 volts) on the emitter of Q18. This voltage disables the transmit and receive mixers by pulling their source voltage up sufficiently to reverse bias them to cut-off.

The third "nand gate" also serves the purpose of sensing when the channel selector switch is set to the blank position. This is done by providing a contact on the channel selector switch which grounds the second input to this nand gate. This, of course, results in a disable output in the same manner an out of phase lock condition would do.

SECTION 5
SERVICING

5.1 TEST INSTRUMENTS REQUIRED

General

The test equipment required for citizens band servicing includes a number of the items commonly found in service shops specializing in entertainment electronics repair. However, for economical and expedient repair of citizens band equipment, certain items of test gear not normally found in entertainment electronics service shops are required.

Four items of test equipment indispensable to citizens band servicing are a calibrated signal generator, a wide band oscilloscope, an accurately calibrated wattmeter, and a frequency counter. In the following discussions the required characteristics for each of these units will be delineated and desired features will be discussed.

Signal Generator

The signal generator used for alignment and testing of citizens band receivers must adhere to considerably more precise specifications than "service type" generators commonly found in service shops.

Stability is an important factor in signal generators used for alignment of citizens band transceivers. The fact that C.B. transceivers are inherently narrow band receivers, combined with the fact that they are crystal controlled, makes this specification an important one. Accurate alignment of citizens band receivers requires that the frequency of the generator remains stable to within a few hundred hertz over a period of several minutes. This is beyond the capability of most service type generators at a frequency of 27 MHz.

Frequency calibration accuracy is another useful feature in a signal generator for citizens band service. However, if sufficient output is available from the signal generator, a frequency counter may be used to set the generator frequency to excellent accuracy. This makes accurate frequency calibration a nice, but unnecessary, feature.

Reasonably well calibrated modulation capability with the modulation level either variable or preset at 30%, is required for A.M. transceiver alignment. The preferred modulation frequency is 1,000 hertz. However, 400 hertz is satisfactory.

Output calibration is the last and most critical specification of the signal generator. The generator should be capable of signal outputs of .5 microvolts or less. The output calibration should be in the form of a dial or a meter and be accurately readable (±20%) at these levels. The output of the signal generator should be continuously variable up to at least 500,000 microvolts.

The generator preferably should be capable of output on the I.F. frequencies used in C.B. receivers as well as at the 27 MHz R.F. input frequency range. The most common of these frequencies are 10.7 MHz, 7.8 MHz, and 455 KHz.

OSCILLOSCOPE

The servicing techniques we have developed at the SBE Factory over the last several years make heavy use of a high quality wide band oscilloscope for trouble-shooting. This philosophy is reflected in the very considerable use made of oscilloscope wave-forms in this manual.

Taking advantage of the considerable capability of the oscilloscope to shorten and simplify service procedures, requires that certain basic minimum specifications be adhered to in selection of an oscilloscope for C.B. servicing.

Bandwidth is the single most important consideration. We consider the minimum 3db bandwidth for a suitable oscilloscope to be 25 MHz. This specification is considerably beyond that required for most other electronics servicing.

A bandwidth of this magnitude allows inspection of the signal wave-form throughout the entire transmitter. This ability to observe both carrier levels and modulation envelopes throughout the various points in the transmitter is critical to quick and easy analysis of transmitter failures. Although a 25 MHz bandwidth is sufficient for basic oscillosocpe functions, a wider bandwidth in the area of 50 MHz is preferable. This is due to the fact that specifications for bandwidth are made at the so called 3db point. Essentially, this means that in a 25 MHz oscilloscope, signals with a frequency of 25 MHz will be displayed with approximately seven tenths the apparent amplitude of a low frequency signal. This means that if an oscillosocpe is used at anything more than 50% of its rated bandwidth, a correction factor must be applied to the reading for all but relative measurements. Oscilloscopes used in the SBE service facility all have a bandwidth of 35 MHz or greater.

Another important consideration to successful use of the oscilloscope in servicing is the sensitivity of the vertical amplifier. Because of the necessity of using a 10X low capacity probe for most oscilloscope measurements (all wave-forms taken in this manual were made with a 10X probe), the effective sensitivity of the vertical amplifier is reduced by a factor of 10. We have found that a sensitivity of 50 millivolts per division with a 10X probe is the minimum satisfactory sensitivity for C.B. transceiver servicing.

This means a basic oscilloscope sensitivity of 5 millivolts per division at its input jack. Calibration of the vertical input of the oscilloscope is necessary for easy trouble-shooting. We find that the best form of step attenuator uses the 1-2-5 sequence of sensitivity steps.

An oscilloscope having a vertical bandwidth as described above will generally have sufficient horizontal sweep capabilities for proper display of the signal. Two factors are important in the oscilloscope's horizontal sweep capability: The first of these is a sufficient number of calibrated horizontal sweep speeds. These should preferably range in a 1-2-5 sequence over one second or longer to 1/10 micro-second or less per division. The second factor is triggering capability. Triggered sweep capability is important in general servicing and absolutely indispensable in digital servicing. A good triggered sweep system offers the advantage of allowing a repetitive wave-form of any frequency to be displayed as a stable trace on the oscilloscope at any sweep speed. This allows the calibrated capabilities for amplitude and frequency measurement to be used to their fullest advantage.

Additional features are useful but not indispensable to the C.B. servicing oscilloscope. These features include: dual trace, delaying sweep, and trigger hold-off. Although not necessary, these additional features should be considered, especially with digital synthesizer servicing in mind.

WATTMETER

Wattmeters of professional class only should be considered for citizens band servicing. This limits the choice to two brands that are nationally distributed. These are Bird and Sierra.

The most important specification in selecting a wattmeter for citizens band servicing is calibration accuracy. The wattmeter you choose should specify this figure to 5% or better at the frequency of operation.

FREQUENCY COUNTER

Four specifications are of importance when considering the purchase of a frequency counter for citizens band servicing. These include frequency range, resolution, time base accuracy and sensitivity.

A range of 5 Hz to 30 MHz is generally satisfactory for citizens band servicing, however, a slightly wider range counter (5 Hz to 50 MHz) can be useful in the servicing of certain radios which utilize crystal oscillators operating above the citizens band.

The resolution of a frequency counter, in practical terms, is basically set by the number of digits in the readout. Generally speaking, a six digit counter provides sufficient resolution for the purposes of citizens band servicing.

The accuracy of the time base oscillator is usually specified in at least two of three different forms: These include overall accuracy over a period of time (usually a year), ageing rate and temperature stability. The first method of specification is the easiest to interpret as it includes all temperature and ageing factors. Typical values for a satisfactory counter would be in the range of + or - 20 parts per million per year. A good specification for maximum ageing rate would be 10 parts per million per year or 1 part per million per month. A satisfactory figure for temperature stability would be + or - 10 parts per million over a range of 0-40° C.

Specification for the sensitivity of the counter input must include consideration of two factors: The input sensitivity in volts and the impedence of the input line. The preferable input impedence for a citizens band counter is 1 megohm shunted by 20 pfd or less. This allows the use of standard 10X oscilloscope probes for counting frequencies in sensitive circuits where a direct connection with coaxial

FIG. 5.1-2 AUDIO TEST BOX

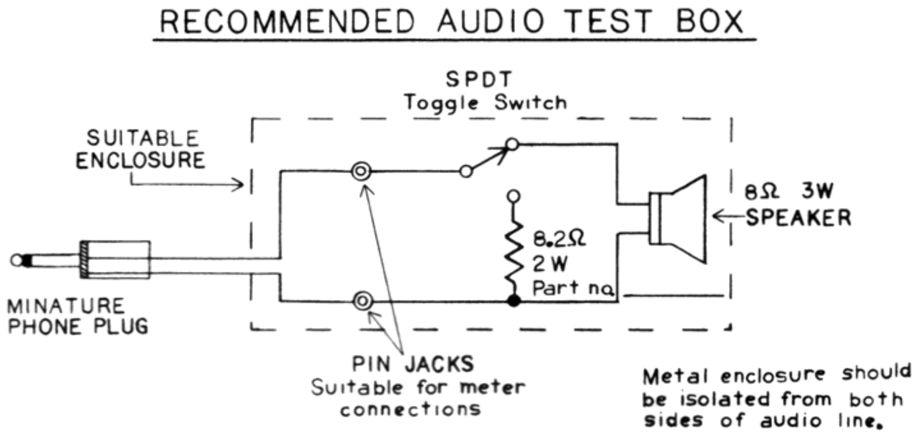


FIG. 5.1-3 MODULATOR TEST BOX

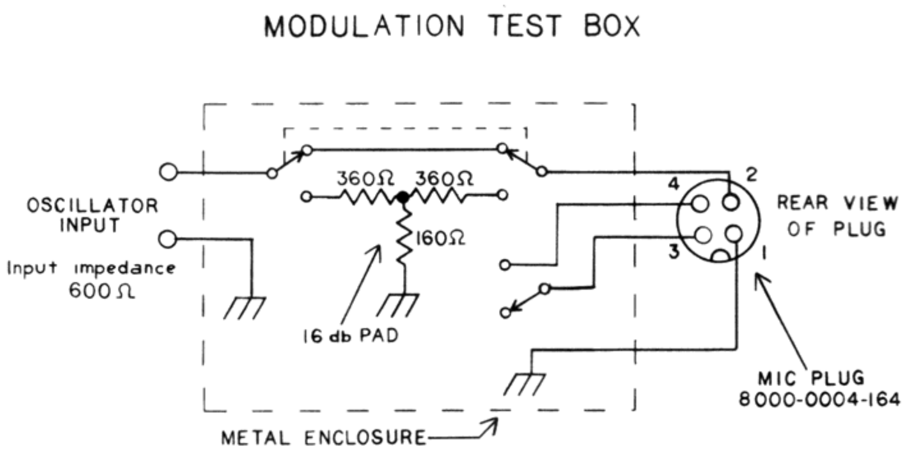
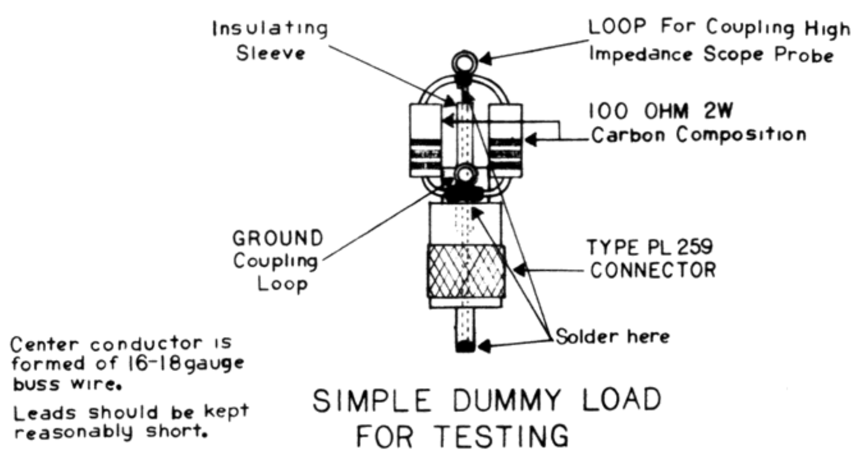


FIG. 5.1-4 SIMPLE DUMMY LOAD



cable will usually upset the circuit. The necessity of using 10X probes to reduce capacitive and resistive loading on the circuitry being tested, requires that the sensitivity of the counter be excellent. 10 millivolts R.M.S. is a satisfactory sensitivity specification for a citizens band servicing counter.

TABLE 5.1-1
RECOMMENDED TEST INSTRUMENTS

TEST INSTRUMENT	REQUIRED SPECIFICATIONS	USE	RECOMMENDED INSTRUMENT TYPE
R.F. Signal Generator	Output frequency: 26.965 to 27.255 MHz. Output level calibrated from .1 microvolts to 500,000 microvolts. Internal modulation capability of 30% minimum at 1 KHz. (Calibrated)	Receiver service and alignment.	Hewlett-Packard Model 606A or B. Wavetek Model 3000.
Oscilloscope	Vertical bandwidth of 25 MHz or greater at 3db point. Triggered sweep capability.	Transmitter and receiver test and alignment.	Tektronics Model T932. Tektronics Model 465. Hewlett-Packard Model 180. Phillips Model PM3260E.
Frequency Counter	Frequency range DC to 30 MHz. Sensitivity: 10mv R.M.S. at 30 MHz. Overall timebase accuracy ±.002%, 6 digit resolution.	Transmitter frequency check and synthesizer troubleshooting.	Heath-Schlumburger Model SM118A
Wattmeter	5 watts full scale into 50 ohm load ±5% accuracy.	Measure power output and S.W.R.	Bird Model 43 with type 5A element. (May be terminated with antenna load described in Figure 5-1-4.)
AC VTVM	-40 to +20db range.	Measure audio output.	Heath Model IM-21.
Audio Oscillator	400 Hz to 4000 Hz output: Adjustable level, 0-1 volt output impedence 600 ohm.	Audio and modulator tests.	Hewlett-Packard Model 204C. Heath Model SG18A.
DC Power Supply	13.8 volt DC ±10% at 2 amperes.	Primary supply voltage for servicing.	Heath Model SP2720 (SBE Model SBE-1AC may be used if available.)
Audio Test Box	8 ohm speaker and resistive load with switching provisions.	Receiver tests and alignment.	Refer to Figure 5.1-2 for fabrication details.
Modulator Test Box	16db 600 ohm pad (switchable), plus keying switch.	Transmitter and modulator checks.	Refer to Figure 5.1-3 for fabrication details.

5.2 PERFORMANCE VERIFICATION

RECEIVER

Step 1. Connect unit to 13.8 volt DC supply.

Step 2. Set generator frequency to 27.115 MHz with 30% modulation at 1 KHz. Connect the signal generator to the antenna jack of the transceiver.

Step 3. Set channel selector switch to channel 13, the DIS/LOC switch to distance position, CB/PA switch to CB position, noise limiter switch to NL position and delta tune to mid-position.

Step 4. Set signal generator output at 1 microvolt and verify 5 volts AC audio across external speaker jack using 8 ohm resistive load.

Step 5. Adjust the test equipment as in Step 4 above. Turn off the signal generator modulation and verify a 10db or greater reduction in audio output.

Step 6. Increase generator output to 100 microvolts. Check for "S" meter indication of approximately "S9".

Step 7. Observe meter lamp and channel selector lamp to insure that both are operational.

Step 8. Reset generator output to 1 microvolt. Rotate delta tune control to both extremes, verify a slight decrease in audio output and "S" meter reading at both extremes, return delta tune to center position.

Step 9. Increase signal generator output to 200 microvolts. Rotate squelch knob fully clockwise and verify full squelch of the receiver with an input of 200 microvolts (tight squelch may be adjusted with VR8).

Step 10. Decrease generator output to 1 microvolt, adjust squelch control to the point that the receiver is just muted. Increase signal generator output by ½ microvolt and verify that the squelch opens.

Step 11. Set CB/PA switch in the PA position. Connect an external speaker or 8 ohm load across PA jack and observe the audio output while speaking into the microphone.

TRANSMITTER

Step 1. Connect the unit to 13.8 volt DC supply. Set channel selector to channel 13, CB/PA switch to CB position. Connect standard microphone to the microphone input jack. Connect wattmeter and dummy load to antenna jack. Key the transmitter and check that the transmit lamp comes on. Observe an output of 3 watts or greater on the wattmeter. Observe a nominal internal R.F.O. meter reading of approximately 2/3 scale. (R.F.O. may be adjusted by VR6.)

Step 2. Whistle into microphone with transmitter keyed and verify that 80% positive and 90% negative modulation capability is obtained.

Step 3. Connect counter through 10X probe to wattmeter load and check the transmit frequencies on all channels.

SYNTHESIZER

Step 1. Check the voltage at the emitter of Q18. If high, (approximately 3 volts) go to section 5.3. If low, (less than .5 volts) go to step 2.

Step 2. Check wave-form at the collector of Q23 (refer to wave-form no. 9 on the synthesizer schematic.) If wave-form is not present or is substantially reduced in amplitude, go to section 5.3. If wave-form appears normal, go to step 3.

Step 3. Monitor the output frequency of the synthesizer at the collector of Q23 (coupled to the counter with the 10X oscilloscope probe) in both transmit and receive modes. Check to see that the output frequency on each channel agrees with the frequencies listed in the programming chart (figure 5.2 1). If the output frequencies are wrong in either mode, on any channel, refer to section 5.3.

If the three above tests are passed by the synthesizer, it may be assumed that any problems in the receiver or transmitter are limited to failures external to the synthesizer. Refer to section 5.4 for receiver problems, section 5.5 for transmitter problems.

FIG. 5-2.1 PROGRAMMING CHART

		BINARY PRESET (5 Least Significant Digits Only)						
V.C.O. Frequency		I.C. 2	I.C. 1				Channel	
Transmit MHz	Receive MHz	Pin 3	Pin 6	Pin 5	Pin 4	Pin 3	No.	Frequency
16.727	16.270	1	1	1	1	0	1	26.965
16.737	16.280	1	1	1	0	1	2	26.975
16.747	16.290	1	1	1	0	0	3	26.985
16.767	16.310	1	1	0	1	0	4	27.005
16.777	16.320	1	1	0	0	1	5	27.015
16.787	16.330	1	1	0	0	0	6	27.025
16.797	16.340	1	0	1	1	1	7	27.035
16.817	16.360	1	0	1	0	1	8	27.055
16.827	16.370	1	0	1	0	0	9	27.065
16.837	16.380	1	0	0	1	1	10	27.075
16.847	16.390	1	0	0	1	0	11	27.085
16.867	16.410	1	0	0	0	0	12	27.105
16.877	16.420	0	1	1	1	1	13	27.115
16.887	16.430	0	1	1	1	0	14	27.125
16.897	16.440	0	1	1	0	1	15	27.135
16.917	16.460	0	1	0	1	1	16	27.155
16.927	16.470	0	1	0	1	0	17	27.165
16.937	16.480	0	1	0	0	1	18	27.175
16.947	16.490	0	1	0	0	0	19	27.185
16.967	16.510	0	0	1	1	0	20	27.205
16.977	16.520	0	0	1	0	1	21	27.215
16.987	16.530	0	0	1	0	0	22	27.225
17.017	16.560	0	0	0	0	1	23	27.255

5.3 SYNTHESIZER SERVICING

Three basic forms of defect occur in the digital synthesizer of the Formula D.

1. LOSS OF PHASE LOCK

Under these conditions, the voltage controlled oscillator, Q21, is no longer under control of the phase lock loop system. There are several possible causes for this. A break anywhere in the loop, causing a loss of one of the inputs to the phase detector, a defect in the oscillator control circuitry including I.C. 9, Q20 and associated circuitry, (this of course, is also a break in the loop, in effect), a division ratio so far from correct in one of the divider chains that it is not possible for the oscillator to pull far enough in frequency to phase lock under these conditions.

A quick test to determine whether or not the V.C.O. will operate at the correct frequency, is to clamp test point 3 with a variable power supply voltage. By varying this voltage, in the area of 1-4 volts, it should be possible to obtain the full range of normal oscillator frequencies. With the voltage at approximately 2.5 volts, it should be possible to tune L14 for an oscillator frequency of approximately 16.5 MHz. If this is not true, it may be assumed that D26 or one of the other associated frequency determining components is defective, including C509, C511 and C510.

If phase lock is lost, or if the unit is operated with the channel selector in the blank position, the "out of lock disabler" circuit will become active. This circuit is a handy reference to determine if the synthesizer is in phase lock. If the circuit is working normally, the emitter of Q18 will be pulled up to approximately 2½ to 3 volts whenever phase lock is lost.

2. NO OUTPUT OR LOW OUTPUT

The general symptom is insufficient or nonexistent output at the collector of Q23. This is the easiest and most conventional fix. It is simply a question of checking the oscillator and its two buffers to determine where the defective component may be. The oscillator may be treated as a conventional L.C. oscillator, and the two buffers as common emitter amplifiers.

3. WRONG DIVISION RATIO

The third group of possible defects is when the oscillator frequency is wrong but phase locking is obtained. In this case, generally the error in frequency will be some multiple of 10 KHz, 20 KHz, 40 KHz, 80 KHz or 160 KHz. Reference to the programming defects chart will help to isolate problems in the programming (channel selector) switch. If the pattern of defects is the same as that specified in one of the conditions on the chart, you may safely assume that either the switch section noted, the pull-up resistor noted, or the I.C. involved, is defective. Although problems of this nature are generally found in the programmable divider, occasionally defects causing a wrong frequency output will be found in the reference divider. Defects in the reference divider circuit may be easily isolated by comparing the input and output frequencies of the various I.C.'s with those specified on the synthesizer circuit diagram. PLEASE NOTE: The use of a sensitive counter and a 10X 10 megohm input oscilloscope probe is recommended to avoid loading the inputs and outputs, which may cause erroneous readings.

On occasion, internal defects in I.C. 9 may result in excessively wide output pulses at either pin 2 or pin 13 of I.C. 9. Under these conditions, the synthesizer will appear to operate normally and oscillator frequency will be normal, however, the "out of lock disabler" circuit will be active. It is normal for the output pulses at pins 2 and 13 of I.C. 9 to be negative going and of very short duration when the synthesizer is in phase lock. If, however, one of these pulses should, due to a defect internal to I.C. 9, become excessively wide, this will cause the out of lock detector, D25, to detect sufficient average negative voltage to cause Q19 to be turned off, which will allow the gating circuits to turn on Q18 and disable the transmit and receive mixers. This defect can also be caused by internal problems in I.C.