3 GENERATING THE SIGNAL FREQUENCIES

Figure 2-1 showed basic CB transceiver block diagrams. In the diagrams were blocks called the "Master Oscillator" which fed both the Receive and Transmit mixer stages. The Master Oscillator is the subject of this chapter. It's the heart of any CB transceiver, the point from which all other signals are developed, mixed, or amplified. The modern Master Oscillator is one of two types: the multiple crystal synthesizer, or the PLL (Phase Locked Loop) synthesizer. Walkie-Talkies (except 40-channel types) and old tube CBs with plug-in crystals use direct generation rather than synthesizers.

CRYSTALS & CRYSTAL OSCILLATORS

The crystal oscillator is found in virtually every CB radio. If a piece of quartz is cut a certain way, sandwiched between two metal plates, and the proper electrical voltage applied, a molecular strain develops which causes the quartz to vibrate or "oscillate." The reverse is also true: if a crystal (like that in a crystal mike) is mechanically strained, it produces an AC output voltage. This is known as the "piezoelectric effect." The oscillation occurs at a very precise frequency. It's this stability which makes quartz crystals so useful as control devices; the oscillator's frequency can be controlled within a very tight and predictable range.

Figure 3-1 shows the electrical equivalent of a quartz crystal, and its internal construction. A crystal is the equivalent of a series-resonant circuit having high inductance and low capacitance. "R" represents the crystal's mechanical resistance to vibration; the higher this resistance, the harder it is to make it vibrate. A crystal with good "activity" has a low resistance, while one with high resistance will be sluggish and may not even oscillate. Sometimes a crystal loses activity with age and eventually fails. $C_{parallel}$ represents the capacitance of the holder and any other external shunt capacitance in the circuit.

Crystals are grown artificially from a sample of quartz material. Like diamonds, quartz crystals have several possible cutting angles relative to the major axis. The specific cut depends upon the intended operating frequency and has a great effect on performance. Most common for CB use is the "AT" cut. It has a very small temperature coefficient, which means it's not as affected by temperature as some other cuts. This makes it especially useful for high frequency circuits, where stability is a major concern. Figure 3-2 shows the AT cut on a typical bar of cultured crystal.

FIGURE 3-1
ELECTRICAL EQUIVALENT OF QUARTZ CRYSTAL AND ITS CONSTRUCTION

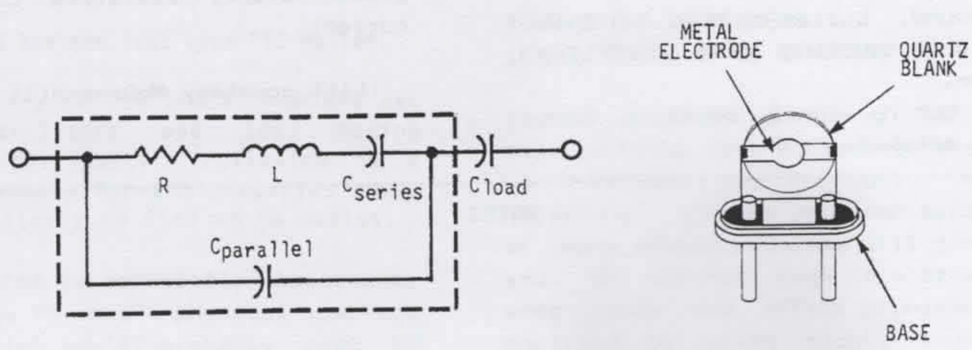
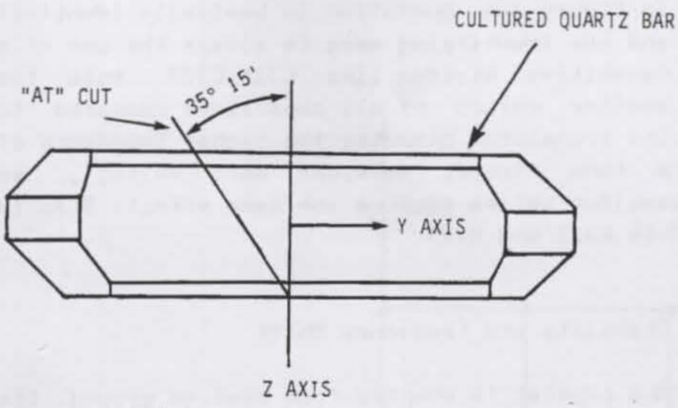


FIGURE 3-2
THE AT CRYSTAL CUT



Series and Parallel Resonance

A crystal can oscillate with either series or parallel resonance, depending upon the cut and its placement in the circuit. The series-resonant circuit has a slightly lower natural frequency than the parallel-resonant or "anti-resonant" circuit. For example, surplus FT-243 crystals have about a 2.2 KHz mode difference at 5 MHz. If a parallel-mode crystal in used in the series mode, it oscillates at the series-resonant frequency and will appear to be lower than its marked frequency.

A series-resonant circuit has the lowest impedance, and its frequency is determined only by the crystal's vibration. In Figure 3-1, if C_{load} weren't present, the crystal would be series-resonant and would look purely resistive to the circuit; no load capacitance would need to be specified. As it's tuned off resonance the circuit becomes parallel-resonant, since the inductive reactance of L becomes greater than the capacitive reactance of C_{series}. So it looks inductive to the circuit.

When this reactance is in parallel with the crystal holder or any other external parts (represented by $C_{parallel}$), it forms a parallel-resonant circuit. The resonant frequency of such a circuit is determined by mechanical vibrations and external capacitance; the load capacitance must be specified for such crystals. This partly explains why you may get misleading frequency measurements when using an out-of-circuit crystal tester compared to the actual oscillator operating conditions.

A parallel-resonant circuit has a much higher impedance than a series circuit. Because it's extremely sharp tuning (high Q), moving the oscillator slightly off frequency decreases its feedback voltage, discouraging it from oscillating at any but the intended frequency. That's what makes a quartz crystal such an excellent and stable frequency source. CB crystal oscillators use several methods to maintain this stability.

Transistor Oscillators

Transistor oscillators are patterned after the same circuits used by vacuum tubes, and the same general rules apply. The main differences are the input/output impedances and voltages involved. Bipolar transistors have much lower impedances than tubes, and input/output capacitances are usually higher. In choosing oscillator transistors, a rough rule-of-thumb is that they should high gain ("beta") and an f_T (point where gain = 1) at least 10 times higher than the intended operating frequency. That's why devices like the 2N2222A, 2N3904, 2SC710, 2SC945, or 2SC1675 are used as CB oscillators, even though they're also capable of certain VHF/UHF applications too.

What makes a circuit oscillate in the first place? If part of an amplifier's output is connected back to its input so the signals are in phase, this extra input adds to the existing input to further increase the gain. This is known as "positive feedback." There must be at least enough feedback to compensate for the circuit losses; otherwise the oscillations would eventually die out just as friction makes mechanical vibrations die out. Once the gain passes a certain point the circuit can sustain itself with no help from the original input, in a sort of perpetual motion.

The crystal (or any similar control element like an LC network) sets the frequency at which this happens. You can think of an oscillator as a sort of high-gain amplifier that's gone out of control. In this case it's exactly what we want to happen, but there'll be other times when self-oscillation is very undesirable and must be prevented at all costs, like in RF and audio amplifiers. Oscillators are often biased Class C for its very high efficiency. Both a regulated supply voltage and voltage-divider bias methods are used to increase stability.

The Colpitts Oscillator

There are several types of oscillators, and their main differences are in the way the feedback is applied. For CB use the Colpitts circuit is standard, probably because capacitors are much cheaper than coils. One side of the crystal is grounded, which also simplifies the problem of stray capacitance in crystal switching circuits. The crystal is normally used in its parallel-resonant mode except in certain SSB circuits.

Refer to Figure 3-3. The Colpitts oscillator is identified by a capacitive voltage divider (C1/C2) which provides the feedback. Feedback is via C2 which couples back about 25-35% of the output voltage. Thus the value of C2 is generally chosen to be roughly 1/4 or 1/3 of C1 for best stability. If the feedback is too small it won't oscillate; if too large it won't give good amplification, lowering the output voltage and possibly fracturing the crystal. You'll see oscillators using ratios from 10:1 to 2:1 depending upon the particular circuit, crystal cut and frequency; the minimum feedback value for reliable oscillator starting is always chosen. R3 provides a DC emitter return while keeping Q1 above RF ground. Sometimes you'll see an RF choke used here but a resistor works fine. Biasing is by the voltage divider R1/R2, and the main supply is always well regulated; both measures insure good stability.

A tube version of the Colpitts circuit is shown in Figure 3-4. Operation is basically identical and the identifying mark is always the use of a capacitive divider like C326/C327. Note the smaller values of all capacitors compared to the transistor circuit; the higher impedance of a tube circuit develops more voltage, so smaller values produce the same effect. Bias is via R321 and R323.

Stability and Frequency Shift

The crystal is shunted from base to ground. Its frequency is often made adjustable by a small value of inductance or capacitance, as shown below. Because the bipolar Colpitts circuit already has a fairly high input shunt capacitance, the trimmer is always placed in series with the crystal for maximum effect. Sometimes you'll see an additional small fixed capacitor (under 10 pF) in parallel with the trimmer; this helps stabilize the frequency for temperature drift by dampening the effect of the trimmer and distributing the heating effects of the RF currents more evenly. While this isn't always done in AM radios, SSB requires the extra stability measures.

FIGURE 3-3
COLPITTS CRYSTAL OSCILLATOR

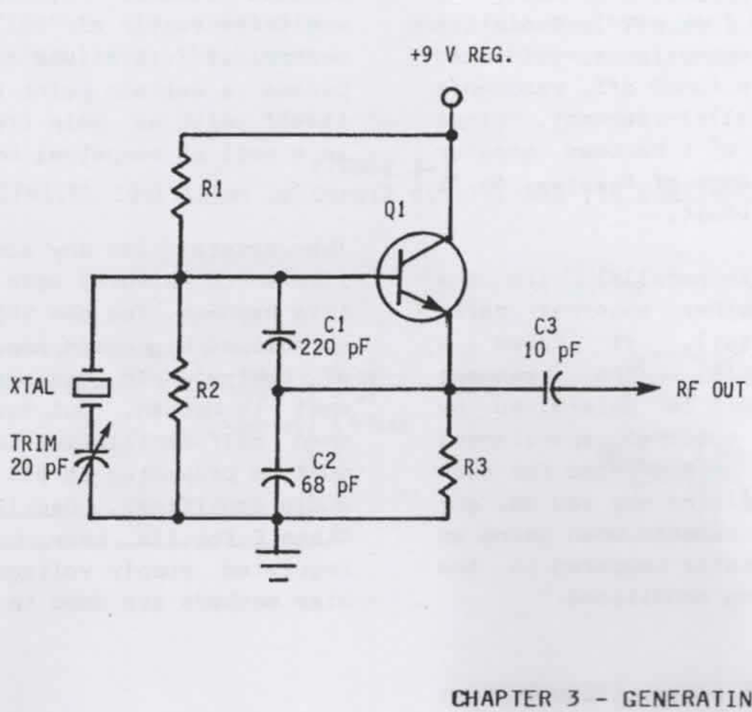
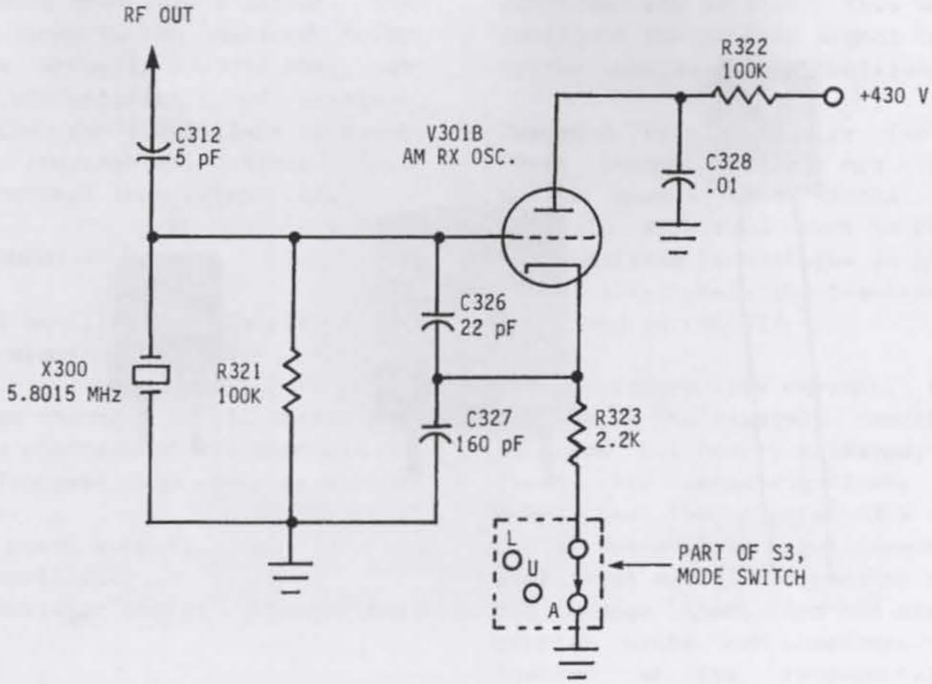


FIGURE 3-4
VACUUM TUBE COLPITTS OSCILLATOR
(Tram D201/D201A)



For best stability the trimmer is always a high-quality ceramic rather than a mica compression type. Voltage-divider bias is used for stability. In addition oscillator V_{CC} is kept to a minimum, under 9.0 VDC, and always Zener- or transistor-regulated by a separate branch of the power supply.

Sometimes the frequency is purposely shifted, like in Delta Tune and SSB Clarifier controls. The standard AT cut crystal will "slide" very nicely, as will third-overtone types used in their fundamental modes. To minimize stray capacitance they're usually soldered directly to the PC board without sockets. The most common CB crystal holder types are the HC18/U, HC6/U, and HC25/U, Figure 3-5. The larger (and more expensive) HC6/U was used mostly before the 23-channel era. It has the largest tuning shift, which is why it's still used in the Cobra 148/2000GTL chassis Clarifier circuit.

Overtone Oscillators

Crystals of less than about 20 MHz are of the "fundamental" type, meaning they vibrate directly at the cut frequency. Above 20 MHz, the crystal wafer becomes physically too thin and fragile to be practical. For higher oscillator frequencies an "overtone" crystal is used. This is specially cut to oscillate at an approximate odd harmonic like the 3rd, 5th, 7th, etc. The third overtone is most common. Overtone crystals have much higher Q than fundamental types of the same frequency, making them more stable and less affected by external circuit capacitance. Many CB synthesizers require signals in the 33-37 MHz range, generated from third overtone crystals. For example, in Figure 3-6 the desired AM output is 33.3350 MHz; an 11.1125 MHz third overtone crystal and tripler stage are used. In overtone oscillators, the crystal is always used in its series-resonant mode.

Notice that a separate tripler stage (TR23) follows the 11 MHz oscillator. While a harmonic oscillator could be used directly (and is, in cheaper designs), its fundamental note and other undesired harmonics would also appear in the output and would have to be filtered. Overtone crystals don't have this problem. But

FIGURE 3-5
CRYSTAL HOLDER TYPES
(Courtesy McGraw-Hill Book Co.)

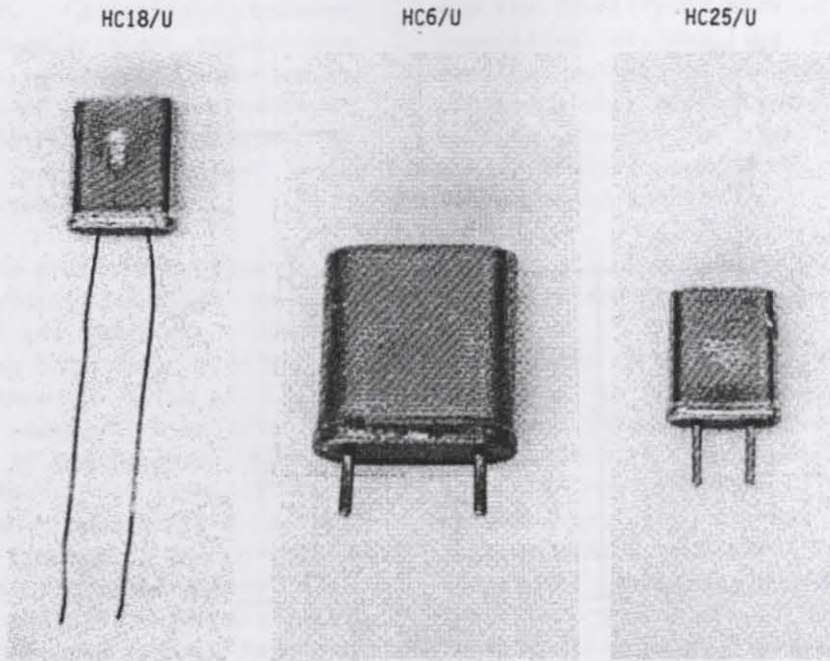
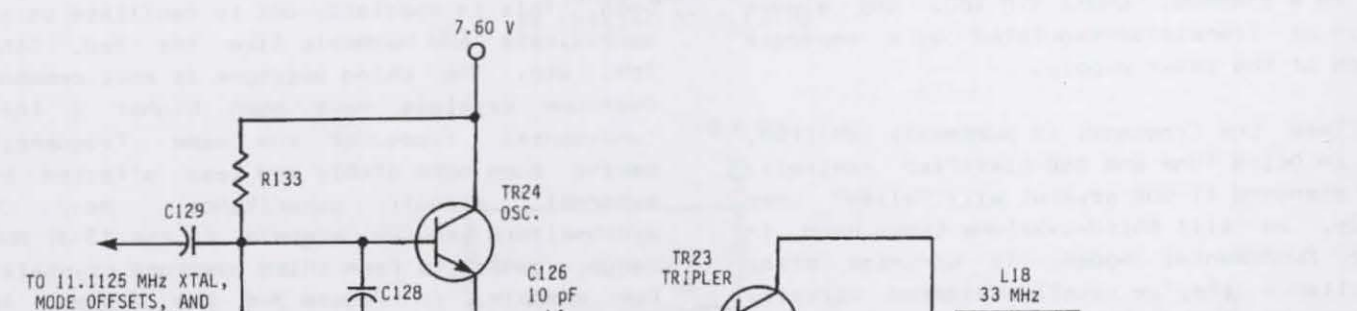


FIGURE 3-6
OVERTONE CRYSTAL OSCILLATOR
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)



they're extremely fragile, only a few mils thick, and are generally operated with the minimum feedback that will sustain oscillation. The rest of TR24 is a standard Colpitts circuit. R133 and R134 provide voltage-divider bias. Output coupler C126 is purposely kept small to avoid loading down TR24's output. The output at L18 is tuned to the desired third harmonic, which is actually 33.3350 MHz, not 33.3375 MHz. One characteristic of overtone crystals is that they don't oscillate on exact multiples of the fundamental, since their action is more mechanical than electrical.

OSCILLATOR TROUBLESHOOTING

Repairing a crystal oscillator is fairly easy. Oscillator failure symptoms include:

1. No Transmit, some channels or all channels.
2. No Receive, some channels or all channels.
3. No Receive or Transmit, and radio is a PLL-synthesized type.
4. Low transmitter power output.
5. Weak receiver sensitivity.
6. Intermittent receiver and/or transmitter operation.

Transistor and tube-type oscillators are not much different except for the operating voltages. A gassy oscillator or mixer tube will account for many problems in tube circuits. The high voltages used in tube circuits tend to break down other parts faster too, especially electrolytics which dry out with heat and age. Crystals are a common failure point in both oscillator types.

The first step is to determine if the oscillator is running. A 'scope or frequency counter at its output reveals this immediately, although the counter is preferred since it gives the exact frequency. Since an oscillator develops base (or grid) bias when oscillating, check for this with the crystal removed or shorted by a capacitor; the voltages should be different. If not, the problem is either a bad crystal or insufficient feedback from an open or leaky capacitor.

The amplitude of a Colpitts transistor crystal oscillator is about 1.5-2.5 VAC when measured directly at the actice device. Otherwise use very loose coupling or you may load it down and get false readings or kill it completely. A couple of turns of wire is usually enough. I prefer the "RF Sniffer" probe described in CHAPTER 1, since there's no physical contact.

If you're reasonably sure the oscillator isn't running, you can try coupling in a stable signal source like that from a signal generator. If operation is restored you've confirmed the problem. This method can be used to inject the carrier signal in the transmitter or the receiver Local Oscillator(s).

Assuming the oscillator isn't running, the first things to check are the power to the active device, the device itself, and the crystal. Referring back to Figure 3-3, check the specified DC voltages on Q1. If they're way out of line, check the transistor using methods described in CHAPTER 2.

When voltages are correct, the most likely problem is the crystal. Sometimes the crystal is good but poorly soldered; that's all it takes. Try reheating first; if that doesn't work, test the crystal in a crystal checker. Don't worry about exact frequency readings in your test oscillator because stray capacitance can change them. And the placement of your counter probe can sometimes read a harmonic instead of the fundamental. Conversely, overtone crystals may read their fundamental frequency instead. (Many CB oscillators operate in the 33-37 MHz range, which means you might read the 12 MHz fundamental note.)

If you have another crystal handy in the same frequency range, try it in place of the original. If the circuit has a series trimmer like a capacitor or coil, check for RF continuity from the crystal low side to ground. This is especially important in SSB radios because the Clarifier circuit is often between the crystal and ground. (Eg, Cobra 140/142GTL chassis, Cobra 148/2000GTL chassis.) If there's a tuning adjustment on a crystal oscillator, recheck it. Some older radios had an oscillator coil. If it's adjusted right at the critical peak it may not start every time. Such coils should always be set just past the peak on the inductive (slow-tuning) side. Screw the slug into the coil a bit further.

If none of these things work, check the individual resistors and capacitors; if a capacitor in the feedback circuit opened or changed enough, it could kill the oscillator even though the DC transistor voltages are correct. (One nice use for a capacitance meter!) And excess feedback from an increased coupling value can fracture a crystal.

How To Order Crystals

Assuming you need a replacement crystal, or the customer wants other frequencies installed, you must know some basic technical and mechanical specs or you'll feel like a dummy when you contact crystal companies; they'll ask those questions. Specs are left out of service manuals, so here they are for future reference:

FREQUENCY: As desired. (Fundamental under 20 MHz, third overtone over 20 MHz.)

HOLDER TYPE: See the photos in Figure 3-5; solder leads (HC18/U), plug-in (HC25/U), etc.

ACCURACY: .005% or better. You'll pay a lot more for higher accuracy. Some crystal circuits have no trimmer, so you may need the better one if stray capacitance affects it. Determine by the specific circuit.

RESONANCE: Specify parallel resonance for fundamental Colpitts types, and series resonance for overtone applications.

LOAD CAPACITANCE (C_L): Standard AM or FM circuits used for synthesizers, receiver Local Oscillators, transmitter oscillators, etc. are 32 pF. For SSB Carrier Oscillators or Clarifiers, where several KHz shift is needed, use a smaller value like 20 pF. The smaller the load capacitance, the more the external circuitry affects it.

Some recommended crystal suppliers are listed in CHAPTER 1. Expect to wait 2-4 weeks for it.

Miscellaneous Oscillator Problems

Strange things can happen in high-frequency circuits, especially when stray capacitive coupling exists. Usually you find this in radios where somebody tried to install a crystal switch using long wires, or some other non-standard "improvement" to the radio.

Here's a classic example: I was fixing a President Adams. It worked fine in all modes until the bottom cover was attached. When attached, it wouldn't transmit correctly on SSB; AM was OK. Keying the mike on SSB produced a solid carrier which was obviously self-oscillation. It was clear nothing on the PCB was shorting to the cover.

This baffled me until I investigated further. Turns out some fool tried to broadband a mixer coil near the Balanced Modulator IC by cutting the coil traces and rejumpering. This would have been OK, except he used #16 solid wire for the jumpers, which were bent over into "U" shaped loops parallel to the chassis and therefore the cabinet cover. With the cover attached, there was enough capacitive coupling from the loops to the metal cover to feed the signal right back where it didn't belong, causing self-oscillation. Rewiring the jumpers cured the problem. But it took that closer inspection and the old "Never overlook the obvious" to even get me thinking about it!

In 23-channel radios it's possible for one crystal to take over the function of another crystal that's dead or weak. The oscillator wants to start and will, if given the slightest encouragement. The RF power output may be normal, but off frequency. Or the power and sensitivity may be lower than normal but channels are duplicated; for example, you can receive and transmit Ch.11 from both the Ch.11 and from the Ch.15 positions. This means the crystal common to Ch.15 Receive and Transmit is probably bad. Corrosion or dirty switch contacts can also cause this.

If the problem is limited to a single channel the switch is the most likely cause; bad synthesizer crystals affect several channels at once, usually in groups of four or six channels. (Unless it's an older radio with separate crystals for each channel.) Only the position of the Channel Selector switch is unique to a single channel.

Another problem among older radios having less shielding is that a broadband signal can be transmitted covering a lot more than just one channel within the 27 MHz band! Confirm with another receiver or a spectrum analyzer.

Some RF power amplifiers, again in the older 23-channel models with their easier technical standards, are capable of transmitting a full power signal even if one of the synthesizer oscillators is dead. It might not be on 27 MHz though. For example, a 23 MHz signal might be transmitted in a radio that uses the 23/14 MHz crystal synthesizer circuit. I discovered this the hard way while trying to adjust a mobile antenna. The SWR just wouldn't come down, even though the coax was good and the radio showed a perfect match into a dummy load. I was positive the antenna was good. The rig was transmitting a beautiful 4-watt signal, on 23 MHz! In those days I couldn't afford a frequency counter or I would have caught this immediately. Be aware!

Non-Synthesized Circuits

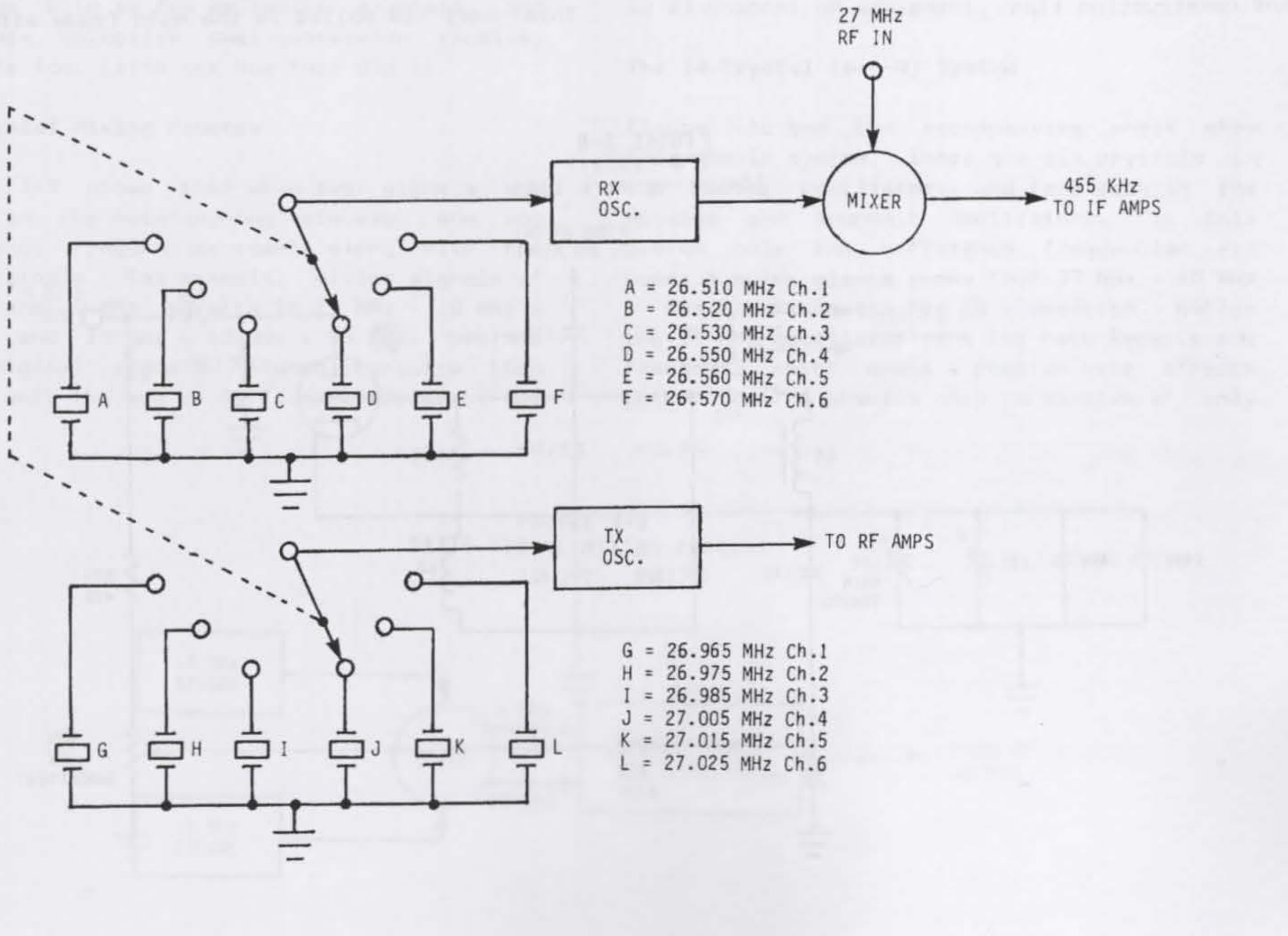
In the early days CB radios didn't have a Master Oscillator stage; they used individual oscillators for Receive and Transmit, which meant one pair of crystals per channel. The crystals were plug-in types so the user could change channels easily once the crystal socket capacity was exceeded. The pair was separated by 455 KHz to provide one receiver intermediate frequency (IF) in a simple single-conversion circuit. This allowed some selectivity, but not much. The idea worked fine back then because few people had CBs, so they didn't need many channels or any great selectivity. Imagine what that situation would be like today!

Figure 3-7 shows the basic idea. The Transmit crystal is always the direct 27 MHz frequency, and the Receive crystal is 455 KHz lower. From the oscillator, signals go directly to the transmitter amplifier or receiver mixer stages respectively. A typical example was the old "white face" Johnson Messenger II. Since many oldtimers still use these rigs and want them maintained, you should know how they work.

The very same idea is still used today for simple 3- or 6-channel Walkie-Talkies. Except for their simplified single-conversion crystal scheme, handhelds have all the same circuits as synthesized radios whose operation is explained throughout this book.

Speaking of Walkie-Talkies, a simple way to improve performance is to reverse the Transmit/Receive crystal pair. This allows operation on a frequency which is 455 KHz below

FIGURE 3-7
CRYSTAL MIXING FOR 6-CHANNEL SINGLE-CONVERSION WALKIE/TALKIE



the marked channel, on a "0" frequency rather than a "5." For example, reversing a Ch.19 pair (27.185 MHz) means Transmit is now on 27.185 MHz - 455 KHz = 26.730 MHz instead. The required 455 KHz Receive IF offset remains, except now it's high-side injection rather than low-side injection. (See P. 99.) No retuning is usually needed, the range is improved since it's on a quiet (but illegal) channel, and the customer will think you're a genius.

The VFO

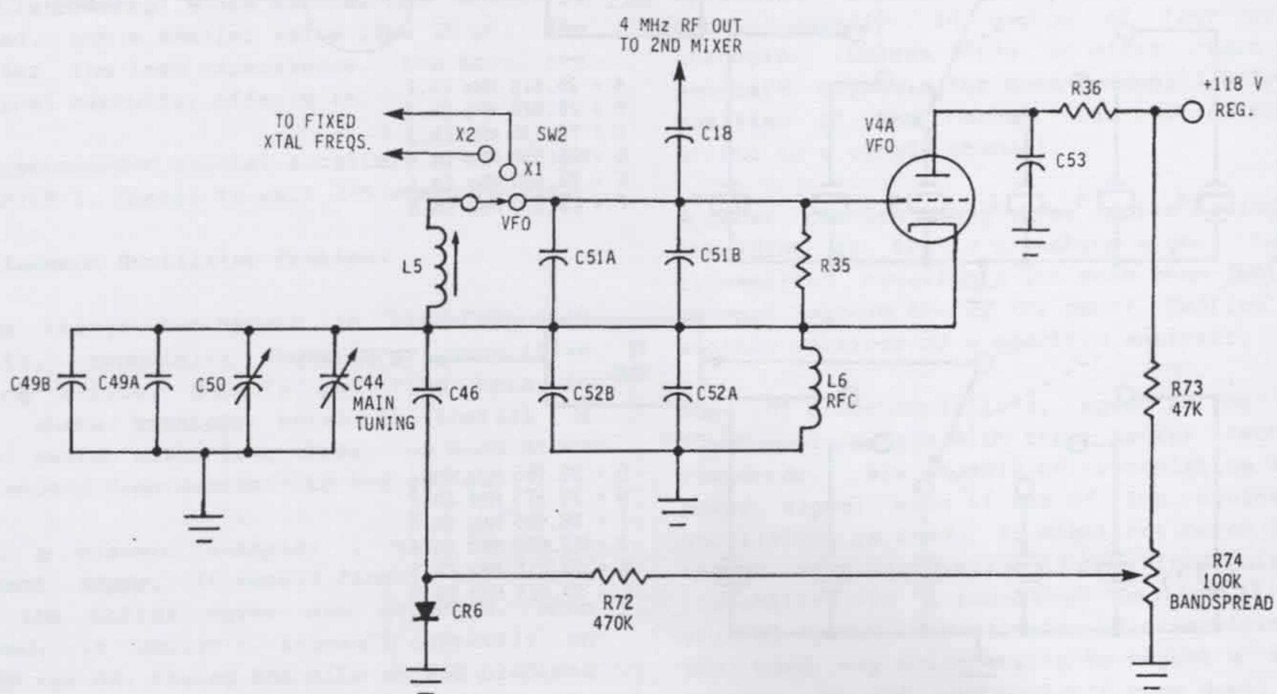
The VFO (Variable Frequency Oscillator) is a circuit you won't find much anymore, but I've included it to show its similarity to the crystal-controlled oscillator. (Don't confuse this with a Variable Crystal Oscillator or VXO, which is the technical name for a Delta-Tune or Clarifier circuit.) Some of the classic old Trams and Brownings included VFOs before FCC rule changes prohibited them. And a few VFOs were sold as add-on accessories. Many people are still interested in them. The serious builder should consult the DeMaw book or THE RADIO AMATEUR'S HANDBOOK for detailed theory and construction tips.

Figure 3-8 shows the popular Browning and Tram type VFO, minus the switching for simplicity. This is another Colpitts circuit, now series-tuned. (Most crystal oscillators are parallel-tuned.) A triode tube is used here, similar to the bipolar transistor except for biasing and impedances. Note the same use of a capacitive feedback divider, C51b/C52a. The frequency controlling elements are L5, C44, C49a, C49b, C50, C46, and the Bandspread circuit.

The parallel tank circuit isn't practical in a VFO. The high combined shunt capacitance of C51a/C51b and C52a/C52b would require the inductance of L5 to be an unreasonably low value. Even if it works right, the smallest changes in lead length or PC traces would cause electrical and mechanical instability. These problems are solved by using a series-tuned tank circuit, with L5/C44 (and the associated shunt trimmers and stabilizers) in series from grid to ground. The reduced shunt capacitance allows a larger and more practical coil value for L5, which in turn reduces the effects of stray circuit capacitance.

This coil is bolted to the main frame with a

FIGURE 3-8
VFO CIRCUIT
(Browning Mark III)



locking nut for good mechanical stability. Multiple parallel trimmers (C49a/C49b, C50) are used across the Main Tuning capacitor. These add thermal stability by distributing the RF currents among several capacitors rather than just one. The +118 VDC supply is Zener-regulated from the main HV supply.

The Bandspread circuit is a simple way to fine-tune the VFO. As the voltage to CR6 is increased via R74 the diode turns on, shunting the additional capacitance of C46 into the circuit. The capacitance is controlled by the forward bias on the diode. The high value of R72, R73, and R74 is for RF isolation from the power supply, similar to modern Clarifier circuits. By using a regulated voltage for the Bandspread control, there's no initial power-up drift caused by diode junction heating when switching from standby to active use.

CRYSTAL SYNTHESIZERS

As CB radios gained popularity, all of the original 23 channels were quickly filled up. Crystals are very expensive relative to other components and it wasn't practical to use 46 separate crystals to cover the band, let alone 80 crystals when the band was expanded to 40 channels. And as overcrowding became the rule, more selective receiver circuits were needed.

The answer to the problems of cost, physical chassis space and greater selectivity was a process called "crystal synthesis" or "crystal-plexing." This allowed complete 23-channel AM coverage with as few as twelve crystals, and the more selective dual-conversion receiver circuits too. Let's see how they did it.

The Crystal Mixing Process

Figure 3-9 shows that when two signals are mixed in the heterodyning process, sum and difference frequencies result along with the two originals. For example, mixing signals of 15 MHz and 10 MHz results in 15 MHz - 10 MHz = 5 MHz, and 15 MHz + 10 MHz = 25 MHz, besides the original signals. Tuned circuits then select only the sum or difference frequency for further processing. In CB synthesizers both sum and difference signals may be used.

Forget the additional crystals used in SSB equipment for the moment, since this is completely covered in CHAPTER 6. This leaves basically two crystal synthesis methods for most AM radios: the 12-crystal scheme, and the 14-crystal scheme. In both cases, three oscillators are used: a Master Oscillator, a Transmit Oscillator, and a Receive Oscillator. There are subtle differences between the two mixing methods, and each was used about equally in 23-channel AM equipment.

The 14-Crystal (6-4-4) System

Figure 3-10 and the accompanying chart show this basic system. There are six crystals in the Master Oscillator, and four each in the Receive and Transmit oscillators. In this system only the difference frequencies are used; a quick glance shows that 37 MHz - 10 MHz = the 27 MHz needed for CB operation. Notice the 37 MHz oscillator runs for both Receive and Transmit, which means a problem here affects both modes. A problem only on Receive or only

FIGURE 3-9
BASIC SIGNAL MIXING PROCESS

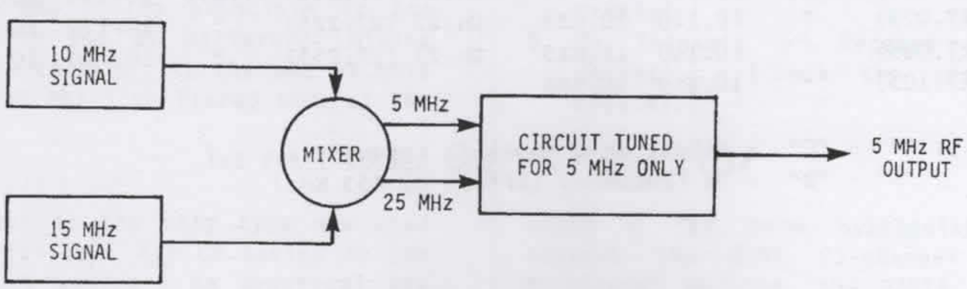
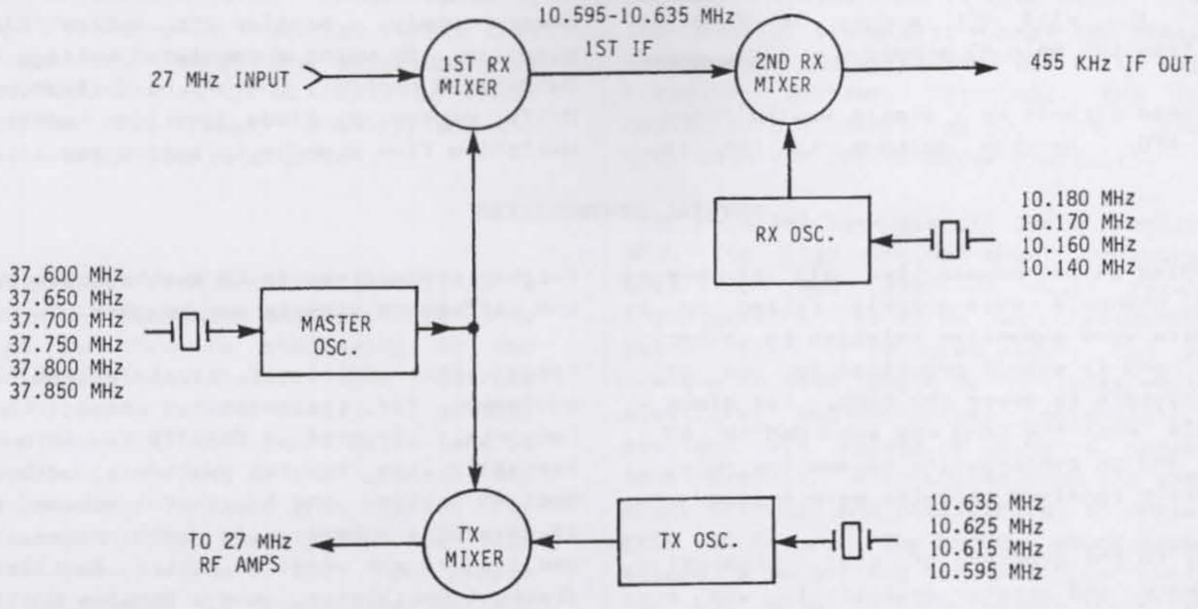


FIGURE 3-10
THE 14-CRYSTAL (6-4-4) AM MIXING SYSTEM



THE 14-CRYSTAL AM SYNTHESIZER

	BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"		BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"
Ch. 1 (26.965)	37.600	10.180	10.635	Ch.13 (27.115)	37.750	10.180	10.635
Ch. 2 (26.975)	"	10.170	10.625	Ch.14 (27.125)	"	10.170	10.625
Ch. 3 (26.985)	"	10.160	10.615	Ch.15 (27.135)	"	10.160	10.615
Ch. 4 (27.005)	"	10.140	10.595	Ch.16 (27.155)	"	10.140	10.595
Ch. 5 (27.015)	37.650	10.180	10.635	Ch.17 (27.165)	37.800	10.180	10.635
Ch. 6 (27.025)	"	10.170	10.625	Ch.18 (27.175)	"	10.170	10.625
Ch. 7 (27.035)	"	10.160	10.615	Ch.19 (27.185)	"	10.160	10.615
Ch. 8 (27.055)	"	10.140	10.595	Ch.20 (27.205)	"	10.140	10.595
Ch. 9 (27.065)	37.700	10.180	10.635	Ch.21 (27.215)	37.850	10.180	10.635
Ch.10 (27.075)	"	10.170	10.625	Ch.22 (27.225)	"	10.170	10.625
Ch.11 (27.085)	"	10.160	10.615	Ch.23 (27.255)	"	10.140	10.595
Ch.12 (27.105)	"	10.140	10.595				

Synthesis: "A" - "C" = direct on-channel TX frequency;
"A" - "B" = RX frequency (offset by 455 KHz)

on Transmit means you should consider the separate Transmit and Receive oscillators, not the Master Oscillator.

This system is divided into six major groups. The last group (Ch.2½2/23) has one less frequency than the others; we only need 23 channels, and the missing combination would generate the 24th channel. The jump of 30 KHz between Ch.22 and Ch.23 later became Ch.24 and Ch.25 in the expanded 40-channel FCC band.

For example, Channel 1 (26.965 MHz) mixes the 37.600 MHz crystal with both the 10.180 MHz crystal on Receive, and the 10.635 MHz crystal on Transmit. The transmitter mixing produces the direct channel frequency of 37.600 MHz - 10.635 MHz = 26.965 MHz. However the receiver mixing results in 37.600 MHz - 10.180 MHz = 26.510 MHz. Note this is 455 KHz lower, which provides the required 2nd IF for the dual-conversion receiver circuit.

Use this information whenever you suspect oscillator-related problems. The most common causes will be faulty crystals, a faulty mixer, poor soldering of a particular crystal, or poor contact(s) for a particular crystal at the Channel Selector switch.

Symptoms of 6-4-4 synthesizer failure are:

1. No Transmit or Receive on any channel. (Check active devices, mixer, and switch wiring.)
2. No Transmit or Receive on four consecutive channels. (Check the associated 37 MHz crystal.)
3. No Receive on every fourth channel. (Check the associated 10 MHz crystal.)
4. No Transmit on every fourth channel. (Check the associated 10 MHz crystal.)

There are some variations on the 6-4-4 crystal system using frequencies other than the common 37-10-10 MHz scheme, and you may occasionally encounter these. Examples are most Johnson radios, which use 32-6-6 MHz, and the SBE scheme of 17-9-9 MHz. The principle is the same, although both sum or difference mixing frequencies may be chosen. At the end of this chapter (Pp. 87 and 88) I've listed some of the other common AM-only mixing schemes for your reference. Also go to my Web link reference shown at the bottom of Page 85 to see all the known AM and SSB schemes.

The 12-Crystal (6-4-2) System

This system differs in the way the mixing signals are generated. See Figure 3-11 and the accompanying chart. There are now two Master Oscillators running at 14 MHz and 23 MHz. The resulting sum of 38 MHz is chosen and then mixed with separate 11 MHz Receive and Transmit oscillators. When subtracted from the 38 MHz composite signal, we get the required 27 MHz. Like the 14-crystal system with its 10 MHz Receive/Transmit crystal pairs that are separated by 455 KHz, in this system the 11 MHz crystals are also separated by 455 KHz to generate the required offset for dual-conversion receivers.

Example: For CB Channel 1 (26.965 MHz) the 23.290 MHz crystal mixes with the 14.950 MHz crystal. This gives 23.290 MHz + 14.950 MHz = 38.240 MHz. The Transmit oscillator is always 11.275 MHz, which results in 38.240 MHz - 11.275 MHz = 26.965 MHz, the channel frequency. For Receive, the result will be 38.240 MHz - 11.730 MHz = 26.510 MHz. This is the same as the 14-crystal scheme; we simply got there by a different route. This 6-4-2 synthesizer method was very popular in Uniden AM radios sold under the Cobra, Courier, HyGain, Lafayette, Midland, and Realistic names, among many others.

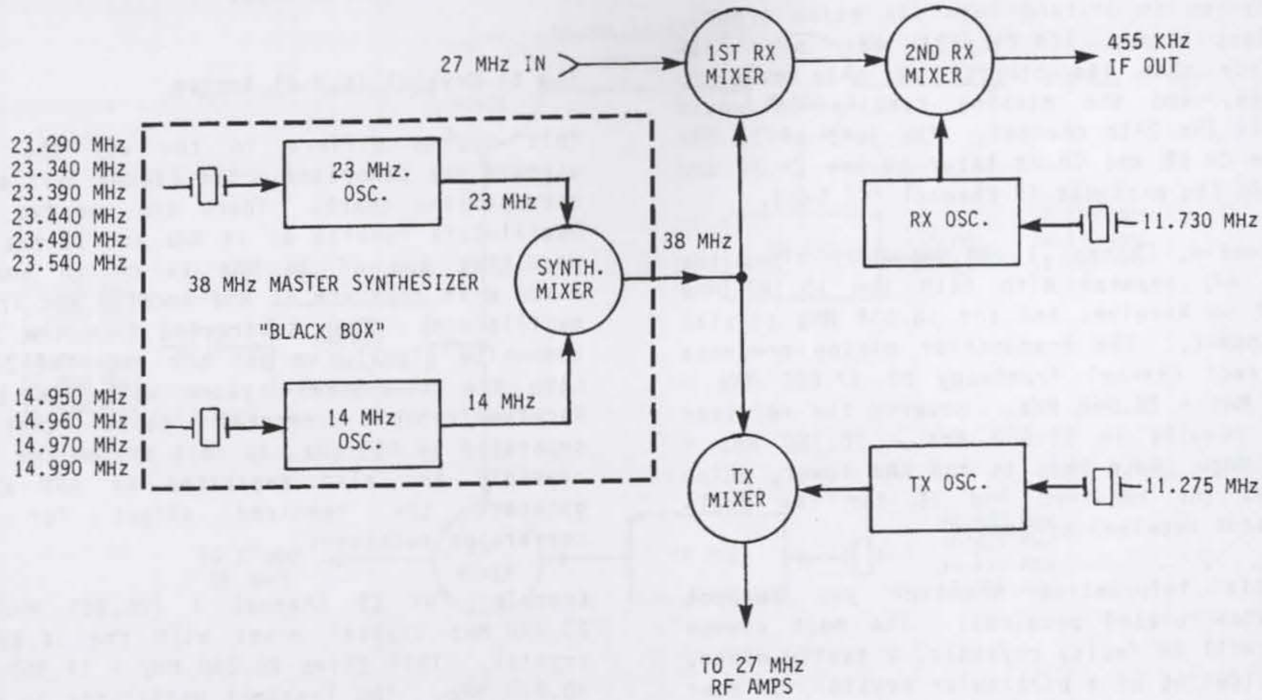
Symptoms of synthesizer failure in the 6-4-2 crystal system are:

1. No Transmit, all 23 channels. (Check the 11.275 MHz oscillator circuit.)
2. No Receive, all 23 channels. (Check the 11.730 MHz oscillator circuit.)
3. No Transmit or Receive, all 23 channels. (Check the 38 MHz mixer stage.)
4. No Transmit or Receive on four consecutive channels. (Check the associated 23 MHz crystal.)
5. No Transmit or Receive on every fifth channel. (Check the associated 14 MHz crystal.)

THE PHASE-LOCKED-LOOP (PLL) SYNTHESIZER

The PLL synthesizer is the only type now used for CB radios worldwide. Any CB having 40 (or more) channels just wouldn't be practical any other way because of the extra crystal expense. One exception was the Tram D201A, which simply added a few more synthesizer crystals to convert the D201 23-channel radio to the 40-channel version, the D201A. It had plenty of room, and was a very expensive rig anyway. A handful of late 23-channel American CBs like

FIGURE 3-11
THE 12-CRYSTAL (6-4-2) AM MIXING SYSTEM



THE 12-CRYSTAL AM SYNTHESIZER

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	23.290	14.950	Ch.13 (27.115)	23.440	14.950
Ch. 2 (26.975)	"	14.960	Ch.14 (27.125)	"	14.960
Ch. 3 (26.985)	"	14.970	Ch.15 (27.135)	"	14.970
Ch. 4 (27.005)	"	14.990	Ch.16 (27.155)	"	14.990
Ch. 5 (27.015)	23.340	14.950	Ch.17 (27.165)	23.490	14.950
Ch. 6 (27.025)	"	14.960	Ch.18 (27.175)	"	14.960
Ch. 7 (27.035)	"	14.970	Ch.19 (27.185)	"	14.970
Ch. 8 (27.055)	"	14.990	Ch.20 (27.205)	"	14.990
Ch. 9 (27.065)	23.390	14.950	Ch.21 (27.215)	23.540	14.950
Ch.10 (27.075)	"	14.960	Ch.22 (27.225)	"	14.960
Ch.11 (27.085)	"	14.970	Ch.23 (27.255)	"	14.990
Ch.12 (27.105)	"	14.990			

Synthesis: "A" + "B" - 11.275 = direct on-channel TX frequency;
"A" + "B" - 11.730 = RX frequency (offset by 455 KHz)

the SBE Formula D, Realistic TRC57, Royce 601, Midland 13-857B and similar Cybernet chassis used PLL circuits, often composed of many discrete ICs. Today's IC technology reduces the PLL circuit to just one or two chips, a few external components, and 1-7 crystals. Besides the obvious advantages of cost and space reduction, performance is also improved because every channel has the same degree of accuracy; the same crystal is being used to generate every mixing frequency.

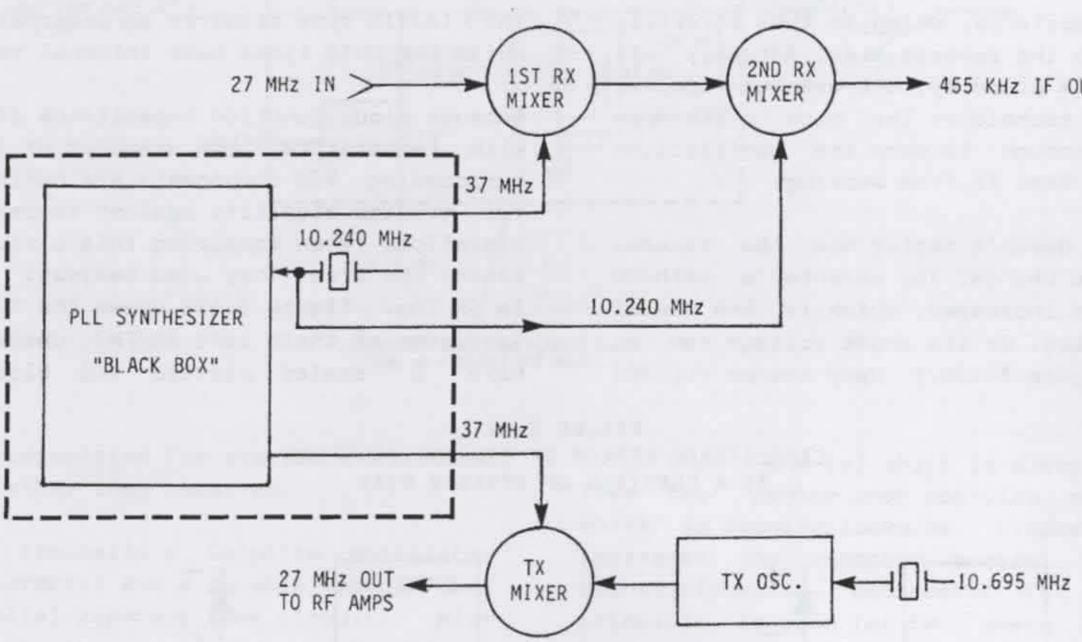
PLL circuits look more complicated than crystal synthesizers, but really aren't when you compare their end results; i.e., generating a specific set of mixing signals. The main distinction is that the PLL is a digital rather than analog system. Let's compare both in a very general way to see how they evolved.

Comparison of PLL and Crystal Synthesizers

Return to the 12-crystal 6-4-2 synthesizer on the preceeding page. For the moment ignore whatever's going on inside the dotted lines. The important point is that coming from this area is a set of 38 MHz frequencies, one for each CB channel, which when mixed with the associated 11 MHz Receive/Transmit oscillators will produce the required signal frequencies.

Now compare this to the equivalent PLL synthesizer of Figure 3-12. Again, the area inside the dotted lines can be considered a "black box" for the moment. Its output is a group of 37 MHz frequencies, plus a 10.240 MHz signal. When mixed with the appropriate Receive/Transmit circuits, the same signal frequencies are generated. Note the 10.240 MHz oscillator is sampled and also used to supply the injection for the 2nd receiver IF. This eliminates the extra cost and complexity of another crystal oscillator, and also helps reduce the number of spurious signals generated within the radio. Except for some other minor changes for SSB, there's little difference between the function of either "black box."

FIGURE 3-12
EQUIVALENT SYNTHESIZER OF FIG. 3-11 USING A PLL



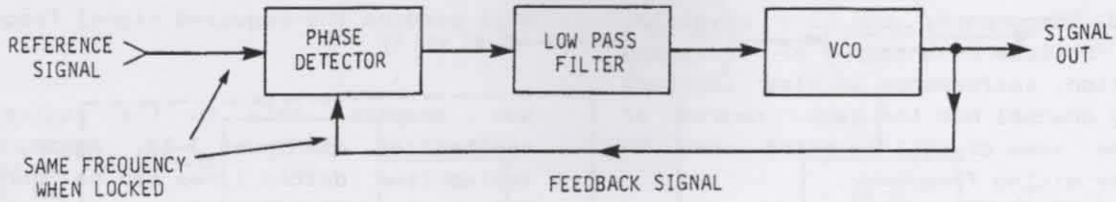
ELEMENTS OF THE PLL SYSTEM

Now let's dissect the PLL "black box" to see what's happening inside that makes it produce the needed mixing signals. Figure 3-13 shows its three basic elements: a Voltage-Controlled Oscillator or VCO, a Low-Pass Filter, and a Phase Detector or Phase Comparator.

The VCO

The VCO is an oscillator whose frequency change

FIGURE 3-13
BASIC PLL SYSTEM



depends not upon coils, capacitors, or quartz crystals, but on a special semiconductor device called a "varactor," "varicap," or "VVC" (Voltage-Variable Capacitance) diode. This has the ability to change its capacitance at a predictable rate as its reverse-bias voltage changes. The concept makes more sense when you consider the construction of a typical silicon PN junction. See Figure 3-14.

The two halves of the PN junction can be thought of like the two plates of a capacitor separated by the junction barrier. Near the junction are [+] and [-] charged particles. The varactor operates with reverse-bias, and as this bias increases, the charged particles are forced further away from the junction. This lowers the capacitance, which is thus inversely proportional to the reverse bias. Actually all diodes have this property, but without special manufacturing techniques the back resistance could be low enough to damp the oscillations completely and keep it from working.

Note that it doesn't matter how the reverse bias is made to change. The varactor's cathode voltage can be increased, which is the usual case in most PLLs. Or its anode voltage can be decreased. (Figure 3-15B.) Many common PLL ICs like the PLL02A, SM5104, and MC145106 use a negative-going Phase Detector output in which the higher the input frequency, the lower the DC output voltage to the varactor.

The most common varactor diodes for CBs are the 22 pF or 33 pF types. (1S2339G, ITT310, ECG613, ECG614, etc.) This is the capacitance value at a specific reverse bias, typically 4.0 VDC. In practice a fixed DC bias is first applied to establish operation in the diode's linear range, and the changing control voltage is added to this. Figure 3-15A shows a VCO circuit using a discrete varactor. Many newer chassis use ICs containing most of the VCO circuit, and often part of the mixer too. Examples are the TA7310/AN103/C3001, and the UHIC005 or UHIC007. The TA7310 type requires an external varactor, while the UHIC types have internal varactors.

Because diode junction capacitance also changes with temperature, the varactor or IC and the surrounding VCO components are buried in wax for greater stability against temperature and vibration. When repairing this circuit, always reseal the area. They used beeswax; candle wax is OK too. Figure 3-15B shows the Cybernet SSB (and some of their late AM/FM) chassis, which have a sealed plastic VCO block that's

FIGURE 3-14
CAPACITANCE EFFECT OF SILICON JUNCTION
AS A FUNCTION OF REVERSE BIAS

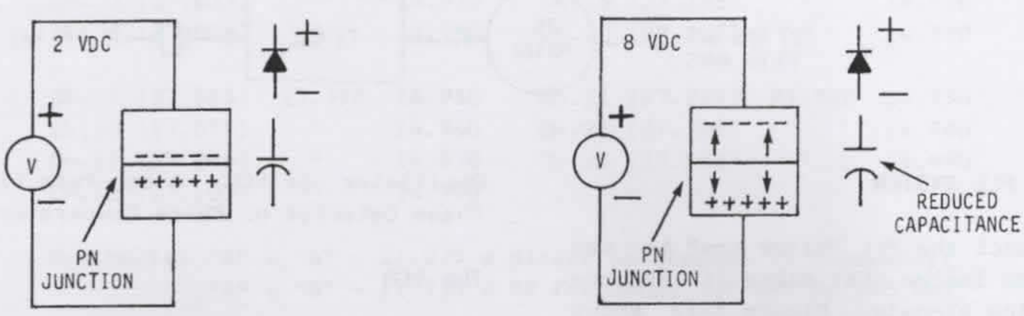
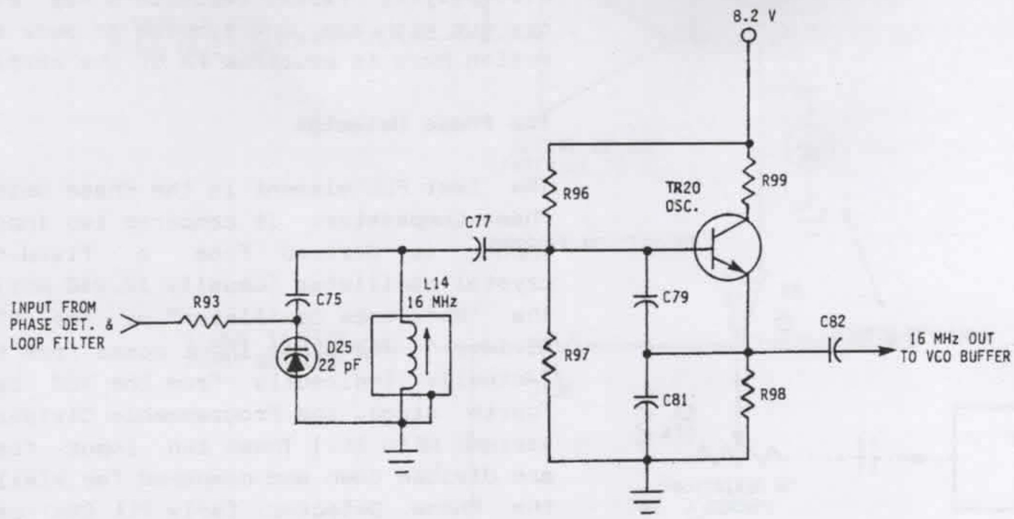
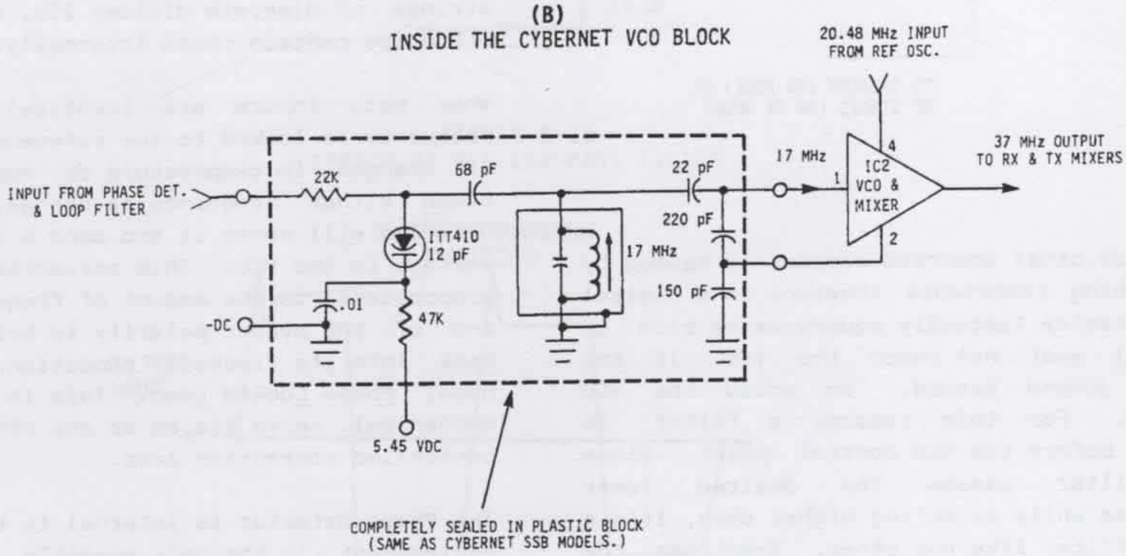


FIGURE 3-15
VCO CIRCUITS

(A)
COLPITTS VCO USING DISCRETE COMPONENTS
(Cobra 146GTL, President AR144, Realistic TRC451, Uniden PC244, etc.)



(B)
INSIDE THE CYBERNET VCO BLOCK



completely encapsulated for stability and must be replaced rather than repaired.

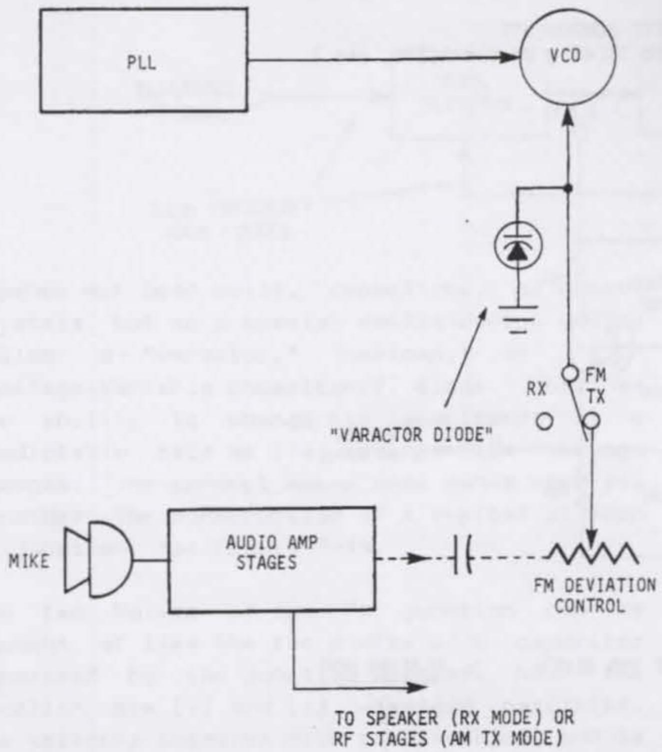
The VCO is typically a Colpitts oscillator where the varactor and a tunable shunt coil form its parallel-resonant tank circuit. With a varactor in the oscillator tank circuit (Figure 3-15A), any change in its reverse bias changes the capacitance, which in turn changes the frequency. The higher the applied voltage, the smaller the capacitance and hence the higher the frequency, and vice-versa. This is precisely the circuit idea used in the Delta Tune or Clarifier control of a modern CB radio.

Note that the [+] shift is always clockwise from the center knob position and the [-] shift is counterclockwise. Clockwise rotation increases the varactor control voltage and counterclockwise decreases it. The same principle is used for FM, where a sample of the mike audio is applied to the VCO varactor and causes it to change frequency at an audio rate. See Figure 3-16.

The Low-Pass Filter

Since the VCO is driven by a DC control voltage, its purity is critical. Ripple,

FIGURE 3-16
USING A VARACTOR TO PRODUCE FM



spikes, or other unwanted components caused by the switching transients inherent in a digital Phase Detector (actually square waves rich in harmonics) must not reach the VCO. If the voltage jumped around, so would the VCO frequency. For this reason, a filter is inserted before the VCO control point. Since this filter passes the desired lower frequencies while rejecting higher ones, it's a Low-Pass filter like any other. Sometimes the filter is called a "Charge Pump" on the schematic, since its capacitors charge up from the Phase Detector output and then "pump" the filtered DC voltage out to the VCO.

The Low-Pass Filter may be of a simple RC type, or nowadays, an active filter inside the PLL chip. See Figure 3-17. The op-amp type filter has a lower output impedance, making it easier to drive a VCO. This filter's also called an "integrator," since it integrates or rounds off the sharp corners of the digital square wave. Think of it as a Digital-to-Analog Converter.

When the filter's RC time constant is long enough, the voltage spikes disappear and the waveform is similar to pulsed DC. Figure 3-18 shows this graphically. The top trace has a small glitch, which is removed by the filter in the bottom trace. You can check the effectiveness of the LP filter using a fast dual-trace 'scope at the input and output. Its electrolytic filter capacitors may eventually dry out with age. One symptom of poor filtering action here is spurious FM of the carrier.

The Phase Detector

The last PLL element is the Phase Detector or Phase Comparator. It compares two inputs: one input is derived from a fixed-frequency crystal oscillator (usually 10.240 MHz) called the "Reference Oscillator" or the "Reference Divider." The other input comes from the VCO. (Actually indirectly from the VCO because a fourth stage, the Programmable Divider, is in series with it.) These two input frequencies are divided down and compared for similarity in the Phase Detector. Early PLL CBs used long strings of discrete divider ICs, while modern PLL chips contain these internally.

When both inputs are identical, the VCO frequency is locked to the reference frequency. If changes in temperature or supply voltage cause either frequency to change, the Phase Detector will sense it and send a DC correction voltage to the VCO. This correction voltage is proportional to the amount of frequency change and of the proper polarity to bring the loop back into its "locked" condition. Hence the name, <u>P</u>hase <u>L</u>ocked <u>L</u>oop. This is similar to a mechanical servo system or any other feedback-controlled correction loop.

The Phase Detector is internal to the IC, and replacement is the only possible repair. The actual circuit is an edge-triggered RS flip-flop of the type shown in Figure 3-19. The circuit is reset once each cycle by the reference signal, and toggled once each cycle by the feedback signal from the VCO. (The SET line isn't used.) Also shown is the characteristic sawtooth output waveform as a function of the input phase difference. The output goes to an integrator (Low-Pass Filter), which provides the proper VCO varactor bias.

PLL Capture & Lock Conditions

Once the VCO begins to shift frequency, it's in the "capture" state. It stays this way until its output frequency is the same as its input.

FIGURE 3-17
LOW-PASS FILTERS

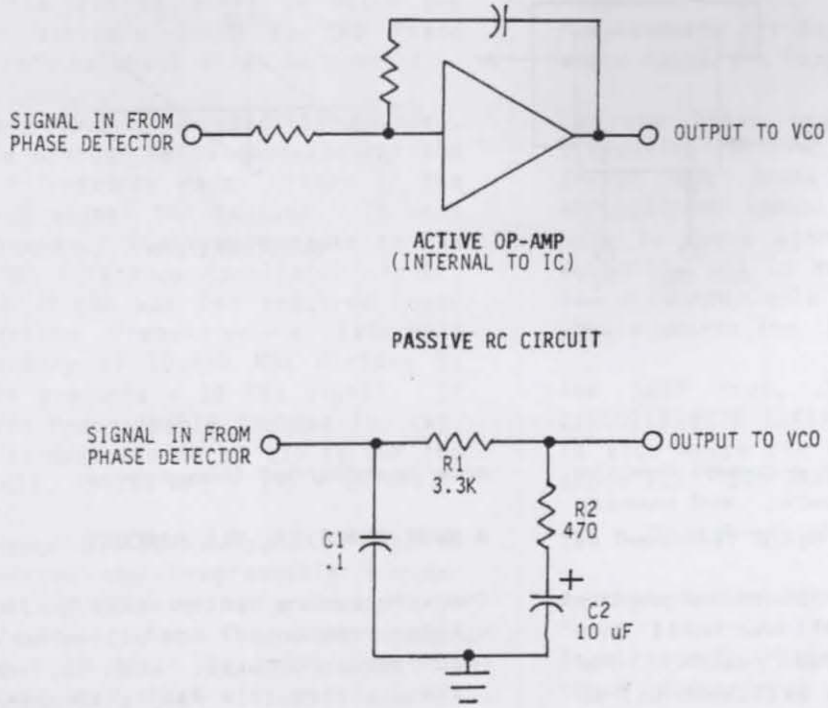
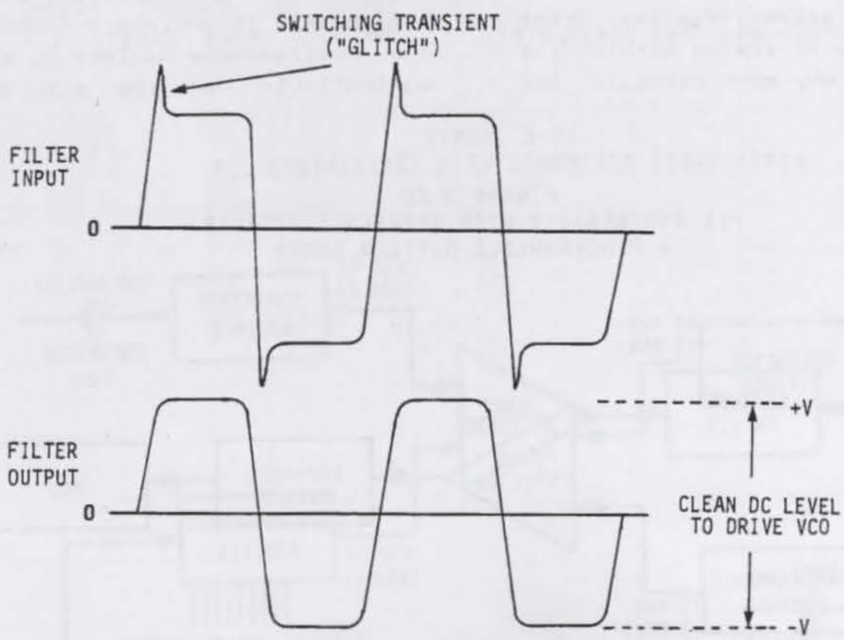


FIGURE 3-18
EFFECT OF PLL LOW-PASS FILTER

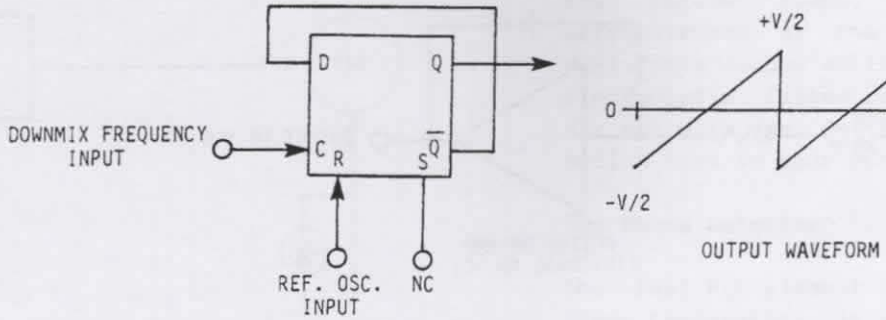


At that point it's locked. So the PLL has three possible operating conditions:

1. Free-running.
2. Capture.
3. Locked or "tracking."

Each PLL circuit has an associated capture range, which defines how far off frequency the error can be and still lock up. If the two frequencies are outside the capture range, the VCO will free-run at a frequency determined by the LC components in the oscillator circuit.

FIGURE 3-19
PHASE DETECTOR USING R-S FLIP-FLOP
(Courtesy Hayden Book Co.)



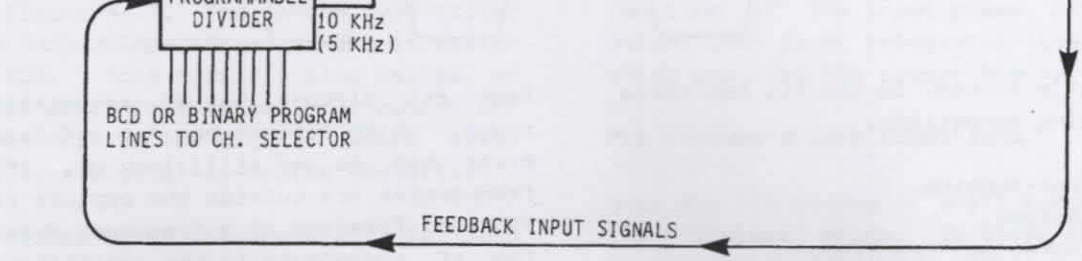
This out-of-lock condition is a common symptom in malfunctioning CB synthesizers, and usually indicates a problem external to the PLL IC.

When the error is within the capture range, the capture process begins and continues until the locked or tracking condition is reached. The actual lock-up time takes only milliseconds, as you've no doubt observed when switching CB channels. The frequency range over which the VCO can remain locked is much wider than the range actually needed for capture, similar to the AFC circuit in an FM stereo receiver. These ranges are determined by RC timing within the PLL, and help explain why some circuits are more broadbanded than others.

A MORE PRACTICAL PLL CIRCUIT

The preceeding system works quite well for a single frequency, but allows no way to change the frequency other than by changing the reference itself. For a 40-channel band of frequencies, it's not good enough. Figure 3-20 shows two more blocks added to the basic loop: a Reference Divider, and a Programmable Divider. The Reference Divider is internal in the modern IC and has a fixed division ratio. The Programmable Divider is also internal but controllable at the outside world by the

FIGURE 3-20
PLL SYNTHESIZER WITH REFERENCE DIVIDER
& PROGRAMMABLE DIVIDER ADDED



Channel Selector switch, which changes the division ratio as needed. It's the key to synthesizing many channels from one oscillator signal. The objective is still to match the output of both dividers going to the Phase Detector so there's no phase error to correct.

In addition to selecting a specific channel, the Programmable Divider helps down-convert the VCO signal to a frequency range closer to the divided reference signal for capture. In most PLLs the VCO frequency isn't even close to the normal 10.240 MHz Reference Oscillator signal. For example, if 10 KHz was the required Phase Detector comparison frequency, a Reference Oscillator frequency of 10.240 MHz divided by the number 1,024 produces a 10 KHz signal. If the signal to the Programmable Divider is, say, 1.35 MHz, then it must divide by 135 to get the same 10 KHz result. (1.35 MHz ÷ 135 = 10 KHz.)

When the Reference Divider outputs 10 KHz to the Phase Detector, the Programmable Divider must also output 10 KHz or an error voltage will be generated. For the Programmable Divider to output 10 KHz, its input from the VCO must be a frequency which will equal 10 KHz when divided by the currently-programmed divisor. If this divisor is, for example, the number "330," the input signal must have been 330 x 10 KHz = 3.30 MHz. A signal other than exactly 3.30 MHz would produce an error voltage. If the VCO signal were 3.10 MHz instead, the result would be 3.10 MHz ÷ 330 = 9.39393 MHz. This error would generate a correction voltage to drive the VCO higher in frequency again, until the input to the Programmable Divider reached 3.30 MHz, which would cause the loop to be locked once again.

For you heavy technical types, an excellent discussion of PLLs and related synthesizer design was found in the SIGNETICS ANALOG APPLICATIONS MANUAL. Signetics is now located only in Korea with the contact info on their Web site, and it may be worth a try. I saw a few still for sale from Amazon.com or else you should search the 'Net using Google, etc.

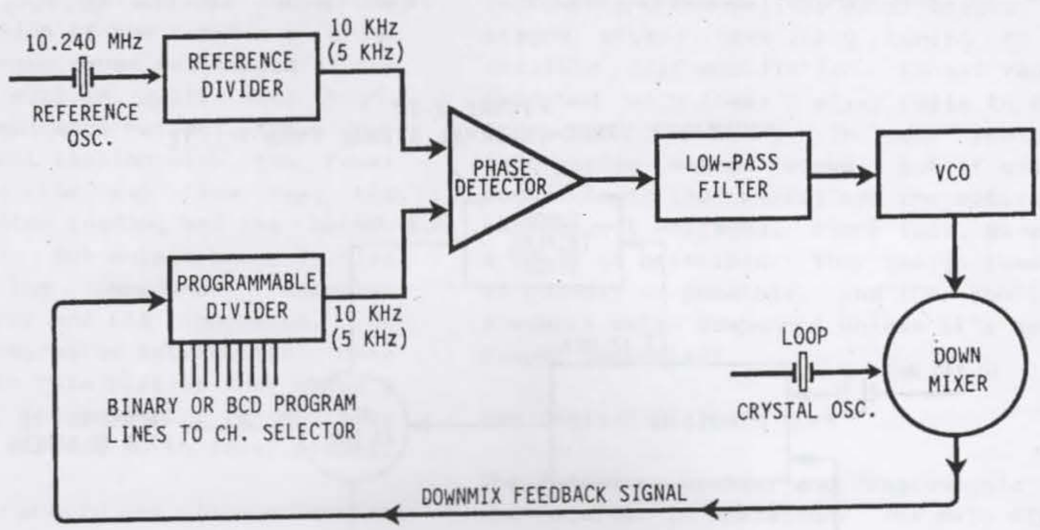
The SAMS book, DESIGN OF PHASE-LOCKED-LOOP CIRCUITS WITH EXPERIMENTS, by Howard M. Berlin is also worth checking. (ISBN #0-672-21545-4, about $15. See SAMS address in CHAPTER 1.)

The Downmixer Stage

Another common PLL synthesizer element is the "Loop Mixer," "Loop Oscillator," "Offset Oscillator," "Offset Mixer," "Down Mixer," "Down Converter," or "Down Oscillator." All mean the same thing when indicated on a schematic. Figure 3-21 below shows this stage added to the loop; note it's otherwise identical to the basic circuit of Figure 3-20.

This stage must be added to many PLL circuits

FIGURE 3-21
PLL SYNTHESIZER WITH DOWNMIXER STAGE ADDED



because the Programmable Divider isn't fast enough to directly divide the VCO signal, generally in the 16 MHz or 35 MHz range. Its purpose is to mix the VCO signal down to a lower frequency, usually under 4 MHz, which the PLL can handle. The result is the "downmix" signal, which goes to the Programmable Divider input. The newer AM-only or FM-only chips like the C5121, LC7130/31, LC7132, LC7136/37, SM5123A, SM5124A, or TC9106/9109/9119 are fast enough to divide a VCO up to 20 MHz directly, completely eliminating the Downmixer stage.

Sometimes included in the chip is an additional circuit which divides the 10.240 MHz reference frequency in half, to 5.120 MHz. This signal is available at one of the IC pins and is coupled to an external tripler coil to generate a 15.360 MHz signal used for loop downmixing. (5.120 MHz x 3 = 15.360 MHz.) See Figure 3-22. This saves the cost of an extra discrete oscillator which would otherwise be needed. Chips which have used this option include the LC7120, SM5107, µPD858, µPD861, µPD2810, µPD2812, µPD2814, µPD2816, and µPD2824.

Frequency Multiplication

Just as the Downmixer lowers a frequency, sometimes it's necessary to raise an oscillator frequency. The most common frequency multiplication for CB synthesizers is the doubler or tripler stage. Many VCOs run in the 34-37 MHz range to take advantage of high-side mixer injection. It's often cheaper and more convenient to take an existing crystal oscillator and sample part of its signal, rather than to add another discrete active stage at the higher frequency. Another reason is that the Delta Tune or Clarifier is connected to one of the crystal oscillators. Since it's difficult to pull a crystal very far off frequency, a multiplier stage automatically multiplies the frequency shift too. If a crystal can be pulled 1 KHz directly, a doubler or tripler would make the total shift 2 KHz or 3 KHz respectively.

Multiplier stages are always biased Class C, a condition that encourages distortion (i.e., harmonics) and greater efficiency. Generally speaking a doubler will be about 50% efficient, a tripler about 30%, etc. At first glance many commercial circuits appear to be Class A stages, since some forward bias may exist. A perfect example is the MB8719/8734 synthesizer (Page 83) whose tripler circuit is repeated in Figure 3-23. The TR23 tripler stage has about 1.45 V forward base bias, since R128 raises the emitter 1KΩ above ground. Regardless of this positive bias, the input signal is even higher and will drive it into Class C operation. (Class C <u>power</u> stages are directly grounded for DC; see CHAPTER 5.)

The reason for some forward bias is to make the stage easier to drive. Transistors sometimes need this; vacuum tubes rarely do, since their high input impedances discourage loading and power loss. The 11 MHz oscillator can still drive TR23 into the Class C region on RF voltage peaks. With transistor multipliers the harmonics result not only from the inherent Class C envelope distortion, but also from non-linearities in the transistor junction capacitance as the driving signal swings

FIGURE 3-22
DOWNMIXER USING INTERNAL SIGNAL FROM PLL IC

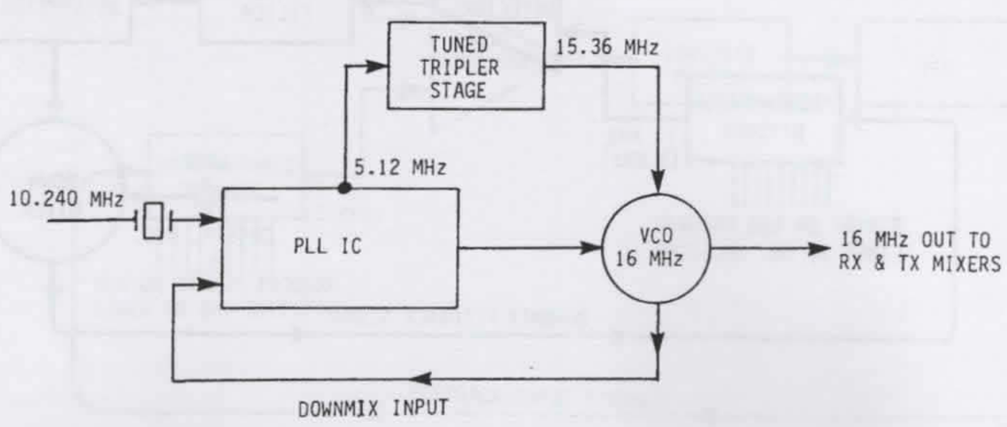
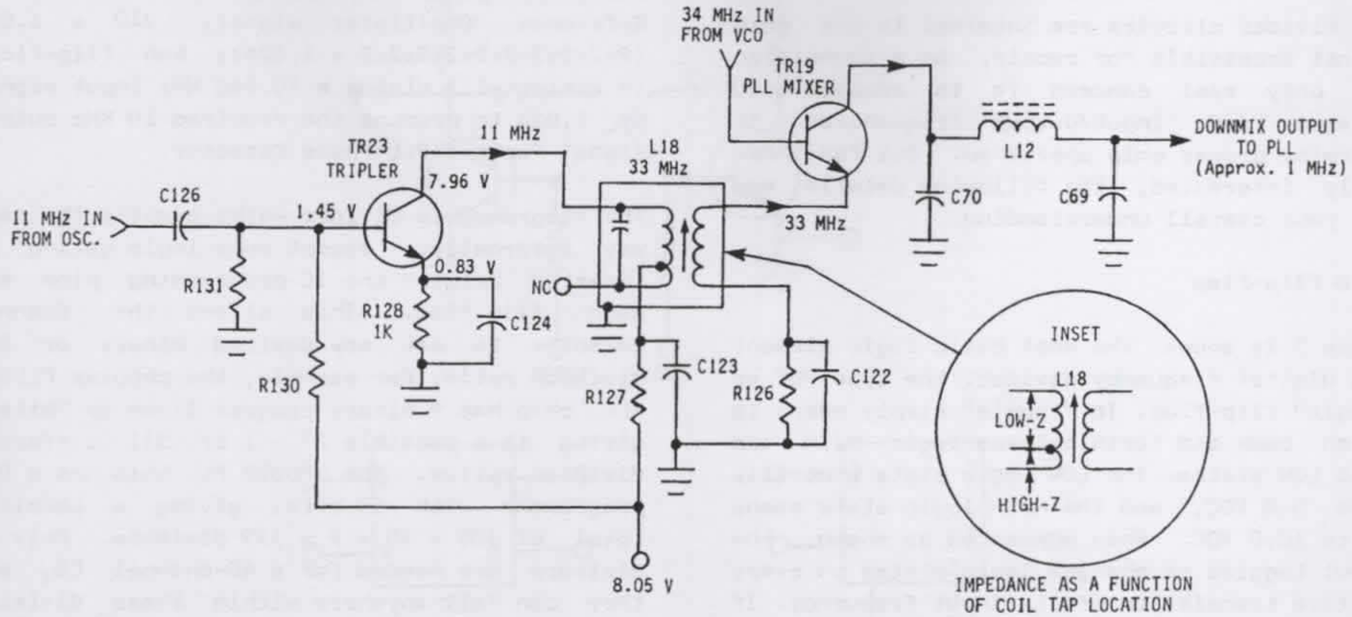


FIGURE 3-23
TUNED MULTIPLIER STAGE
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)



through its amplitude and phase changes. Again, this doesn't happen with vacuum tubes. Besides the desired 3rd harmonic (33 MHz) which is peaked by L18, there will also be undesirable harmonics in the output. These are removed by the Pi section filter C70/L12/C69.

Controlling Coil Q & Coupling Impedances

Note L18 has a tapped primary with one end unconnected. This is very common in CB RF circuits. The position of the tap has a great effect on performance. When not tapped at the exact center the coil is split into high-impedance and low-impedance halves; the higher impedance is the coil section with the fewer turns. The further the tap from V_{CC}, the lighter the collector loading and the better the filtering action. But output power is also reduced because the impedance mismatch between the collector and L18 increases. The tap location is a compromise between efficiency and signal purity. In this circuit they chose a lower impedance for the collector to maximize gain; harmonics are cleaned up in later stages.

As a technician you should pay close attention to possible changes made to these tuned circuits by previous repairmen. Like the above example, many tapped RF transformers have an unconnected end. In modifying CBs for channel expansion and greater bandwidth, people sometimes cut the tapped foil trace and rejumper its circuit to the unused end. This has the effect of lowering its Q, since a bigger coil means lower impedance. <u>But it also lowers the stage gain</u>. This may or may not matter, depending upon the particular circuit.

You'll find hi-Z/low-Z coil splits used in the receiver and transmitter mixer stages; RF power stages always have low-Q tuning to prevent possible self-oscillation. Export radios are designed with lower Q mixer coils to cover the increased bandwidth. In some radios this rejumpering method works, but if stage gain seems lower than normal and the active device has correct voltages, check this. Never forget a basic CB principle: they design these things as cheaply as possible, and they don't include a single extra component unless it's needed for proper operation!

How Digital Dividers Work

The Reference Divider and Programmable Divider are similar in operation. The main difference is that the Reference Divider uses a fixed reference frequency, while the Programmable Divider works on a variable frequency that changes with the division ratio set by the Channel Selector. The reference signal itself is generated either by a separate transistor oscillator, or by an internal chip oscillator needing just an external crystal to oscillate.

The divider circuits are internal to the chip and not accessible for repair. As a technician your only real concern is to measure IC voltages and input/output frequencies to determine proper chip operation. But for those really interested, the following details may help your overall understanding.

The D Flip-Flop

Figure 3-24 shows the most basic logic element of a digital frequency divider, the type "D" or "Toggle" flip-flop. To "toggle" simply means to switch back and forth between logic HIGH and logic LOW states. The LOW logic state generally means 0.0 VDC, and the HIGH logic state means 4.5 to 10.0 VDC. When connected as shown, the output toggles or changes logic states on every positive transition of its input frequency. If the input frequency is a pure square wave (which it would be when the oscillator signal is properly shaped), then the output will also be a square wave whose frequency is exactly half that of the input frequency. Thus we can say that the D flip-flop is a ÷ 2 circuit.

By "cascading" or stringing a number of such flip-flops in series, division is possible by any power-of-2 factor. If the flip-flops are cascaded such that the output of one is used to trigger the input of the succeeding one, it's called a "ripple carry" or asynchronous divider. Input changes must ripple through the entire divider chain, a relatively slow process, to produce the divided-down output. Tying all inputs together in parallel so each flip-flop is driven from a single input and changes simultaneously creates a "synchronous" divider or counter. This is much faster and also eliminates the problem of glitches due to the propagation delays inherent in the asynchronous type of divider.

Using the previous example of the 10.240 MHz Reference Oscillator signal, $2^{10} = 1{,}024$ (2x2x2x2x2x2x2x2x2x2 = 1,024); ten flip-flops in series will divide a 10.240 MHz input signal by 1,024 to produce the required 10 KHz output signal for the PLL Phase Detector.

The Programmable Divider works exactly the same way internally, except some logic gating is inserted between the IC programming pins and each flip-flop. This allows the Channel Selector to set any desired binary or BCD division ratio. For example, the popular PLL02A PLL chip has 9 binary program lines or "bits," giving it a possible $2^9 - 1$ or 511 different division ratios. The µPD858 PLL chip has a BCD programmer with 10 bits, giving a possible total of 300 + 90 + 9 = 399 divisors. Only 40 divisors are needed for a 40-channel CB, and they can fall anywhere within these division ranges convenient for the circuit design.

The RS Flip-Flop

A refinement of the basic flip-flop allows more precise synchronization. Figure 3-25 shows the "RS" or Reset-Set flip-flop. The two inputs are called SET ("S") and RESET ("R"), and the outputs are called "Q" and "Q-NOT." (The bar or "NOT" mark over the Q is a special digital logic symbol meaning, "the opposite or complimentary logic state of whatever Q is.") Complimentary logic signals are always applied to the SET-RESET inputs. Thus a logic HIGH at R makes Q-NOT HIGH and Q LOW. The S signal will be LOW under this condition. When S switches HIGH, Q goes HIGH and Q-NOT goes LOW, and R will be LOW. The two transistor outputs literally flip-flop back and forth when square

FIGURE 3-24
TYPE "D" FLIP-FLOP

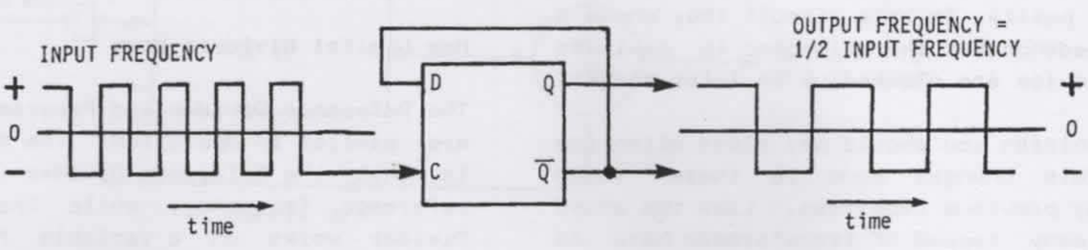
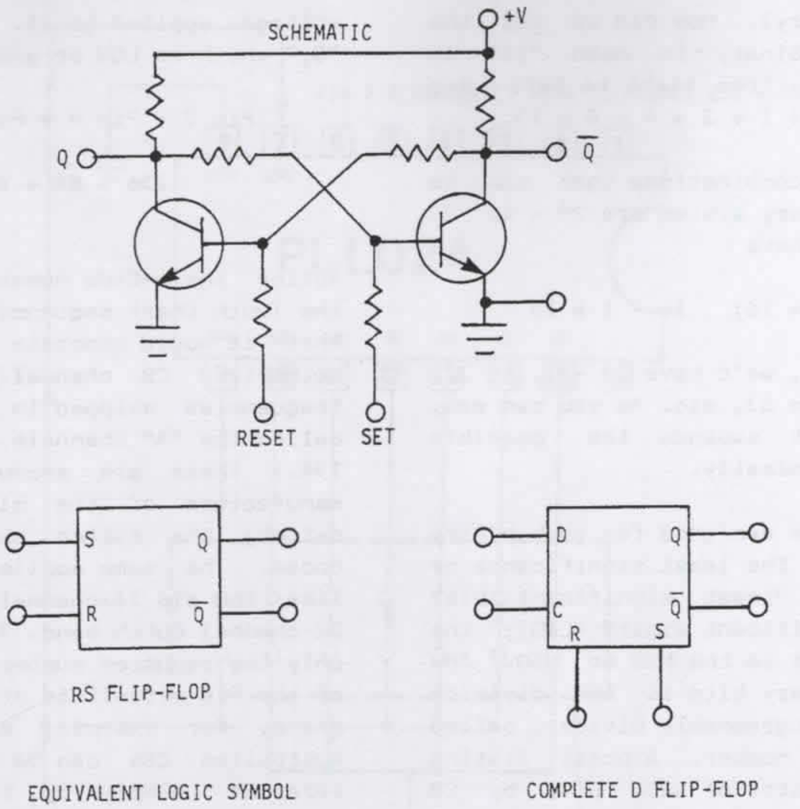


FIGURE 3-25
THE "RS" FLIP-FLOP



wave inputs are applied. You may recognize the schematic as a variation of the basic multivibrator circuit.

A simple flip-flop is not synchronized to any particular signal. By adding CLOCK ("C") and DATA ("D") inputs to the basic RS flip-flop, a more sophisticated "D" flip-flop is created. This allows inputs and outputs to be clocked or synchronized at a desired rate. Each positive logic change at C toggles the circuit, making it a convenient frequency divider.

If the D flip-flop is wired as shown earlier in Figure 3-19, the CLOCK input becomes a voltage sampling input, in this case one input of the Phase Detector. The other Phase Detector input is the RESET line. (The SET line isn't used.) Thus we get a device capable of sampling at a digital rate. Its switching operation is called "edge-triggered" because the transition of the leading edge of a square wave from logic LOW to logic HIGH triggers the output logic change.

Binary Programmable Dividers

Since ÷2 flip-flops are the heart of digital synthesizers, the binary type of numbering system (Base 2) is used rather than the decimal system (Base 10) used by people. That's because electronic switches have at least two useful conditions, "ON" and "OFF." In a binary number system only two conditions are needed to represent a decimal number. These conditions are called "HIGH" and "LOW," "ON" and "OFF," or "1" and "0," and represent two different voltage or logic levels. In CBs the LOW logic state is usually close to 0.0 volts, and the HIGH state varies from about 4.5-10.0 VDC, since PLL ICs are all CMOS devices.

Binary numbers are written like decimal numbers, except only combinations of 1s and 0s are used. The most significant digit is on the left, and the least significant digit on the right. Each digit or "bit" (<u>bi</u>nary dig<u>it</u>) of a binary number has a weight or value twice that of the bit to its immediate right. Compare this to the human decimal system, where each digit has ten times more weight than the digit to its right. (Hundreds, Tens, Ones, etc.) So if four bits are available, you can represent all decimal numbers from "0" ("0000" in binary) to "15" ("1111" in binary). How did we get the number "1111" in binary to mean "15" in decimal? By reading from right to left and adding up each weight: $1 + 2 + 4 + 8 = 15$.

The total possible combinations that can be represented in a binary system are $2^n - 1$. So in a 4-bit system we have

$$2 \times 2 \times 2 \times 2 = 16; \quad 16 - 1 = 15$$

By adding a fifth bit, we'd have $2^5 - 1$, or 31. With $2^6 - 1$, we'd have 63, etc. As you can see, each additional bit expands the possible combinations logarithmically.

The PLL IC has one pin assigned for each binary weight. The pin with the least significance or weight is called the "least significant bit" (LSB) or "least significant digit" (LSD); the heaviest weighted bit is the MSB or MSD. The sum of all HIGH binary bits is the division ratio of the PLL's Programmable Divider, called the "N-Code" or "÷N" number. A chart listing the binary logic states of each pin, by CB channel number, is called a "Truth Chart." Shown below is part of the actual Truth Chart from the PLL02A late-generation AM circuit.

The chart shows the N-Code number for CB Ch.1 is "330." How was this number derived? Simple! Just add up the binary weight of each IC pin with a logic HIGH state of "1," meaning it has voltage applied to it. Ignore any pin with a "0," which is LOW or grounded. Thus,

Pin 7 + Pin 9 + Pin 12 + Pin 14, or

$$256 + 64 + 8 + 2 = 330$$

Notice the N-Code number "327" was skipped in the Truth Chart sequence, because the frequency that it would generate (26.995 MHz) isn't an authorized CB channel. There are five such frequencies skipped in the FCC band, commonly called the "A" channels. (3A, 7A, 11A, 15A, 19A.) These are accounted for during the manufacture of the binary Channel Selector switch; the switch skips the non-CB binary codes. The same applies to other CB services like the old 18-channel Australian band or the 22-channel Dutch band. The Channel Selector has only the required number of positions; the rest of the PLL circuit is otherwise identical. This means, for example, many of the 18-channel Australian CBs can be changed to 40-channel versions simply by replacing the Channel Selector switch and connecting all the correct binary programming pins that would normally be connected for the 40-channel versions.

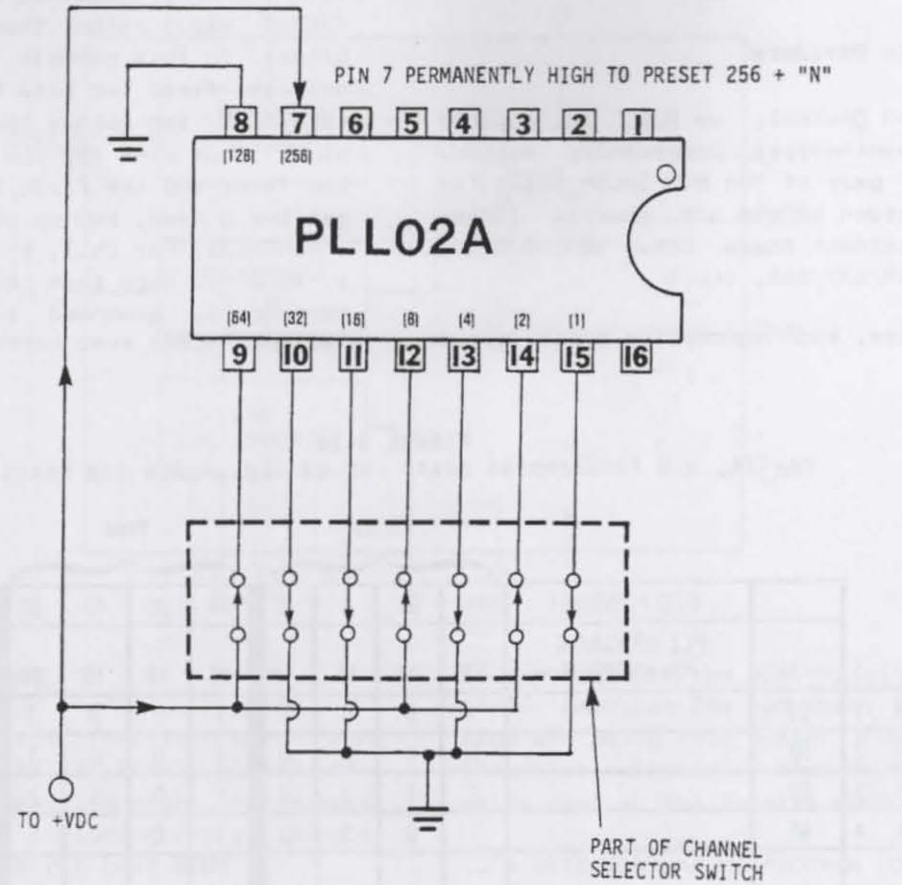
		BINARY POWERS-OF-2:	**(256)**	**(128)**	**(64)**	**(32)**	**(16)**	**(8)**	**(4)**	**(2)**	**(1)**
		IC PROGRAM PINS	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CH.#	**(FREQ. MHz)**	**N-CODE**									
1	26.965	330	1	0	1	0	0	1	0	1	0
2	26.975	329	1	0	1	0	0	1	0	0	1
3	26.985	328	1	0	1	0	0	1	0	0	0
4	27.005	326	1	0	1	0	0	0	1	1	0

Generating The Program Codes

Figure 3-26 shows the actual voltage switching which occurs in the previous example of the PLL02A binary PLL chip. It shows the number "330" being generated by forcing pins 7, 9, 12, and 14 to logic HIGH while pulling the other program pins LOW. The chips generally have internal pull-up or pull-down resistors on every pin that's programmable. In a few cases, like some early Uniden µPD858 SSB radios, external resistor packs were needed because the chip didn't have internal resistors.

The Channel Selector is a multi-layered detent wafer switch capable of producing 40 different binary or BCD N-Codes. The non-CB channel positions are skipped entirely. In some CB services like that of Great Britain having 40 consecutive channels, the switch will also be arranged consecutively with no skips.

FIGURE 3-26
GENERATING THE BINARY N-CODE THROUGH SWITCHED VOLTAGES & GROUNDS



N = 256's BIT + 64's BIT + 8's BIT + 2's BIT = "330" FOR CH.1

FIGURE 3-27
INTERNAL FUNCTIONS OF PLL02A PLL IC

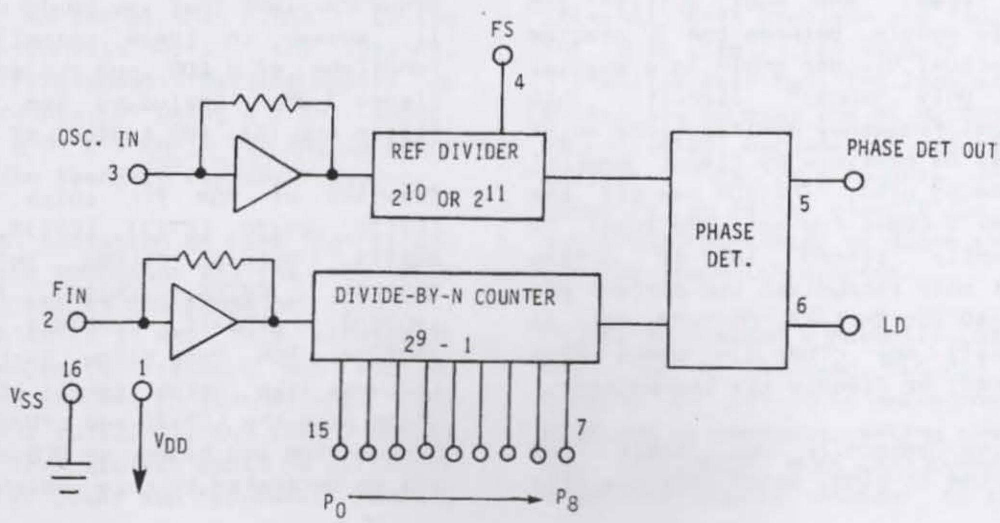


Figure 3-27 shows a block diagram of the PLL02A synthesizer we've been discussing. It shows how the main PLL elements of Reference Divider, Programmable Divider, and Phase Detector are all contained in one IC chip.

BCD Programmable Dividers

The Binary Coded Decimal, or BCD, is another common PLL synthesizer programming method. Figure 3-28 is part of the BCD Truth Chart for the popular Uniden µPD858 SSB chassis (Cobra 138/139XLR, President Adams, Robyn SB510D/520D, Realistic TRC449/457/458, etc.)

In the BCD system, each successive 4-bit group has a weight ten times greater than the group to its left. (Our chart is reversed though.) In each group the usual binary doubling occurs; the highest possible number in any 4-bit group is "9" or its decimal multiple ("9," "90," "900," etc.) rather than the "15" possible in binary. In this example the Hundreds group has only the first two bits because the chip has a total of ten rather than twelve programming pins: four pins for the Ones group, four for the Tens, and the first two of the Hundreds. To get the N-Code, add up each group: Ones + Tens + Hundreds. For Ch.1, this is 1 + (10 + 80) = 1 + 90 = 91. Note that Pin 22 (200's group) is permanently grounded (logic "0"), since the largest N-Code ever needed is "135" for Ch.40.

FIGURE 3-28
PARTIAL BCD PROGRAMMING CHART FOR UNIDEN µPD858 SSB CHASSIS

			Ones				Tens				Hundreds	
		BCD POWERS	1	2	4	8	10	20	40	80	100	200
	÷ N	PLL PROGRAM PIN NUMBER	13	14	15	16	17	18	19	20	21	22
Ch. 1	91		1	0	0	0	1	0	0	1	0	0
Ch. 2	92		0	1	0	0	1	0	0	1	0	0
Ch. 3	93		1	1	0	0	1	0	0	1	0	0
Ch. 4	95		1	0	1	0	1	0	0	1	0	0
⋮	⋮											
Ch. 40	135		1	0	1	0	1	1	0	0	1	0

NOTE: Pin 22 permanently grounded to chassis ("0") for all 40 channels.

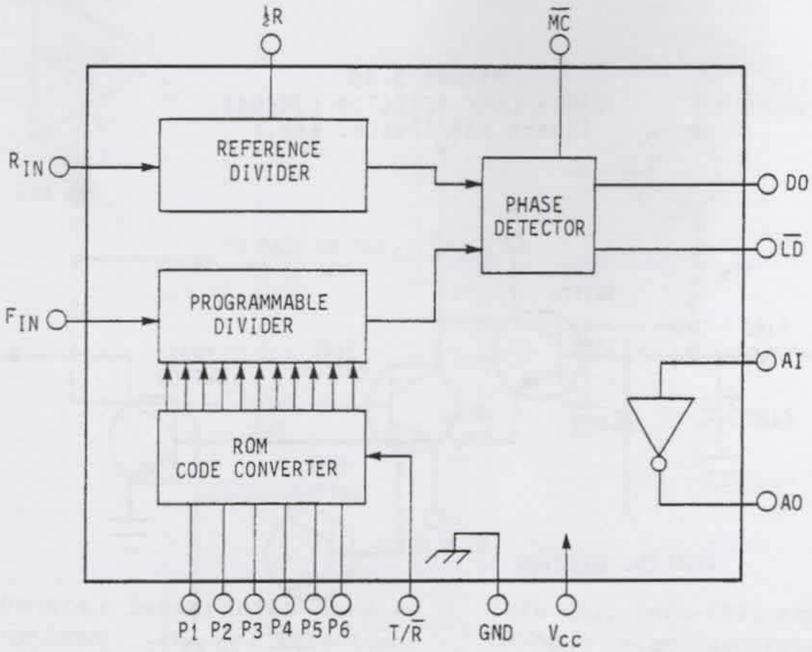
ROM Programming

A third type of synthesizer programming is used in all the new AM-only American radios, the newer AM/SSB types, and most British and European FM-only models. Between the IC program pins and the actual divider chain is a special ROM or "Read Only Memory" circuit. This prevents illegal frequency modifications which would otherwise be possible by direct control of the programming pins. The ROM has all the required channel N-Codes for only the legal CB band permanently stored in it during manufacture. It only recognizes the correct pin codes for Ch.1-40 (or Ch.1-18, Ch.1-22, etc. in other countries); any other pin codes will either be ignored, or disable the transmitter.

The ROM chips generally use 6-bit BCD programming at the IC pins, since only six bits are needed to represent the 40 channel numbers "0" to "39" in BCD. The TC9106/09/19 and LC7132 purposely use a special random 8-bit code to prevent guessing the numerical programming sequence. (Not that you could do anything about it anyway in these chips!) The internal functions of a ROM type PLL are summarized in Figure 3-29, including the active Low-Pass filter amp (AI, AO) typical of the newer chips.

Examples of ROM PLL chips are the C5121, LC7120, LC7130, LC7131, LC7132, LC7136, LC7137, MB8733, PLL03A, PLL08A, SM5123A, SM5124A, SM5125B, TC9106, TC9109, TC9119, µPD861, µPD2810, µPD2812, µPD2814, µPD2816, and µPD2824. ROM does allow certain convenience features like instant recall of Ch. 9 or Ch.19. Chips like the LC7120 and µPD861 are switchable between ROM and binary or BCD programming; one pin is dedicated to this option.

FIGURE 3-29
INTERNAL FUNCTIONS OF ROM TYPE PLL IC



Additional PLL Functions

There are several other IC functions which can add to the flexibility of PLL synthesizers. These are briefly summarized next. For a more complete discussion, including the IC pinout information, see **THE CB PLL DATA BOOK.**

T/R SHIFT PIN: This allows a 455 KHz IF offset for dual-conversion AM (or FM) receivers; SSB models don't use this function even if present. This pin is connected to the Transmit keyline and senses the logic voltage change from Receive to Transmit. In addition the PLL chip uses 5 KHz rather than 10 KHz Phase Detector input frequencies. (It divides the 10.240 MHz reference by 2,048 rather than 1,024.) During the Receive-to-Transmit switch, the internal counter in the Programmable Divider shifts up by exactly 91 counts. By using a 5 KHz input, this results in a 91 x 5 KHz = 455 KHz up-shift of the VCO for the transmit carrier frequency.

One U.S. and U.K. variation on the T/R offset method shifts the ROM count and the VCO down about 3 KHz to the 13 MHz range on Transmit, where it's doubled to 27 MHz. This eliminates the need for separate Transmit and Receive VCOs. The method is used in synthesizers with the TC9109/MB8733, LC7136/37, and LC7132 chips. A direct 27 MHz Transmit VCO would be difficult to shield from RF power amp feedback, causing spurious FM of the VCO. Originally only a few early American CBs had them; the SM5124A PLL rigs are using them again. They require complex inductive switching, because the VCO must now shift down in the Receive mode by 10.695 MHz.

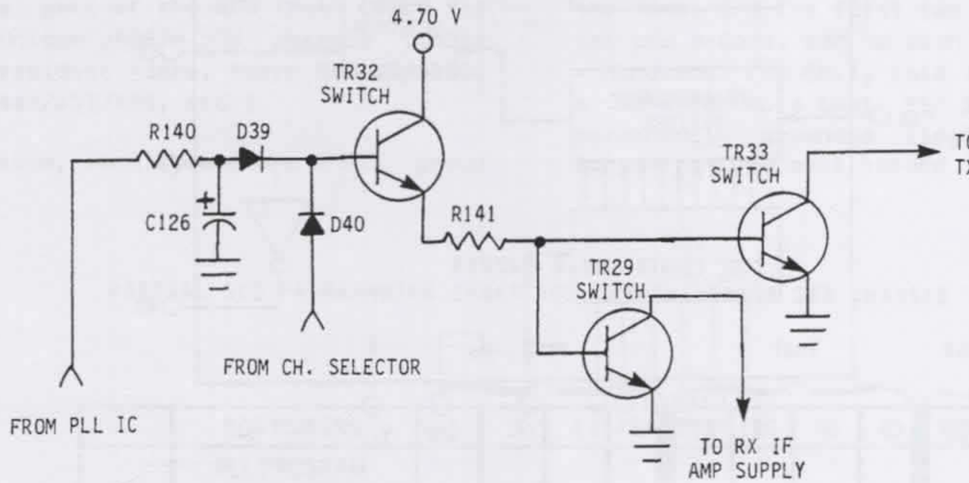
LOCK DETECTOR and MISPROGRAM CODE PINS: When the MC pin is present and connected, incorrect program codes on the IC pins will be sensed. This might be caused by modification attempts or by a faulty Channel Selector. The MC pin will switch logic states, triggering a kill circuit that turns off the transmitter.

The LD pin can be activated by any fault that causes the loop to unlock, which includes both internal chip problems and faults external to the chip itself. For example if the Downmixer transistor were bad, the loop would unlock and switch the LD pin; the MC wouldn't necessarily be activated, because the programming itself is correct. This is a subtle difference. It's possible in either circuit for an associated switching transistor or diode to short, causing the "No Transmit" symptom.

Figure 3-30 shows a normally-LOW LD circuit. If the loop is unlocked, PLL Pin 1 goes HIGH, turning on D39. This makes the base of TR32 HIGH and it conducts, making the bases of TR29 and TR33 HIGH. When TR33 turns on, it pulls down the supply voltage to the transmitter

Mixer. TR29 "ON" shunts a different supply to ground and kills one IF amplifier. D40 "ON" does the same thing; this is connected to the Channel Selector switch. The switch is designed so any in-between channel positions will also output a voltage that triggers the Transmit Inhibit circuit. The majority of 40-channel switches work this way.

FIGURE 3-30
EARLY LOCK DETECTOR CIRCUIT
(Cobra 138/139XLR, etc.)



The preceeding LD is typical of older circuits, where designers spared no expense in the number of components used. Figure 3-31 shows a more current and cheaper T/R inhibit circuit, this one normally-HIGH. When LD Pin 4 goes LOW, it turns on D13 and grounds out the bias of IF amp TR3 in the receiver. It also removes the base bias on TR12, turning it off and pulling its collector HIGH via R95. This raises the emitter of transmitter preamp TR13, turning it off too. Most LD circuits kill both Transmit and Receive. (The MB8719/MB8734 LD circuit is also described later in this chapter.)

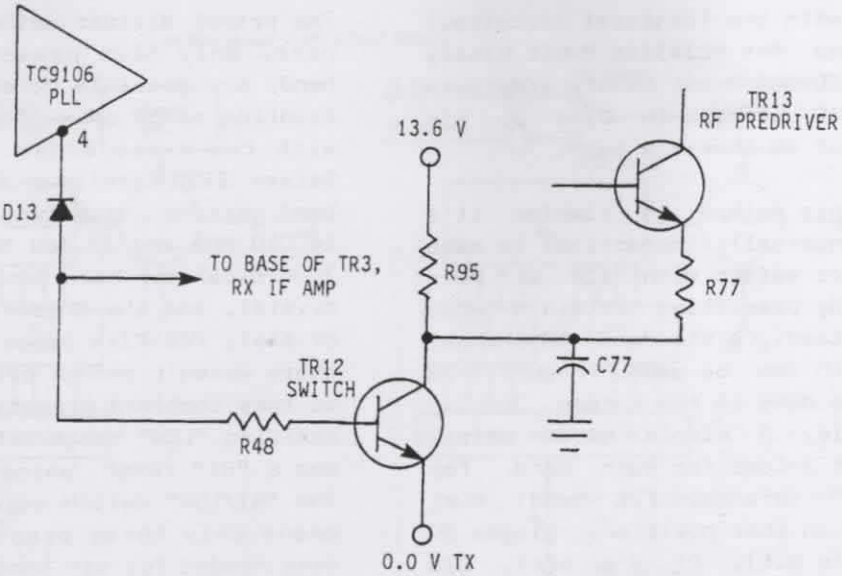
FREQUENCY SELECT: Many PLL chips are designed with great flexibility beyond just CB use. The IC sometimes has an "FS" or "Frequency Select" pin which changes all the Programmable Divider division ratios by the same amount. The most common option is 5 KHz/10 KHz increments. The logic state of this pin must be correct for the circuit design or the radio won't work! For example, a standard 10 KHz CB synthesizer can't be changed to a 5 KHz channel synthesizer, because the Channel Selector that programs it must also be capable of dividing into 5 KHz segments. And that could only happen by doubling the existing N-Codes.

You may get some repairs where this was tried; check the voltage on the FS pin to verify. Examples of chips having this option are the SM5104/MC145104, PLL02A, and MC145106. (The whole Motorola PLL family in general.) These chips have many other non-CB synthesizer uses, such as in aircraft and marine VHF radios, RF and audio signal generators, scanners, etc.

PRESETTABLE DIVIDER: IC pins may also preset a fixed N-Code, which is added to the sum of the other program pins. In the earlier example using the PLL02A, the Ch.1 N-Code was 330. However a look at that full Truth Chart would show that Pins 7 and 8 never change for the full 40 channels. With Pin 7 (256's bit) permanently HIGH and Pin 8 (128's bit) permanently grounded (LOW) for all 40 channels, the N-Code was preset for 256 + the binary sum of whatever is HIGH on Pins 9-15. The preset was therefore 256 + (64 + 8 + 2), which gave the binary total of 330.

This preset divider arrangement is very common in the older chips. Sometimes the preset pin has just two possible options. The best example is the MB8719. Pin 10 is a preset pin, either 64 + N when HIGH, or 128 + N when LOW. "N" is the binary sum of Pins 11-16.

FIGURE 3-31
SIMPLIFIED LOCK DETECTOR
(Cobra 19LTD, President Veep, etc.)



UP/DOWN CHANNEL CONTROL: Some radios have a remote control for UP/DOWN channel selection from the mike or front panel. The mike may also have remote VOLUME and SQUELCH controls. (Eg., Cobra 31+, 33+, Fuzzbuster Z-50, Z-80, HyGain 2679A, 2710X, 2716, Midland 77-149, President AX-11, Realistic TRC419, TRC423, TRC462, Uniden PRO-330E. You can step up or down from the current channel, either one at a time or continuously by holding in the step button.

In the older circuits this consisted of a Scan IC and clock generator, and some logic gating tied directly to the PLL programming lines. The scan was programmed by external PROM ICs or completely in ROM within the scan IC. Pushing the "UP" or "DOWN" button outputs the correct binary or BCD codes in a continuous sequence. This results in channel frequencies that step consecutively. A second Decoder/Driver IC will be paralled across the scanning IC output to generate the correct LED channel display.

The SM5123A PLL chip (Cobra 18+, 21+, 25+, 29+) and the C5121 PLL chip (Midland 77-155, Regency Info-CB1, Info-CB2, etc.) each contain internal UP/DOWN scan generators as well as all the other IC functions we've seen. Individual ROM program lines are no longer even needed, since one or two IC pins can control the scan; the expensive Channel Selector switch can now be completely eliminated if so desired.

Problems in this circuit include:

1. No scan.
2. Scans but LED channel display is wrong or missing.
3. No scan and no LED display.

With symptom #3, the Scan IC (or the SM5123A or C5121 PLL) is the obvious suspect. When it won't scan but the display is otherwise correct, check the PLL program lines against the Truth Chart for the correct logic changes, working backwards towards the Scan IC output lines until they're lost; the IC is the most obvious suspect. When the scan's OK but the display is dead or wrong, suspect the LED Decoder/Driver IC in radios that use them.

EXPANDED COVERAGE SYNTHESIZERS

The current popularity of expanded coverage export models requires that you understand their synthesizers too. Such knowledge also suggests how to expand other radios by using the same methods. Following are examples of the most common expansion techniques and some broadbanding hints for the standard models.

Method #1: The Preset Divider

External programming circuits may also preset N-Codes which expand the frequency range beyond the standard 40 channels. Examples are the Uniden export radios like the Cobra 148GTL-DX, Superstar 360FM, Stalker 9-FDX, President Grant or Jackson. (Also the Superstar 3600, 3900, Galaxy 2100, Super Galaxy, Excalibur Samurai, Excalibur base, and President Franklin; these are Uniden clones with the identical circuits.) The PLL circuit uses the MC145106 9-bit binary PLL and a pair of CD4008 4-bit binary adders to produce up to 240 channels in five or six consecutive bands of 40 channels each.

The reason for this method is simple: it's physically and economically impractical to make a Channel Selector switch with 120 or more positions on it. By presetting certain N-Codes for each band instead, a standard 40-channel binary wafer switch can be used. Figure 3-32 shows how this is done in the Uniden Jackson and similar models. A simple diode matrix controls the preset N-Code for each band. For example, Band "C" (standard FCC band) must preset "157" + N; in that position, diodes D7 (1's bit), D8 (4's bit), D9 (8's bit), D10 (16's bit), and D11 (128's bit) will conduct to result in (1 + 4 + 8 + 16 + 128) = 157.

The preset divider method does have its limits here. Only five presets and therefore five bands are possible before exceeding the binary counting range of a standard 40-channel switch with two 4-bit adder chips. That's why the Galaxy 2100/Excalibur Samurai chassis, a six-band version, uses two loop mixing crystals of 14.010 MHz and 15.360 MHz, where the Superstar 3900/Excalibur base just needed the 14.460 MHz crystal, and the Uniden Jackson the 14.550 MHz crystal, for five bands. Beyond the fifth band there weren't enough preset possibilities left, so they combined presets and crystals: a three-position "LOW" range with a 14.010 MHz crystal, and a "HI" range using a 15.360 MHz crystal. The "HI/LOW" switch selects the crystal, which means only three presets (LOW, MID, HI) are ever needed for six bands. See Figure 3-33A.

FIGURE 3-32
DIODE MATRIX FOR PRESETTING N-CODES
(Uniden Jackson)

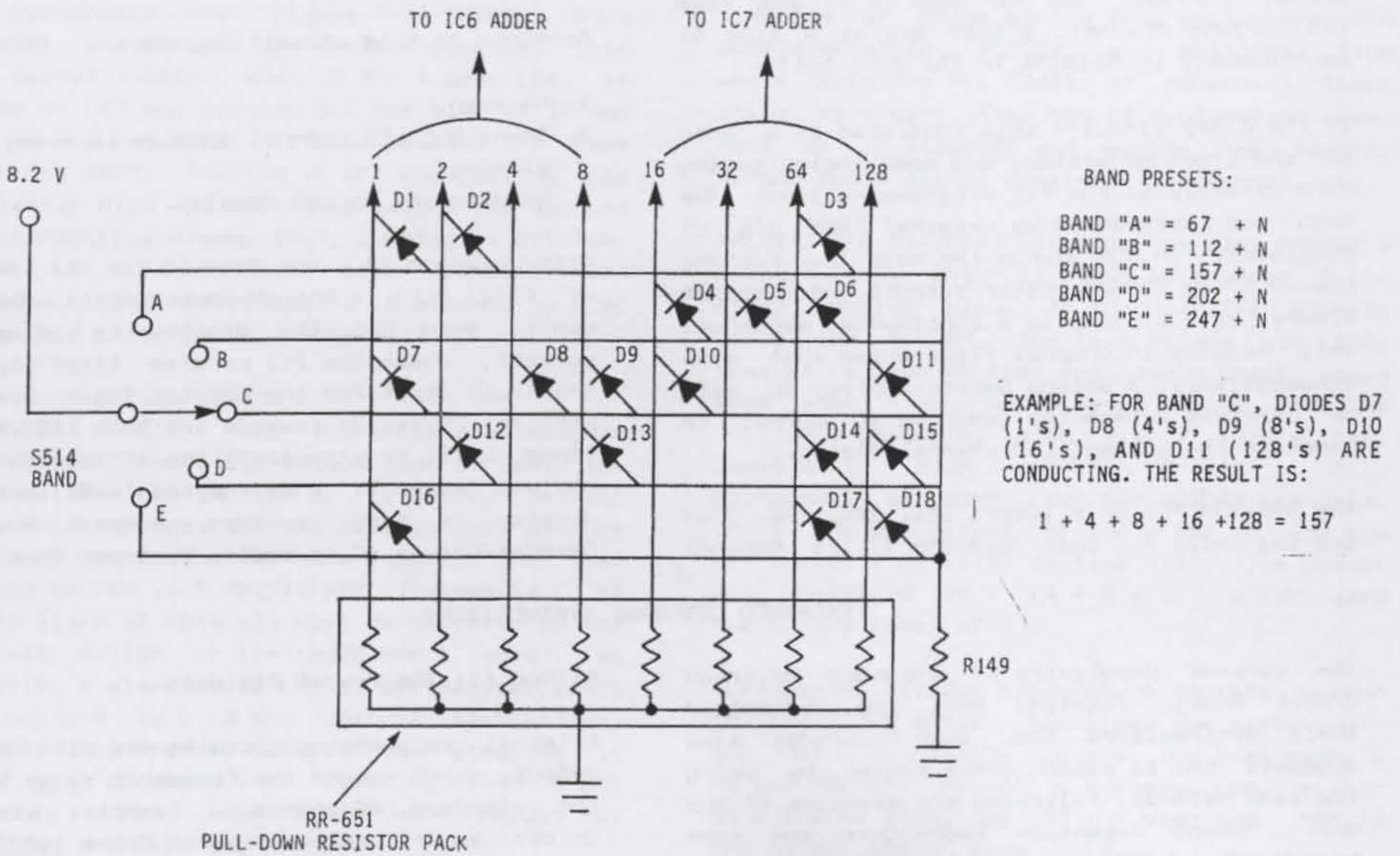
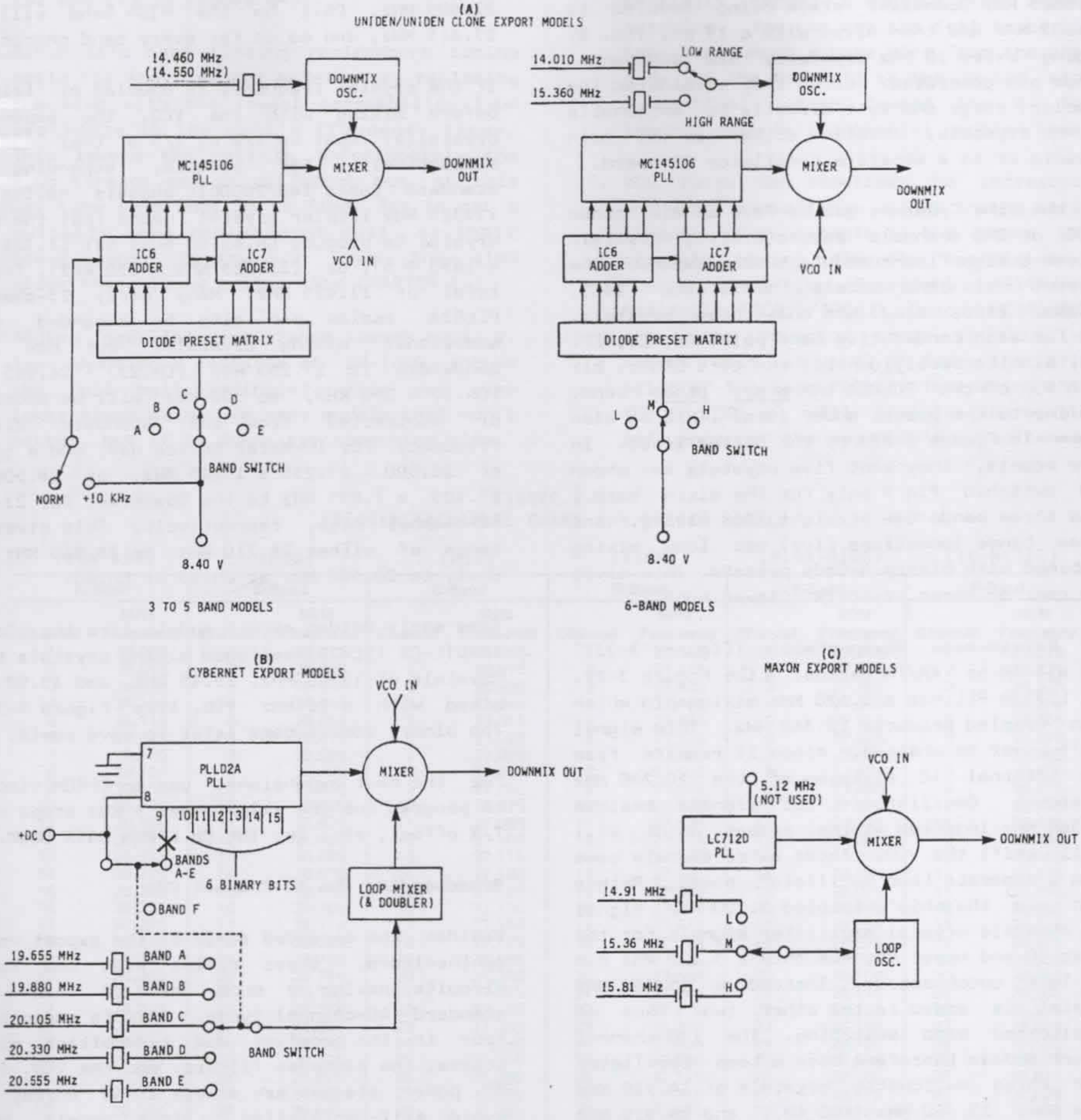


FIGURE 3-33
EXPANDED COVERAGE METHODS



Method #2: The Switchable Downmixer

The other export expansion method changes the Downmixer injection signal. By replacing the fixed Downmixer signal with one that's higher or lower, extra 40-channel bands are produced. Since this signal is derived from a crystal oscillator it's a simple matter of switching crystals. When this signal is changed it drives the VCO up or down, generating new mixing frequencies for the transmitter Mixer and 1st receiver Mixer stages. This method is commonly found in all the Cybernet export models, many of the Korean Maxon chassis, and a few very early Uniden export models. Each manufacturer uses minor variations on this principle to get the same result.

The Cybernet export models (Figure 3-33B) are basically American chassis with extra loop mixing crystals added. The U.S. version has a 10.0525 MHz Downmixer stage being doubled to 20.105 MHz and then mixed with a 17 MHz VCO. By adding extra 10 MHz crystals, new 40-channel bands are generated. Later they eliminated the doubler stage and went directly to switchable 20 MHz crystals, located either on the main chassis or on a separate oscillator PC board.

By the time Cybernet got to five or six bands (200 or 240 channels respectively), crystals became a significant manufacturing expense. The current six-band models (Lafayette 2400, Palomar 2400, etc.) use only three crystals, one for each consecutive band pair: AB, CD, EF. They simultaneously control the 64's binary bit (Pin 9) of the PLL02A on <u>every other</u> band, similar to the preset adder idea. (This is also shown in Figure 3-33B by the dotted lines. In some models, they kept five crystals as shown and switched Pin 9 only for the sixth band.) Thus three bands use straight loop mixing, and three bands (sometimes five) use loop mixing combined with binary N-Code presets. This saves the cost of three crystals. Clever huh?

The Korean-made Maxon chassis (Figure 3-33C) are all AM or AM/FM radios. Like Figure 3-22, the LC7120 PLL has a 5.120 MHz mixing pin which when tripled produces 15.360 MHz. This signal can't ever be changed, since it results from the internal IC division of the 10.240 MHz Reference Oscillator. But signals besides 15.360 MHz injected at the proper point will still shift the VCO. These extra signals come from a separate Loop Oscillator board. Rather than use the chip's tripled 5.120 MHz signal <u>and</u> separate crystal oscillator signals for the lower 40 and upper 40, the chip's 5.120 MHz pin is left unconnected. Instead a 15.360 MHz crystal is added to the other two. Thus no complicated band switching. The 120-channel export models therefore have a Loop Oscillator with three switchable crystals of 14.910 MHz (LOW 40), 15.360 MHz (FCC 40), and 15.810 MHz (HIGH 40). Many American PLL circuits use the 15.360 MHz loop mixer, meaning this expansion principle can be applied to any of them too.

Notice successive loop crystals are 450 KHz higher or lower than the standard FCC band when mixed directly with the VCO. That's because a standard 40-channel CB band is 440 KHz wide. (27.405 MHz - 26.965 MHz = 440 KHz.) Except for the five skips, the channels are 10 KHz apart. By adding 10 KHz to the 440 KHz bandwidth, the frequencies will be continuous when changing bands. For example, if Ch.40 on the MID band is 27.405 MHz, Ch.1 on the HIGH band will be 27.415 MHz, and so on for every band change.

If the crystal frequency is doubled or tripled before mixing with the VCO, the expansion crystal(s) must be 1/2 or 1/3 of that 450 KHz respectively. For example, expanding the standard Cobra 148/2000GTL chassis having an 11.325 MHz tripler crystal means that the next crystal to produce Ch.41-80 must be: 11.325 MHz + (450 ÷ 3), or (11.325 MHz + 150 KHz), for a total of 11.475 MHz. Many early 23-channel PLL02A radios can also be expanded with additional mixing crystals, but now the bandwidth is 27.255 MHz (Ch.23) - 26.965 MHz (Ch.1) = 290 KHz, so 300 KHz will be added to or subtracted from the standard mixing frequency. For 10-Meter Novice use, add a <u>total</u> of 28.500 - 27.255 = 1.245 MHz, or 28.500 - 27.405 = 1.095 MHz to the Downmixer for 23- or 40-channel rigs, respectively. This gives a range of either 28.210 MHz or 28.060 MHz at Ch.1, to 28.500 MHz at Ch.23 or Ch.40.

Some early Uniden export models like the Cobra 148GTL-DX (PC879) switched mixing crystals too. Crystals of 15.00 MHz, 15.45 MHz, and 15.90 MHz mixed with a 16 MHz VCO, like Figure 3-33C. The binary adders came later to save costs.

For the best expansions, use an EPROM circuit to program out the skips, get 5 KHz steps or a T/R offset, etc. See **THE CB EPROM DATA BOOK.**

Broadbanding The 40-Channel CBs

Besides the expanded range of the export model synthesizers, these radios also use tuned circuits having a much lower Q than the standard 40-channel types. This is especially true in the receiver and transmitter mixer stages, the bandpass filters, and the VCO. (The RF power stages are always low-Q anyway to avoid self-oscillation.) Since people will always attempt endless modifications to expand the standard CBs, the following techniques may prove helpful in broadbanding such equipment.

1. One of the simplest ways to broadband tuned circuits is to increase the coupling between them. Most bandpass and mixer circuits are interconnected by a very small (2-5 pF) series coupling capacitor. Try increasing this capacitor from perhaps 10-100 pF. Don't

get carried away with excess coupling or the gain may drop too much. Examples: C47 and C48 in Figure 4-14, C163 in Figure 6-33, and C62 and C63 in Figure 6-31.

2. Since it's hard finding replacement tuning coils for the export models, try replacing the slug with the lowest permeability type available in the coil's frequency range. This lowers the coil Q. Unfortunately the slug threads may be different too, so this may take some hunting to find. Try to get a suitable Toko replacement coil, or their low-Q slugs. Or try S.J. Tonks; they also stock these low-Q coils. (See CHAPTER 1.)

3. Adding parallel resistance lowers coil Q. Try shunting a resistor of 1K-10KΩ across the full coil winding(s). This may also lower stage gain. In many models that won't matter, but if it does, try something else.

4. Many modern CBs have an unused coil connection at one end of the primary and/or secondary winding. Instead the winding is partially tapped to control the impedance matching. You can cut the foil trace to the tap and jumper a bare wire from the circuit side of the tap foil to the unused winding connection, which lowers the Q. Again, lowered gain is a potential problem here.

5. VCO range may sometimes be increased by changing capacitance values in the varactor circuit. For example in the newer Uniden circuits having discrete transistor VCOs (Cobra 146GTL, President AR144/AX144, Realistic TRC451/TRC453, Uniden PC244/PC122, etc.) the varactor anode is usually in series with about 47 pF from the driving point of the loop filter. Increasing this to about .001 µF will greatly increase the influence of the varactor's capacitance and

FIGURE 3-34
FREQUENCY/CHANNEL CHART FOR EXPORT MODELS

(LOW-LOW) A-Band		(LOW) B-Band		(MID) C-Band		(HIGH) D-Band		(HIGH-HIGH) E-Band		(10 METER) F-Band	
Channel	MHz Frequency	Channel	MHz Frequency	Channel	MHz Frequency	Channel	MHz Frequency	Channel	MHz Frequency	Channel	MHz Frequency
1	26,065	1	26,515	1	26,965	1	27,415	1	27,865	1	28,315
2	26,075	2	26,525	2	26,975	2	27,425	2	27,875	2	28,325
3	26,085	3	26,535	3	26,985	3	27,435	3	27,885	3	28,335
4	26,105	4	26,555	4	27,005	4	27,455	4	27,905	4	28,355
5	26,115	5	26,565	5	27,015	5	27,465	5	27,915	5	28,365
6	26,125	6	26,575	6	27,025	6	27,475	6	27,925	6	28,375
7	26,135	7	26,585	7	27,035	7	27,485	7	27,935	7	28,385
8	26,155	8	26,605	8	27,055	8	27,505	8	27,955	8	28,405
9	26,165	9	26,615	9	27,065	9	27,515	9	27,965	9	28,415
10	26,175	10	26,625	10	27,075	10	27,525	10	27,975	10	28,425
11	26,185	11	26,635	11	27,085	11	27,535	11	27,985	11	28,435
12	26,205	12	26,655	12	27,105	12	27,555	12	28,005	12	28,455
13	26,215	13	26,665	13	27,115	13	27,565	13	28,015	13	28,465
14	26,225	14	26,675	14	27,125	14	27,585	14	28,025	14	28,475
15	26,235	15	26,685	15	27,135	15	27,585	15	28,035	15	28,485
16	26,255	16	26,705	16	27,155	16	27,605	16	28,055	16	28,505
17	26,265	17	26,715	17	27,165	17	27,615	17	28,065	17	28,515
18	26,275	18	26,725	18	27,175	18	27,625	18	28,075	18	28,525
19	26,285	19	26,735	19	27,185	19	27,635	19	28,085	19	28,535
20	26,305	20	26,755	20	27,205	20	27,655	20	28,105	20	28,555
21	26,315	21	26,765	21	27,215	21	27,665	21	28,115	21	28,565
22	26,325	22	26,775	22	27,225	22	27,675	22	28,125	22	28,575
23	26,355	23	26,805	23	27,255	23	27,705	23	28,155	23	28,605
24	26,335	24	26,785	24	27,235	24	27,685	24	28,135	24	28,585
25	26,345	25	26,795	25	27,245	25	27,695	25	28,145	25	28,595
26	26,365	26	26,815	26	27,265	26	27,715	26	28,165	26	28,615
27	26,375	27	26,825	27	27,275	27	27,725	27	28,175	27	28,625
28	26,385	28	26,835	28	27,285	28	27,835	28	28,185	28	28,635
29	26,395	29	26,845	29	27,295	29	27,845	29	28,195	29	28,645
30	26,405	30	26,855	30	27,305	30	27,755	30	28,205	30	28,655
31	26,415	31	26,865	31	27,315	31	27,865	31	28,215	31	28,665
32	26,425	32	26,875	32	27,325	32	27,775	32	28,225	32	28,675
33	26,435	33	26,885	33	27,335	33	27,785	33	28,235	33	28,685
34	26,445	34	26,895	34	27,345	34	27,795	34	28,245	34	28,695
35	26,455	35	26,905	35	27,355	35	27,805	35	28,255	35	28,705
36	26,465	36	26,915	36	27,365	36	27,815	36	28,265	36	28,715
37	26,475	37	26,925	37	27,375	37	27,825	37	28,275	37	28,725
38	26,485	38	26,935	38	27,385	38	27,835	38	28,285	38	28,735
39	26,495	39	26,945	39	27,395	39	27,845	39	28,295	39	28,745
40	26,505	40	26,955	40	27,405	40	27,855	40	28,305	40	28,755

NOTE: BAND "C" IS FCC BAND.

therefore the tuning range. This same principle applies to circuits where a capacitor is shunted across the VCO varactor; try increasing its value.

In these same chassis, you can also change the emitter and collector resistors of the VCO transistor to increase its gain. In the PC833/PC965/PB015 it's R98 (1KΩ) and R99 (56Ω) at TR22, and in the PB062 it's R102 (330Ω) and R103 (56Ω) at TR21. Replace both with about 180-220Ω. Combining the capacitor change above with the resistor changes makes these chassis go about 160 channels.

6. For IC VCOs like the UHIC005 or UHIC007, cut the trace connecting the hot side of the VCO coil winding to the IC. Connect a Maxitune or Superdiode in series, with its cathode end toward the IC input pin. These diodes are available from Selman Enterprises or C.C. Distributors; see CHAPTER 1.

Figure 3-34 shows a six-band Frequency/Channel expansion chart for your reference.

PLL SYNTHESIZER EVOLUTION

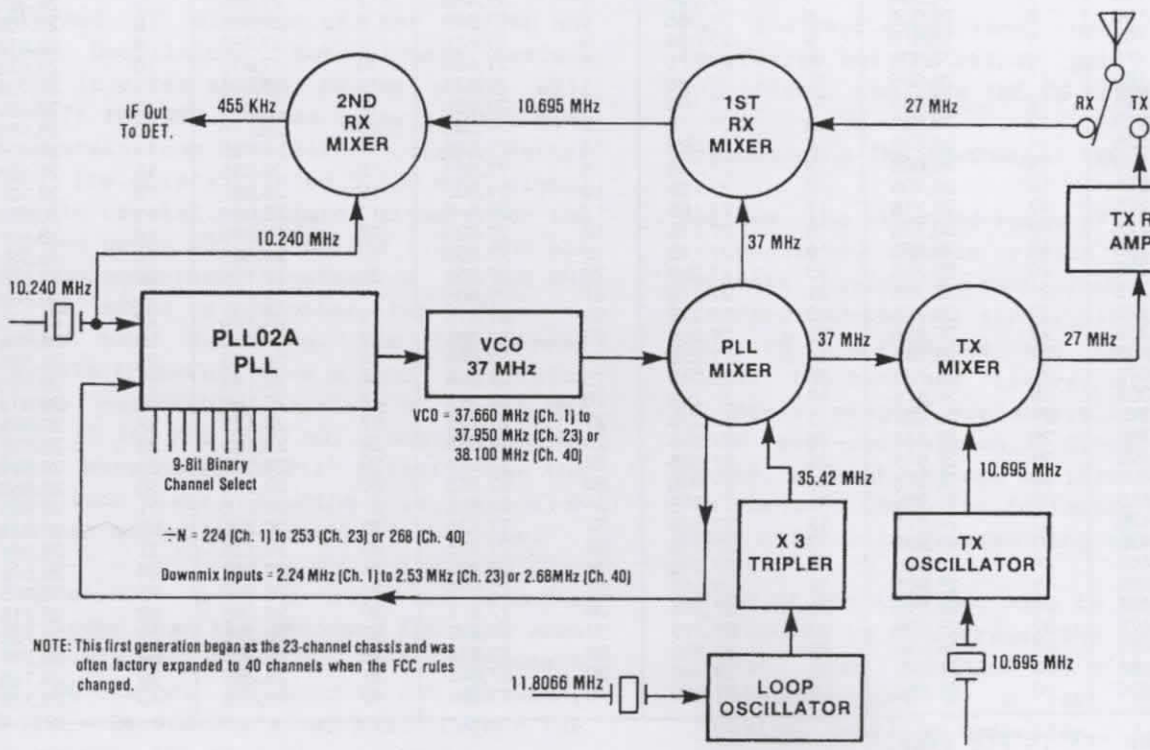
The following common AM-type PLL synthesizer examples are presented in chronological order of evolution, so you can see the changes and simplifications that occurred over the years.

EXAMPLE #1: THE CYBERNET PLL02A EARLY & LATE GENERATION PLL

The PLL02A AM circuit takes one of two forms. The first-generation chassis used three crystals, and the late-generation chassis was reduced to two crystals. The PLL chip uses straight 9-bit binary programming (pins 7-15) with internal pull-down resistors on them. The pins are normally LOW (0.0 V) unless forced HIGH (about 8 VDC) by external switching.

EARLY CIRCUIT: See Figure 3-35. The VCO runs at 37 MHz and is mixed with a 35.420 MHz signal derived from tripling an 11.8066 MHz crystal oscillator. The difference frequency is selected and becomes the downmix input. For example, the Ch.1 VCO is 37.660 MHz; when mixed with 35.420 MHz, the result is 37.660 - 35.420

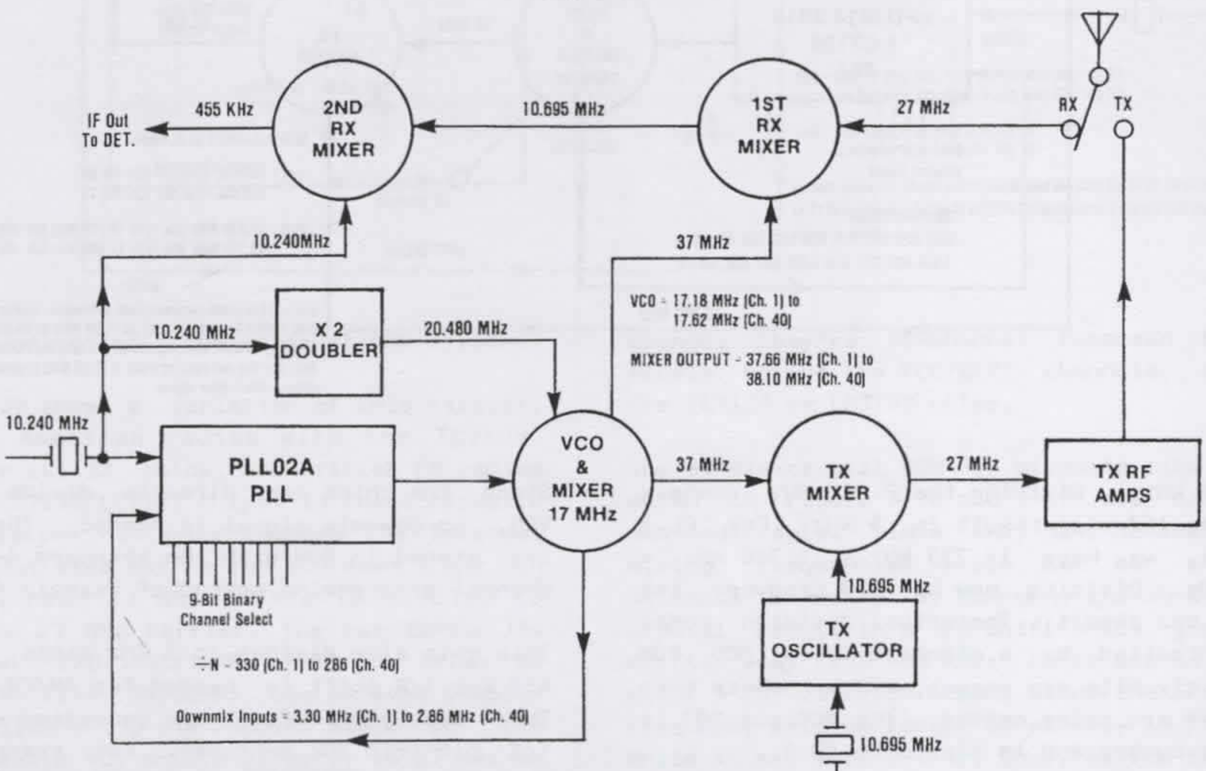
FIGURE 3-35
PLL02A EARLY AM CIRCUIT



= 2.24 MHz. The program pins are set for the binary number "224," which when divided into 2.24 MHz gives the required 10 KHz used by the chip. Pin 8 (128's bit) + Pin 9 (64's bit) + Pin 10 (32's bit) are always HIGH and preset the N-Code to (128 + 64 + 32) = 224; pins 11-15 vary with each channel and the N-Code extends to "253" for 23-channel models or to "268" for 40-channel models. (This was one of those chassis where some models were factory-expanded during the 23-to-40 transition era.)

LATE CIRCUIT: See Figure 3-36. Note this is the same circuit we've been discussing in this chapter. In this version the 11 MHz oscillator and its tripler stage have been eliminated. Instead a sample of the 10.240 MHz Reference Oscillator is doubled to 20.480 MHz and mixed with a 17 MHz VCO. For example, the Ch.1 VCO is 17.180 MHz. Mixing this with 20.480 MHz gives a downmix of 20.480 - 17.180 = 3.30 MHz. Now a binary "330" is programmed to produce the required 10 KHz rather than the "224" needed in the early circuit. Pin 7 (256's bit) presets a binary "256" and is added to the binary sum of pins 9-15. Pin 8 (128's bit) is grounded, since its value is never needed here.

FIGURE 3-36
PLL02A LATE AM CIRCUIT



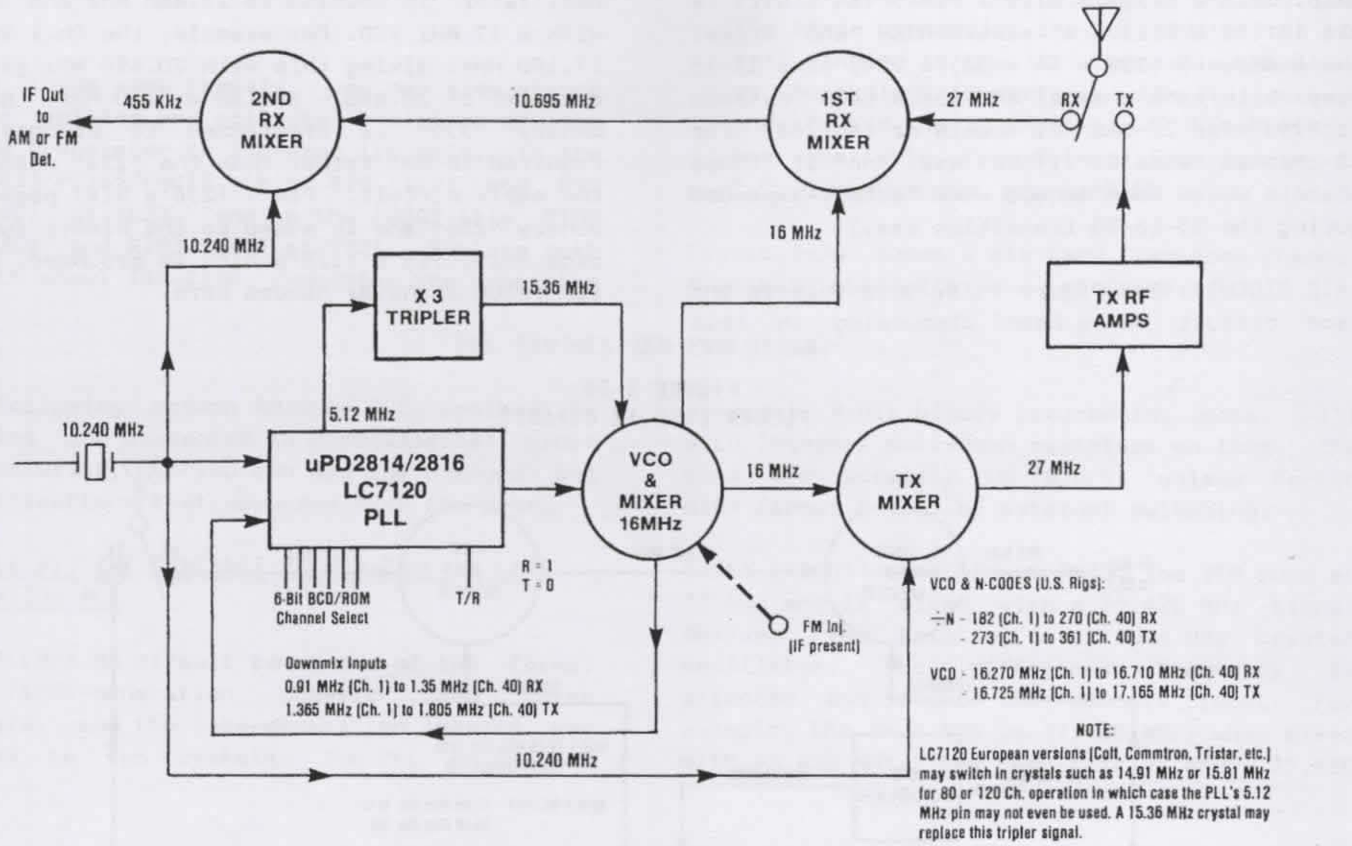
EXAMPLE #2: THE µPD2814/µPD2816 PLL

Refer to Figure 3-37. The µPD2814/2816 chips are pin-for-pin identical. (The µPD2824 is also identical except the Pin 9 T/R shift function is missing. To my knowledge it's never been used in any non-SSB radios.) The chips are the first generation use of ROM programming. There are several possible N-Code sets which can be used, depending upon the particular circuit and the state of Pin 9 (T/R) and Pin 20 (FS). All AM (and FM) chassis use the same method.

Since AM/FM radios require a double-conversion receiver with the low IF at 455 KHz, the T/R shift (Pin 9) is always used. This pin changes between Transmit and Receive to shift the VCO by 455 KHz. The result is an N-Code of 91-135 on Receive, and 136-180 on Transmit.

Pin 10 outputs 5.120 MHz. This is tripled by a coil to 15.360 MHz and mixes with the VCO; the difference frequency is selected to produce the downmix into the PLL chip. Example: The Ch.1 Receive VCO is 16.270 MHz; subtracting the 15.360 MHz downmixer gives 16.270 - 15.360 = 0.910 MHz. Since a T/R shift is involved, the chip uses 5 KHz Phase Detector inputs rather

FIGURE 3-37
µPD2814/2816 AM CIRCUIT
(Sometimes LC7120)



than 10 KHz. Dividing the 0.910 MHz downmix signal by 182 will result in 5 KHz. For Ch.1 Transmit, we have 16.725 MHz - 15.360 MHz = 1.365 MHz. Dividing now by 273 produces the same 5 KHz result. The actual division codes are controlled by a standard 6-bit BCD ROM input; six bits are enough, since numbers more than "39" are never needed. (The BCD sum "0" is the 40th number and is always Ch.40.)

For the export versions, a separate crystal oscillator PCB generates the 15.360 MHz PLL signal directly, along with 14.910 MHz and 15.810 MHz. This allows 120-channel operation. This chassis is most commonly found in the Korean-made Maxon radios (Colt 210, Colt 510, Commtron, Midland 100M, 150M, etc.), where the LC7120 PLL chip is used with the same results.

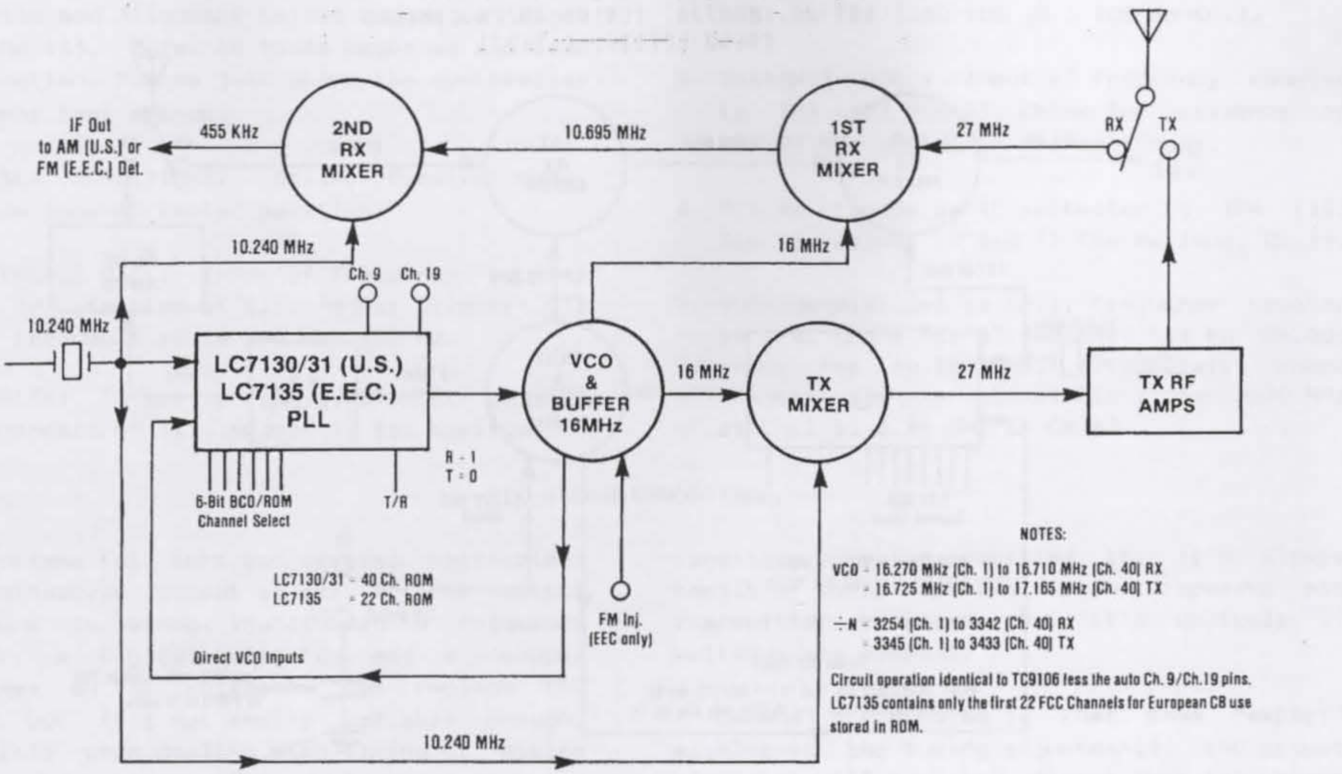
EXAMPLE #3: THE LC7130/LC7131 PLL

See Figure 3-38. The LC7130/31 are examples of the newest PLLs designed to make illegal channel modifications virtually impossible. Since the chips can directly divide a 16 MHz VCO, no downmix signal is needed. The N-Codes are stored in ROM with the standard 6-bit BCD channel programming method of Example #2.

This chip also divides in 5 KHz steps, since a 455 KHz T/R shift is needed for AM/FM radios. Thus separate N-Codes are generated when the T/R pin (Pin 20) switches. For example, the Ch.1 Receive VCO runs at 16.270 MHz. The ROM's N-Code is 3,254; 16.270 MHz ÷ 3,254 = 5 KHz. For Ch.1 Transmit, the N-Code is 3,345 and the VCO frequency is 455 KHz higher, or 16.270 MHz + .455 = 16.725 MHz. The result again is 5 KHz.

A sample of the 10.240 MHz Reference Oscillator goes to both the 2nd receive mixer stage and the transmit Mixer stage. The difference or sum respectively is chosen for the 455 KHz 2nd IF or the 27 MHz transmitter signal. An identical PLL circuit uses the TC9106 (U.S.) or TC9119 (U.K.); the only difference is that these chips don't have the automatic Ch.9/Ch.19 recall feature as additional pins, and a random 8-bit

FIGURE 3-38
LC7130/LC7131 AM CIRCUIT
(ALSO TC9106, TC9119, SM5123A)



program code controls the internal ROM divider.

Figure 3-39 shows a variation of this circuit, found in American radios with the TC9109, MB8733, or LC7132 chips, and British FM radios with the LC7136/LC7137 chips. In these circuits the T/R switch not only changes the internal N-Codes, but also shifts the VCO down 3 MHz on Transmit, near 13 MHz. This is doubled to become the 27 MHz carrier. The new Cobra 33+ and Uniden PRO-510E/520E, 710E and other AM chassis (SM5124A, SM5125B) use an even simpler method, eliminating the doubler stage too: the 16 MHz Receive VCO shifts directly to 27 MHz on Transmit; a transistor switches in more or less inductance across the VCO tank circuit.

The non-standard British CB channels will have changed to the standard FCC/CEPT frequencies by late 1987. Since the only channel difference between the TC9106/TC9119 and LC7132/LC7136 radios is the specific ROM division, it's a simple matter to convert British radios to the standard channels by changing just the PLL chip. (Unfortunately such changes probably won't be legal, and UK operators may have to buy brand new radios complying with stricter technical specs.) The Uniden PC404 and Cybernet Atron 2000FM radios are two examples of this change; they're 40-channel European FM-only models having the FCC/CEPT channels, and use the TC9109 or LC7132 chips.

The single-crystal ROM PLL circuits like those shown in Figure 3-38 and 3-39 are basically non-modifiable, since they have no additional mixing frequencies which can be changed. Attempts to modify by changing the 10.240 MHz crystal result in a T/R shift which gradually drifts away from 455 KHz; there are no longer exact 5 KHz division steps, since the reference frequency will no longer be exactly 10.240 MHz. While it may work on say, Ch.1, by the time you get to Ch.40 the receiver simply quits.

I know one very good English company offering a complete outboard synthesizer that replaces the LC7120, LC7132, LC7137, TC9106, TC9119, and µPD2810 PLL synthesizer circuits: S.J. Tonks (CB Components), 53/55 Darlaston Road, Pleck, Walsall, West Midlands, WS2 9QT, ENGLAND. The telephone is (0922) 646710. Their PLL unit is a compact, pretuned conversion board designed for easy installation, and with no special test equipment. It gives a switchable choice of 40 FCC or 40 upper channels. The price is about US $40; write for current prices and include a schematic and the exact radio model.

FIGURE 3-39
LC71-32, MB8733, TC9109 AM/FM CIRCUIT
(ALSO LC7136, LC7137)

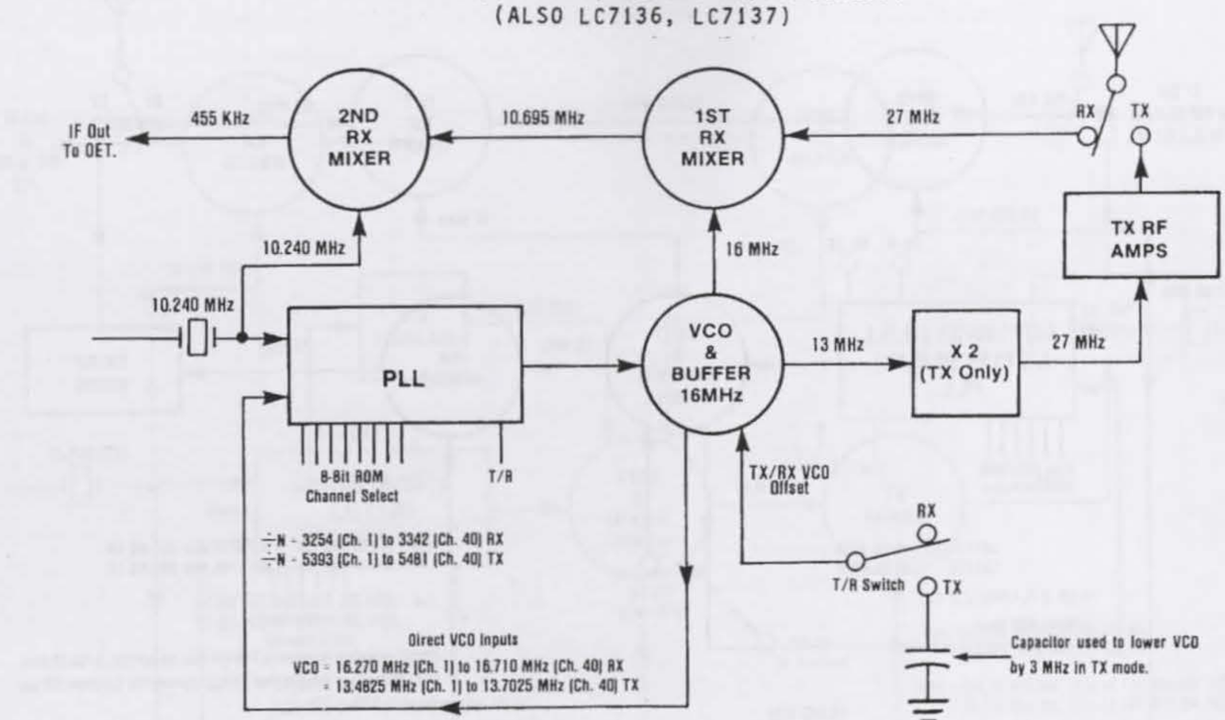
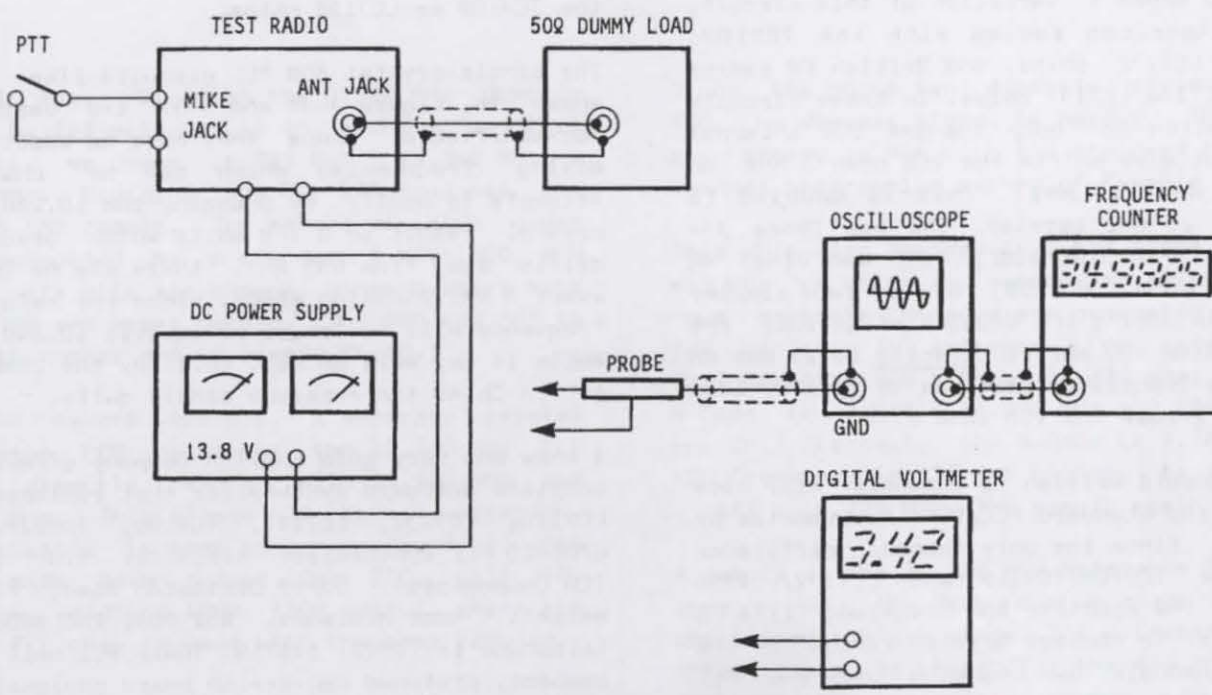


FIGURE 3-40
EQUIPMENT SET-UP FOR PLL ALIGNMENT



PLL SYNTHESIZER ALIGNMENT

Ajustment of PLL synthesizers involves setting all crystal oscillator frequencies, setting the VCO/Phase Detector for correct DC drive voltage on a given channel, and tuning any mixer circuits. SSB radios require some extra steps, as discussed in CHAPTER 6. Here we'll describe the PLL alignment for a popular AM chassis (Cybernet PTBM049A0X, under many names) whose Schematic and Alignment Layout appear on Pages 144 and 145. Refer to those pages as you read this section. Figure 3-40 shows the synthesizer equipment test set-up.

1. PRESET CONDITIONS: Ch.19, Receive mode, Delta Tune at center position.

2. REFERENCE OSC.: Input of frequency counter to TP1 (Emitter of Q1). Adjust trimmer CT1 for frequency of 10.240 MHz ±50 Hz.

3. DOUBLER: 'Scope or RF Voltmeter to TP2 (secondary of T1). Adjust T1 for maximum.

4. VCO: Input of digital DC voltmeter to TP8 (opposite side of R1 from IC1 Pin 5). Adjust coil L1 for 3.60 VDC ±0.1 VDC on Ch.1.

5. TRANSMIT OSC.: Input of frequency counter to TP3 (IC3 Pin 2). Check for presence of 10.695 MHz ±50 Hz in Transmit mode.

6. MIXER: 'Scope or RF voltmeter to TP4 (IC3 Pin 4). Adjust L2 and T2 for maximum, Ch.19.

7. VCO/DOWNMIX: Set to Ch.1, frequency counter to TP4. Check for 37.660 MHz. Set to Ch.40; check for 38.100 MHz. Alternately, check downmix signals at IC1 Pin 2 for 3.30 MHz at Ch.1 to 2.86 MHz at Ch.40.

PLL TROUBLESHOOTING

PLL problems fall into two general categories: no synthesizer output at all, or the output frequency is wrong. You'll need a frequency counter, a digital voltmeter, and a 'scope. Sometimes an RF voltmeter can replace the 'scope but it's not really reliable enough, especially when dealing with timing or mixing problems. A good test set-up if your 'scope has a "Z" axis input is to connect that to your frequency counter; this allows you to use the 'scope probe for simultaneous waveform <u>and</u> frequency readings without having to switch instruments. Of course you <u>do</u> have the service manual or SAMS, which tells you the various voltages and signals to look for, right?

Symptoms associated with PLL synthesizers are:

1. No Transmit.
2. No Receive.
3. No Transmit or Receive.
4. A few channels dead.
5. A few channels duplicated.
6. Low transmitter power and/or poor receiver sensitivity.
7. No channel control; out of lock with the VCO free-running at its natural frequency.
8. No Transmit or Receive, one band end only.
9. Off frequency on all channels.

Following are some general guidelines to isolate PLL problems, and a specific example. With the symptoms of "No Receive or Transmit, Any Channel" and correct voltages to the PLL circuit already verified, you can be pretty sure the synthesizer's the problem. A quick check is to measure the Lock Detector pin; if the voltage level there shows an out-of-lock condition, you've verified it. It's always possible there are two distinct receiver and transmitter problems, but it's unlikely if voltages are correct.

A common PLL problem is that some "expert" misaligned the tuning adjustments, and proper alignment will cure it. Always look for signs of previous "repair" work, and get in the habit of questioning the customer first to determine the exact problem and repair history.

SPECIAL CAUTION! The plastic VCO block used in all the Cybernet PLL02A radios has a tuning slug which is <u>very</u> fragile and will crack if you don't use the correct tuning tool. Once it cracks, you'd have to unsolder the entire block from the main PC board to get to it from the bottom for removal. Worse, if it's the export type chassis you'll never be able to get a replacement. Don't touch this adjustment at all if the synthesizer works through its normal frequency range! If you must adjust it, the GC Electronics #9440 plastic alignment tool is the correct one that fits this slug.

On a related subject, you'll often find the standard tuning slugs cracked or frozen in the coil from a previous "adjustment." These can still be saved if you're very careful. The slugs have the same screwdriver slot at both ends; remove the transformer completely from the PC board and you'll be able to use the <u>bottom</u> slot to unscrew the jammed slug. Then screw it back in from the top side and reinstall the transformer. If some ferrite breaks off in the process, it usually won't be enough to prevent correct tuning anyway.

Here are a few general PLL troubleshooting suggestions:

1. Is there any receiver noise? Usually with a dead PLL you'll hear some hiss noise, but at a lower-than-normal volume. If there's no noise at all, the problem may be in the voltage supply rather than the synthesizer.

   Assuming there's noise, check the synthesizer area with a 'scope or RF voltmeter, looking for the presence of all oscillator and mixing signals. Also 'scope the downmix input pin of the PLL IC to see if it's there. With a dual-trace 'scope, you can view the Reference Oscillator on one channel and the downmix on the other, which should be at a much lower frequency.

   Remember that an RF probe can't tell the difference between a single frequency and mixed frequencies, but a 'scope can. Don't be misled. If one mixer input is missing there will still be RF at the output, but of the wrong frequency. A missing mixer input signal will also cause the stage to have a lower-than-normal RF output voltage.

2. The synthesizer typically has from one to three oscillators and one or two mixer stages. If any one stage is defective, the wrong output is generated. Check each stage with your 'scope until you lose the signal, then make DC and resistance measurements to isolate the bad part. A problem with inexperience is to immediately suspect a bad PLL chip if IC voltages, especially the one driving the VCO, are wrong. The real problem is usually in the VCO or mixer, <u>not</u> the PLL IC. If there's evidence that somebody replaced the PLL chip but the radio still doesn't work, suspect problems in the mixer or oscillator stages.

3. A variation of Step 2 is to inject the missing frequency with your RF signal generator. If operation is restored you know that particular signal was missing. Now work backwards, injecting from the output to the input, one stage at a time. You may have to use more than one generator frequency as you proceed. Once the injection point is moved past the defective area, it no longer restores normal operation so you've got it isolated. Inject using a high-impedance probe or you might load down or mistune something, making your tests meaningless.

4. You can test the VCO and associated circuitry by applying a DC clamping voltage. Disconnect the series component that normally drives the VCO from the PLL/filter circuit, usually a resistor. Apply a filtered DC voltage to this control point instead. The voltage should be in the range normally supplied from the PLL chip; the alignment instructions will say something like "Adjust VCO coil for 3.60 VDC at Ch.1." A DC supply variable from about 1-5 VDC is perfect. Changing this voltage should also make the VCO frequency change.

MISCELLANEOUS SERVICING TIPS: Due to all the amateurish PLL modifications around, it's a good idea when replacing a PLL IC to <u>include a socket</u> for it. PLLs are CMOS, and besides potential static damage, you can't keep soldering and unsoldering those delicate foil traces forever! Keep a small supply of 16, 18, 20, 22, and 24 pin low-profile DIP sockets handy and you'll save yourself many future headaches and call-backs.

On the subject of CMOS, be sure you're doing everything possible to prevent static from destroying the chips. Measures include the use of grounded soldering irons, grounded wrist straps, and leaving the chip in its conductive foam or package until needed. I happen to have a carpeted work area and the Arizona climate is very dry, encouraging static.

Here's a simple way to eliminate static in a carpeted room: get a plastic spray bottle with a trigger squeeze on it, like those used for all-purpose cleaners or Windex. Fill it with a mixture of 50% water and 50% Downey laundry fabric softener. Every month or two, spray a fine mist on the carpeted work areas. This prevents static electricity buildup. Computer owners take note too! (My computer is in the same room as my electronic servicing bench.)

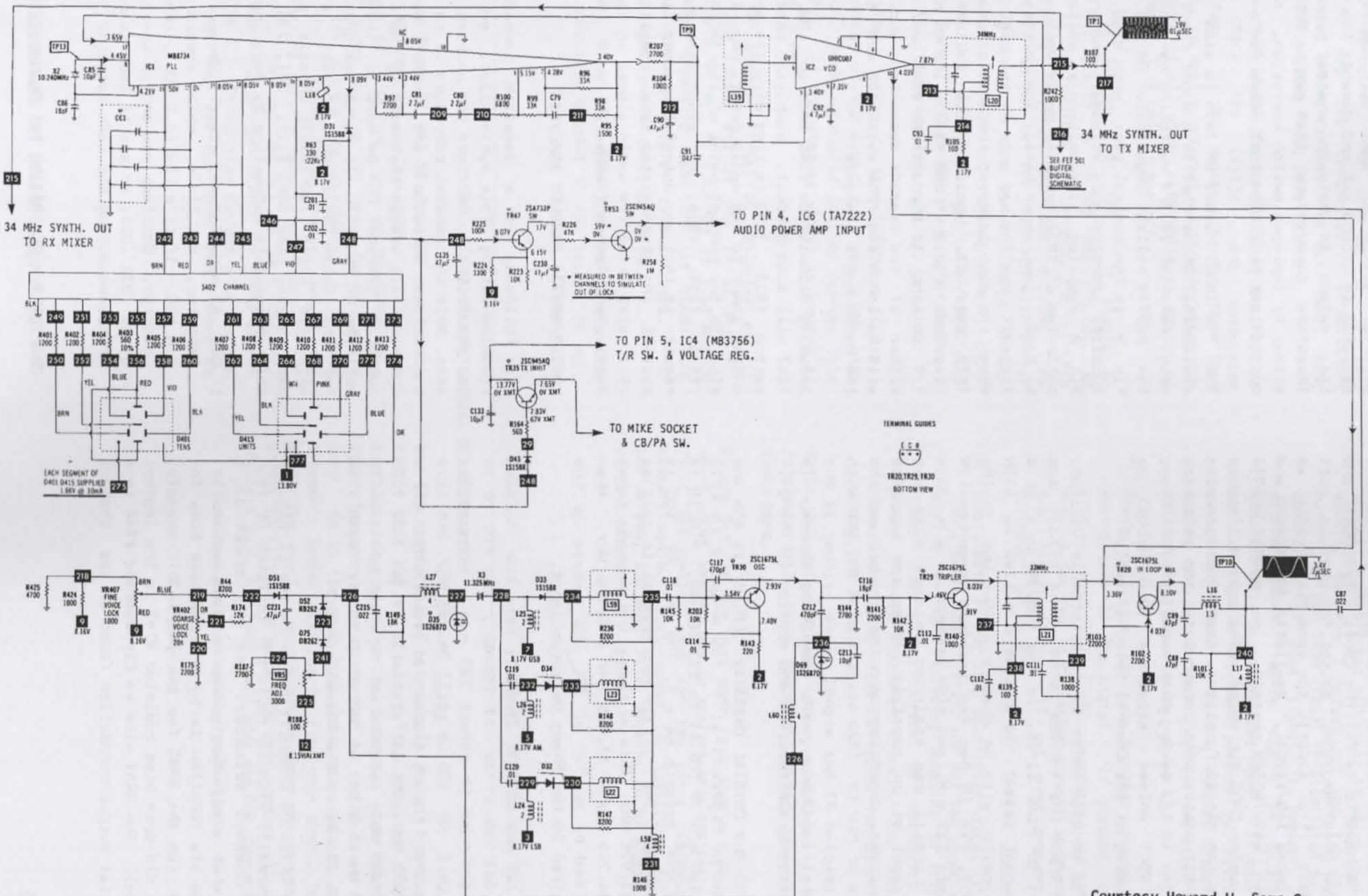
A Practical PLL Example

Now we'll analyze a real circuit. You'll discover that being logical and methodical is all it takes to fix what first appears to be a tough problem! Figure 3-41 is reprinted by permission of the Howard W. Sams Co.

MB8719/MB8734 Frequency Synthesizer Circuit Description

Refer to Figure 3-41. I've purposely chosen

FIGURE 3-41
THE MB8719/MB8734 PLL SYNTHESIZER



Courtesy Howard W. Sams Co.

this circuit because of its great popularity. The schematic is for the Cobra 148/2000GTL and Uniden GRANT/MADISON; except for certain part numbers it's exactly the same PLL circuit as the Cobra 140/142GTL, Realistic TRC450/490 and Uniden WASHINGTON chassis. The MB8719/MB8734 are custom CMOS PLL chips. The only difference is in the Pin 10 functions. Channel programming is 6-bit binary with internal pull-up resistors on pins 10-16, making them normally HIGH (about 8.0 VDC) unless forced LOW (0.0 volts) by grounding at the Channel Selector switch.

Pin 10 on both chips is a Presettable Divider. When HIGH the N-Code is 64 + the binary sum ("N") of Pins 11-16. In the MB8734 this is a permanent preset; it's always pulled up HIGH internally, with no chassis connection. In the MB8719, Pin 10 has two possible presets: LOW presets 128 + N, and HIGH presets 64 + N. This PLL circuit was designed to work with two different mixing crystals. There are two sets of N-Codes, depending upon the crystal and the state of Pin 10. TR20 mixes the 34 MHz VCO with the tripled 33 MHz signal from either 11 MHz crystal oscillator; the resulting downmix is filtered by C89/L16/C88 and applied to Pin 17.

11.325 MHz CRYSTAL CHASSIS: (This is the one shown in Figure 3-41.) The N-Codes in this version are 79 (Ch.1) to 123 (Ch.40). Pin 10 is HIGH and presets 64 + N. The Ch.1 AM VCO is 34.765 MHz. The 11.325 MHz crystal is tripled to 33.975 MHz. This produces the downimx input of 34.765 MHz - 33.975 MHz = 0.790 MHz. When divided by an "N" of 79, the result is the required 10 KHz Phase Detector input.

11.1125 MHz CRYSTAL CHASSIS: Here the N-Codes are 143 (Ch.1) to 187 (Ch.40), and Pin 10 is now grounded to preset 128 + N. For example, the Ch.1 AM VCO is still 34.765 MHz, but this time the tripler signal is 11.1125 MHz x 3 = 33.3375 MHz. The difference is 34.765 - 33.3375 = 1.4275 MHz, which is trimmed to exactly 1.43 MHz. With an "N" of 143, the result is still 10 KHz to the Phase Detector.

LOCK DETECTOR CIRCUIT: Pin 6 is the LD pin and is normally HIGH (8 VDC). D31 isolates it from the Channel Selector. R63 was drawn in a somewhat misleading place on this schematic, since its function is to provide base bias for TR35. (On the SAMS for the 140/142GTL chassis, they did draw bias resistor R147 in the logical place!) The GRAY wire to Circuitrace #248 is a special output connection found on the Channel Selector switch of most PLL radios; it's designed to ground out and disable the radio if the switch is between channel positions. Therefore Circuitrace #248 can be forced LOW either by improper switch operation, or by an out-of-lock condition that makes Pin 6 go LOW.

The "TX INHIT" label on TR35 is also somewhat misleading, since that is a minor function. Its main function is T/R switching by control of the MB3756 voltage regulator. On the MB3756, Pin 5 is the control pin: when HIGH, Pin 6 supplies Receive-only voltage, and when LOW, Pin 8 supplies Transmit-only voltage. The collector of TR35 normally pulls up to 13.8 VDC by R162. (Not shown here.) The emitter is the Transmit keyline and goes to the MIKE socket. When the mike is keyed the emitter grounds and TR35 conducts, pulling its collector and therefore Pin 5 of the MB3756 LOW to make the T/R switch. If Circuitrace #248 goes LOW for either of the reasons described above, TR35 will be inhibited from switching and therefore the radio can't transmit.

Assuming Circuitrace #248 does go LOW, switch TR47 will also conduct, supplying base bias to switch TR53. TR53 is tied directly across the audio input to the audio power amp IC4, and also to the control point of the AMC/ALC amps. (TR34, TR25, TR24, not shown here.) The net result is that any out-of-lock condition will prevent the transmitter from operating, and will also kill the audio signal in both the Receive and Transmit modes.

MB8719/MB8734 PROBLEM ANALYSIS

The following is a detailed procedure for troubleshooting this synthesizer, and assumes you've logically narrowed the problem to this area. Note the general procedure is to start at the mixer output(s) and work backwards, checking all stages that make up the composite output. This idea can be used to troubleshoot any type of PLL circuit. Parts designations are for the Cobra 148/2000GTL chassis, with the alternate Cobra 140/142GTL chassis parts in parentheses. See SAMS #219, 221, 230, 249, or 251 for complete schematics by model numbers.

1. Use AM mode for all steps. Check the Lock Detector, PLL Pin 6, which should be about 8.0 VDC. If it's LOW (0.0 VDC), the loop is unlocked. Unsolder one end of the switching diode D31 (D25) to see if lock is restored. If disconnecting the Lock Detector restores

normal operation, the problem is in this circuit, not the synthesizer; troubleshoot associated active devices like D31, TR47, TR53, D43, TR35. (D25, TR45, D44, TR37.)

2. Do you read 10.240 MHz at Pin 8 of the PLL? If not, check the crystal and associated capacitors. If OK, replace the PLL IC. This PLL has an active internal oscillator which can fail even if all other chip voltages appear to be normal. I've seen it happen!

3. Check the frequency at TP1. It should be 34.765 MHz (Ch.1) to 35.205 MHz (Ch.40), AM mode. If the readings are correct, the PLL chip is working properly and the problem lies elsewhere. If not correct, the VCO will either be free-running in the 35 MHz range or not working at all. If not running at all, check VCO/Mixer IC2 (IC1) voltages and associated passive devices. Also check tuning of VCO coil L19 (L13). If OK and free-running, go to #4.

4. Check signal continuity from VCO/Mixer IC Pin 1 to secondary of VCO output coil L20 (L14) which is TP1. Check associated passive devices like C93 (C75). If free-running signal is present at TP1, go to #5.

5. Check for downmix signal at collector of PLL Mixer TR20 (TR19) and at Pin 17 of PLL IC. Should be 0.790 MHz to 1.23 MHz or 1.43 MHz to 1.87 MHz, depending upon chassis model and specific 11 MHz tripler crystal used. If downmix signal not present, go to #6.

6. Check PLL Mixer TR20 (TR19). The 34 MHz VCO signal should be present at the base. If not, suspect possible bad VCO/Mixer IC which could be working for Pin 1 output but not for Pin 10 output, or bad TR20 (TR19) or associated passive devices. If base signal is present check emitter signal, which should be 33.975 MHz (33.3350 MHz) depending upon model. If base and emitter signals are both present but collector signal (the downmix) is not, suspect transistor and/or the associated passive devices. If emitter signal is missing, go to #7.

7. Check collector of tripler TR29 (TR23) for appropriate 33 MHz signal. If present, check tripler coil L21 (L18) secondary and other passive devices in collector circuit to pinpoint open signal path. If not even present at collector, go to #8.

8. Investigate 11 MHz loop oscillator stage. Check TR30 (TR24), the crystal, and all the associated passive devices, including coupling to tripler stage. Check for crystal RF continuity to ground through Clarifier circuit, and forward bias on switching diode D34 (D33) for AM offset tuning.

NOTE: D32 and D34 were drawn backwards in SAMS Fotofacts #251 (Cobra 2000GTL), but are correct as shown here.

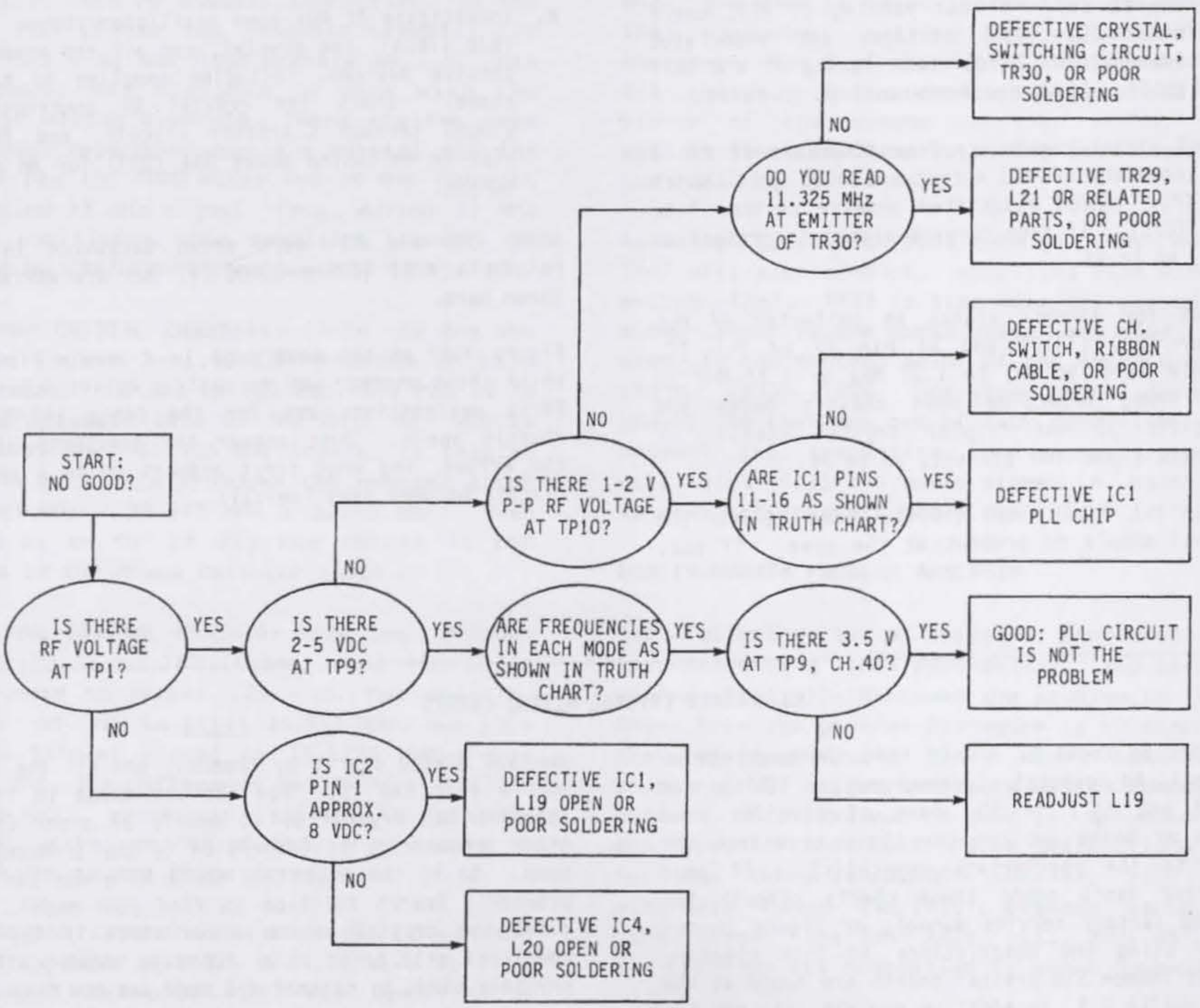
Figure 3-42 on the next page is a simple Flowchart which shows another way to analyze this synthesizer. Parts designations are for the Cobra 148/2000GTL chassis again. Just answer the questions, follow the arrows, and what first appears to be a complex circuit becomes very logical!

23-CHANNEL CRYSTAL MIXING CHARTS

The charts on Pages 87 and 88 show the most common 23-channel AM crystal synthesizers. (Also see Pages 52 and 54.) In the case of specific dead channels or modes you can use these to narrow the problem to the appropriate crystal(s). If your synthesizer isn't among these charts consult the SAMS, the factory service manual, or figure it out yourself using the descriptions in this chapter. (The most common SSB crystal charts are found at the end of CHAPTER 6.) In addition our Web site now has .PDF files that show all the other most common AM and SSB mixing charts by channel, and all the known models that had it. You can use these to find a specific bad crystal or to modify an older CB for other frequencies or conversion to the 10-Meter Ham band. Go to the page link shown here and use your browser's Search function to find your model. Then click the crystal scheme shown above it for that model; it will bring up a .PDF page showing all the crystals used, by channel and mode and how they mix.

www.cbcintl.com/docs/xtals.htm

FIGURE 3-42
MB8719/MB8734 TROUBLESHOOTING FLOWCHART
(Cobra 148/2000GTL, Uniden Grant/Madison)



	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	16.200	4.765	Ch.13 (27.115)	16.350	4.765
Ch. 2 (26.975)	"	4.775	Ch.14 (27.125)	"	4.775
Ch. 3 (26.985)	"	4.785	Ch.15 (27.135)	"	4.785
Ch. 4 (27.005)	"	4.805	Ch.16 (27.155)	"	4.805
Ch. 5 (27.015)	16.250	4.765	Ch.17 (27.165)	16.400	4.765
Ch. 6 (27.025)	"	4.775	Ch.18 (27.175)	"	4.775
Ch. 7 (27.035)	"	4.785	Ch.19 (27.185)	"	4.785
Ch. 8 (27.055)	"	4.805	Ch.20 (27.205)	"	4.805
Ch. 9 (27.065)	16.300	4.765	Ch.21 (27.215)	16.450	4.765
Ch.10 (27.075)	"	4.775	Ch.22 (27.225)	"	4.775
Ch.11 (27.085)	"	4.785	Ch.23 (27.255)	"	4.805
Ch.12 (27.105)	"	4.805			

Additional Crystals Used: 5.545 MHz RX all 23 channels;
6.000 MHz TX all 23 channels

Synthesis: "A" + "B" + 6.000 = direct on-channel TX frequency;
"A" + "B" + 5.545 = RX frequency (offset by 455 KHz)

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	32.845	10.180	Ch.13 (27.115)	32.995	10.180
Ch. 2 (26.975)	"	10.170	Ch.14 (27.125)	"	10.170
Ch. 3 (26.985)	"	10.160	Ch.15 (27.135)	"	10.160
Ch. 4 (27.005)	"	10.140	Ch.16 (27.155)	"	10.140
Ch. 5 (27.015)	32.895	10.180	Ch.17 (27.165)	33.045	10.180
Ch. 6 (27.025)	"	10.170	Ch.18 (27.175)	"	10.170
Ch. 7 (27.035)	"	10.160	Ch.19 (27.185)	"	10.160
Ch. 8 (27.055)	"	10.140	Ch.20 (27.205)	"	10.140
Ch. 9 (27.065)	32.945	10.180	Ch.21 (27.215)	33.095	10.180
Ch.10 (27.075)	"	10.170	Ch.22 (27.225)	"	10.170
Ch.11 (27.085)	"	10.160	Ch.23 (27.255)	"	10.140
Ch.12 (27.105)	"	10.140			

Additional Crystals Used: 4.300 MHz TX all 23 channels;
4.755 MHz RX all 23 channels

Synthesis: "A" - "B" + 4.300 = direct on-channel TX frequency;
"A" - "B" + 4.755 = RX frequency (offset by 455 KHz

	BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"		BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"
Ch. 1 (26.965)	16.965	9.5450	10.000	Ch.13 (27.115)	17.115	9.5450	10.000
Ch. 2 (26.975)	"	9.5550	10.010	Ch.14 (27.125)	"	9.5550	10.010
Ch. 3 (26.985)	"	9.5650	10.020	Ch.15 (27.135)	"	9.5650	10.020
Ch. 4 (27.005)	"	9.5850	10.040	Ch.16 (27.155)	"	9.5850	10.040
Ch. 5 (27.015)	17.015	9.5450	10.000	Ch.17 (27.165)	17.165	9.5450	10.000
Ch. 6 (27.025)	"	9.5550	10.010	Ch.18 (27.175)	"	9.5550	10.010
Ch. 7 (27.035)	"	9.5650	10.020	Ch.19 (27.185)	"	9.5650	10.020
Ch. 8 (27.055)	"	9.5850	10.040	Ch.20 (27.205)	"	9.5850	10.040
Ch. 9 (27.065)	17.065	9.5450	10.000	Ch.21 (27.215)	17.215	9.5450	10.000
Ch.10 (27.075)	"	9.5550	10.010	Ch.22 (27.225)	"	9.5550	10.010
Ch.11 (27.085)	"	9.5650	10.020	Ch.23 (27.255)	"	9.5850	10.040
Ch.12 (27.105)	"	9.5850	10.040				

Synthesis: "A" + "C" = direct on-channel TX frequency;
"A" + "B" = RX frequency (offset by 455 KHz)

	BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"		BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"
Ch. 1 (26.965)	33.300	6.490	6.035	Ch.13 (27.115)	33.150	6.490	6.035
Ch. 2 (26.975)	"	6.480	6.025	Ch.14 (27.125)	"	6.480	6.025
Ch. 3 (26.985)	"	6.470	6.015	Ch.15 (27.135)	"	6.470	6.015
Ch. 4 (27.005)	"	6.450	5.995	Ch.16 (27.155)	"	6.450	5.995
Ch. 5 (27.015)	33.050	6.490	6.035	Ch.17 (27.165)	33.200	6.490	6.035
Ch. 6 (27.025)	"	6.480	6.025	Ch.18 (27.175)	"	6.480	6.025
Ch. 7 (27.035)	"	6.470	6.015	Ch.19 (27.185)	"	6.470	6.015
Ch. 8 (27.055)	"	6.450	5.995	Ch.20 (27.205)	"	6.450	5.995
Ch. 9 (27.065)	33.100	6.490	6.035	Ch.21 (27.215)	33.250	6.490	6.035
Ch.10 (27.075)	"	6.480	6.025	Ch.22 (27.225)	"	6.480	6.025
Ch.11 (27.085)	"	6.470	6.015	Ch.23 (27.255)	"	6.450	5.995
Ch.12 (27.105)	"	6.450	5.995				

Synthesis: "A" - "C" = direct on-channel TX frequency;
"A" - "B" = RX frequency (offset by 455 KHz)

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	11.705	7.4600	Ch.13 (27.115)	11.855	7.4600
Ch. 2 (26.975)	"	7.4700	Ch.14 (27.125)	"	7.4700
Ch. 3 (26.985)	"	7.4800	Ch.15 (27.135)	"	7.4800
Ch. 4 (27.005)	"	7.5000	Ch.16 (27.155)	"	7.5000
Ch. 5 (27.015)	11.755	7.4600	Ch.17 (27.165)	11.905	7.4600
Ch. 6 (27.025)	"	7.4700	Ch.18 (27.175)	"	7.4700
Ch. 7 (27.035)	"	7.4800	Ch.19 (27.185)	"	7.4800
Ch. 8 (27.055)	"	7.5000	Ch.20 (27.205)	"	7.5000
Ch. 9 (27.065)	11.805	7.4600	Ch.21 (27.215)	11.955	7.4600
Ch.10 (27.075)	"	7.4700	Ch.22 (27.225)	"	7.4700
Ch.11 (27.085)	"	7.4800	Ch.23 (27.255)	"	7.5000
Ch.12 (27.105)	"	7.5000			

Additional Crystals Used: 7.800 MHz TX all 23 channels;
7.345 MHz RX all 23 channels

Synthesis: "A" + "B" + 7.800 = direct on-channel TX frequency;
"A" + "B" + 7.345 = RX frequency (offset by 455 KHz)

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	10.850	8.6150	Ch.13 (27.115)	11.000	8.6150
Ch. 2 (26.975)	"	8.6250	Ch.14 (27.125)	"	8.6250
Ch. 3 (26.985)	"	8.6350	Ch.15 (27.135)	"	8.6350
Ch. 4 (27.005)	"	8.6550	Ch.16 (27.155)	"	8.6550
Ch. 5 (27.015)	10.900	8.6150	Ch.17 (27.165)	11.050	8.6150
Ch. 6 (27.025)	"	8.6250	Ch.18 (27.175)	"	8.6250
Ch. 7 (27.035)	"	8.6350	Ch.19 (27.185)	"	8.6350
Ch. 8 (27.055)	"	8.6550	Ch.20 (27.205)	"	8.6550
Ch. 9 (27.065)	10.950	8.6150	Ch.21 (27.215)	11.100	8.6150
Ch.10 (27.075)	"	8.6250	Ch.22 (27.225)	"	8.6250
Ch.11 (27.085)	"	8.6350	Ch.23 (27.255)	"	8.6550
Ch.12 (27.105)	"	8.6550			

Additional Crystals Used: 7.500 MHz TX all 23 channels;
7.975 MHz RX all 23 channels

Synthesis: "A" + "B" + 7.500 = direct on-channel TX frequency;
"A" + "B" + 7.975 = RX frequency (offset by 455 KHz)

	BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"		BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"
Ch. 1 (26.965)	38.275	11.765	11.310	Ch.13 (27.115)	38.375	11.715	11.260
Ch. 2 (26.975)	38.285	"	"	Ch.14 (27.125)	38.385	"	"
Ch. 3 (26.985)	38.295	"	"	Ch.15 (27.135)	38.395	"	"
Ch. 4 (27.005)	38.315	"	"	Ch.16 (27.155)	38.415	"	"
Ch. 5 (27.015)	38.275	11.715	11.260	Ch.17 (27.165)	38.475	11.765	11.310
Ch. 6 (27.025)	38.285	"	"	Ch.18 (27.175)	38.485	"	"
Ch. 7 (27.035)	38.295	"	"	Ch.19 (27.185)	38.495	"	"
Ch. 8 (27.055)	38.315	"	"	Ch.20 (27.205)	38.515	"	"
Ch. 9 (27.065)	38.375	11.765	11.310	Ch.21 (27.215)	38.475	11.715	11.260
Ch.10 (27.075)	38.385	"	"	Ch.22 (27.225)	38.485	"	"
Ch.11 (27.085)	38.395	"	"	Ch.23 (27.255)	38.515	"	"
Ch.12 (27.105)	38.415	"	"				

Synthesis: "A" - "C" = direct on-channel TX frequency;
"A" - "B" = RX frequency (offset by 455 KHz)

	BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"		BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"
Ch. 1 (26.965)	34.971	8.006	8.461	Ch.13 (27.115)	35.121	8.006	8.461
Ch. 2 (26.975)	"	7.996	8.451	Ch.14 (27.125)	"	7.996	8.451
Ch. 3 (26.985)	"	7.986	8.441	Ch.15 (27.135)	"	7.986	8.441
Ch. 4 (27.005)	"	7.966	8.421	Ch.16 (27.155)	"	7.966	8.421
Ch. 5 (27.015)	35.021	8.006	8.461	Ch.17 (27.165)	35.171	8.006	8.461
Ch. 6 (27.025)	"	7.996	8.451	Ch.18 (27.175)	"	7.996	8.451
Ch. 7 (27.035)	"	7.986	8.441	Ch.19 (27.185)	"	7.986	8.441
zh. 8 (27.055)	"	7.966	8.421	Ch.20 (27.205)	"	7.966	8.421
Ch. 9 (27.065)	35.071	8.006	8.461	Ch.21 (27.215)	35.221	8.006	8.461
Ch.10 (27.075)	"	7.996	8.451	Ch.22 (27.225)	"	7.996	8.451
Ch.11 (27.085)	"	7.986	8.441	Ch.23 (27.255)	"	7.966	8.421
Ch.12 (27.105)	"	7.966	8.421				

Synthesis: "A" - "B" = direct on-channel TX frequency;
"A" - "C" = RX frequency (offset by 455 KHz)

	BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"		BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"
Ch. 1 (26.965)	32.700	6.190	5.735	Ch.13 (27.115)	32.850	6.190	5.735
Ch. 2 (26.975)	"	6.180	5.725	Ch.14 (27.125)	"	6.180	5.725
Ch. 3 (26.985)	"	6.170	5.715	Ch.15 (27.135)	"	6.170	5.715
Ch. 4 (27.005)	"	6.150	5.695	Ch.16 (27.155)	"	6.150	5.695
Ch. 5 (27.015)	32.750	6.190	5.735	Ch.17 (27.165)	32.900	6.190	5.735
Ch. 6 (27.025)	"	6.180	5.725	Ch.18 (27.175)	"	6.180	5.725
Ch. 7 (27.035)	"	6.170	5.715	Ch.19 (27.185)	"	6.170	5.715
Ch. 8 (27.055)	"	6.150	5.695	Ch.20 (27.205)	"	6.150	5.695
Ch. 9 (27.065)	32.800	6.190	5.735	Ch.21 (27.215)	32.950	6.190	5.735
Ch.10 (27.075)	"	6.180	5.725	Ch.22 (27.225)	"	6.180	5.725
Ch.11 (27.085)	"	6.170	5.715	Ch.23 (27.255)	"	6.150	5.695
Ch.12 (27.105)	"	6.150	5.695				

Synthesis: "A" - "C" = direct on-channel TX frequency;
"A" - "B" = RX frequency (offset by 455 KHz)