

Video Transmitter

*Delta—the ATV transmitter you can change to fit your needs.
Three bands, one design.*

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ATV was the reason I got my ham license. Being able to talk to people without using Ma Bell was OK, but being able to see them at the same time—no slow scan for me—was cool.

I had been attending HATS and South Texas BLT meetings for several months before I got my ticket, and I was able to

observe many different systems, both on 440 MHz and 1.2 GHz. I was a new ham with little or no equipment, no disposable income—but lots of spare parts. My options were down to one—build it myself.

I looked at all the circuits and equipment I could find, for ideas about which manufacturers made parts for

ATV frequencies. By this time almost a year had passed and HATS had determined that the Houston area did not lend itself to in-band 440 MHz ATV. My focus was abruptly narrowed to creating a 1.2 GHz transmitter.

Alpha board

I found a chip that would phase-lock a 1.2 GHz signal using a crystal control. This was great! A one-chip solution to my problem—and there were application notes for building a 1.5 GHz VCO to use with the chip, a Plessey SP5070F that cost about \$17. Not too bad, I thought, and I didn't think the other parts would be any more difficult to find in small quantities. *Wrong!*

I could get samples of some of the parts but most had a minimum purchase quantity of 3,000-5,000 pieces. I spent several weeks searching for alternate sources and components, and finally wound up with enough samples to build two prototypes, following the VCO application note, and another eight or nine variations on the theme.

I created artwork and made the first circuit board. I had all the video components but couldn't find the transformer

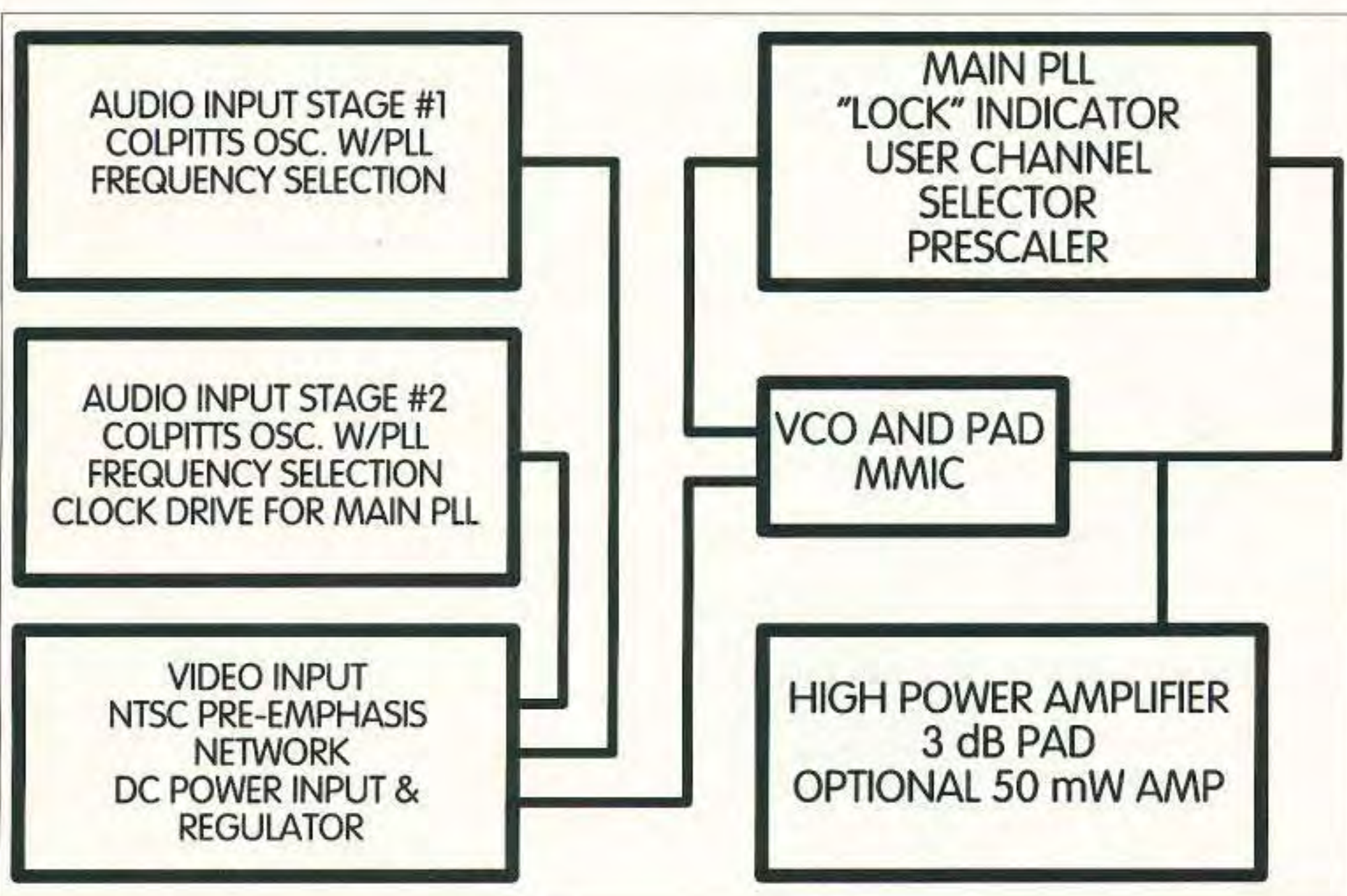


Fig. 1. System block diagram.

used in the audio circuit I had found in the *ARRL Handbook*. Well, I had bitten off a lot on this first board, so I gave up trying to find that stupid transformer and concentrated on the video section. Video pre-emphasis and two transistor gain stages weren't too hard to debug—but nothing came out the other end. It was at that point that I found out why they call them application "notes." Nice idea—but has anybody ever built it to see if it works? Two weeks later, after calls to anyone who would listen (and a few that didn't want to but did anyway), I'd got to the point of finding out where the free-running frequency of the VCO excited—disconnected from the PLL and video signals. Surprise! No wonder the PLL wouldn't/couldn't lock. It couldn't correct a VCO running 100 MHz too low on the voltage I had given it, and I didn't have a 17-volt car battery handy to correct the problem. I spent another week tweaking that sorry VCO. Actually, it wasn't *that* bad (I'm still married). But *now* I was getting cocky. I had

a VCO that would free run at 1170 MHz. I reattached the PLL and it locked on frequency. Then I added the video.

A little more troubleshooting on the video board—and what do you know ... It actually worked.

Beta board

Some people were so impressed that I'd made a low-power ATV video-only transmitter for under \$40 that they wanted one too. Buoyed by the fact that I'd survived the Alpha, I boldly conceived the next board—but I was smarter this time.

Audio would go on its own board until I resolved the parts problems it created. About that time I was shown an article from *VHF Communications* on a 13 cm ATV exciter. Their design had moved many of the "flying" parts onto a 50-ohm stripline on the PC board. This made a lot of sense: fewer parts to break off; a 50-ohm trace to make the MMIC amplifier happy; and a match to the coax going to the high power amplifier.

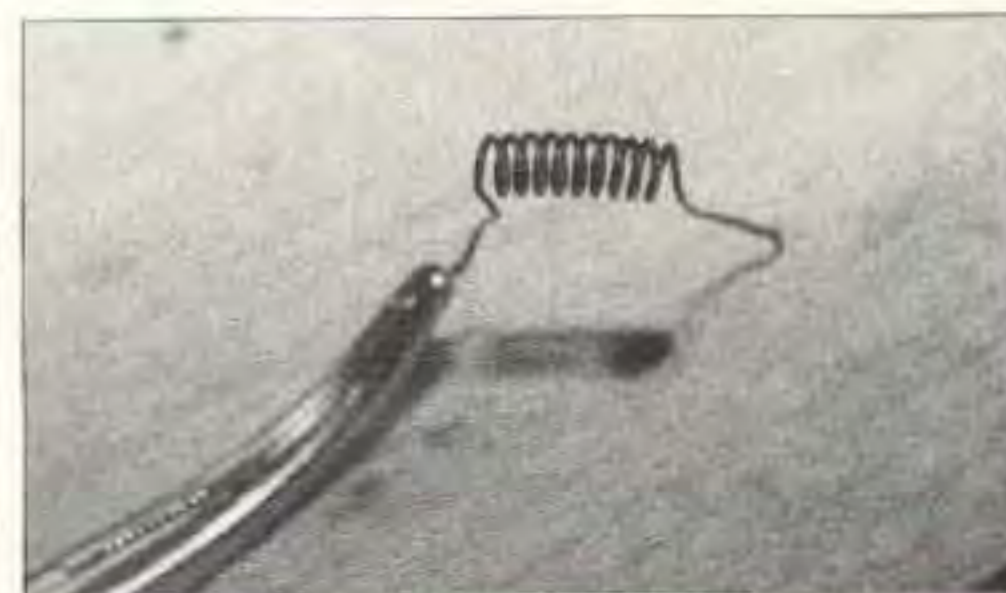


Photo A. Coil with both sides spread. No more curve!

I was on the right track. Once more, I began creating different VCO designs using my free samples. I made up the first of eight boards and gave it to my first victim. He got it to work in a matter of hours, and made his own audio circuit. Unfortunately for him, my first victim did such a good job of making my mess work, he got to help with most of the rest of these little beasts. Somewhere around the seventh or eighth VCO, I got samples of a TriQuint general purpose downconverter, the TQ9272. One section of it contained a VCO with buffered outputs. All it

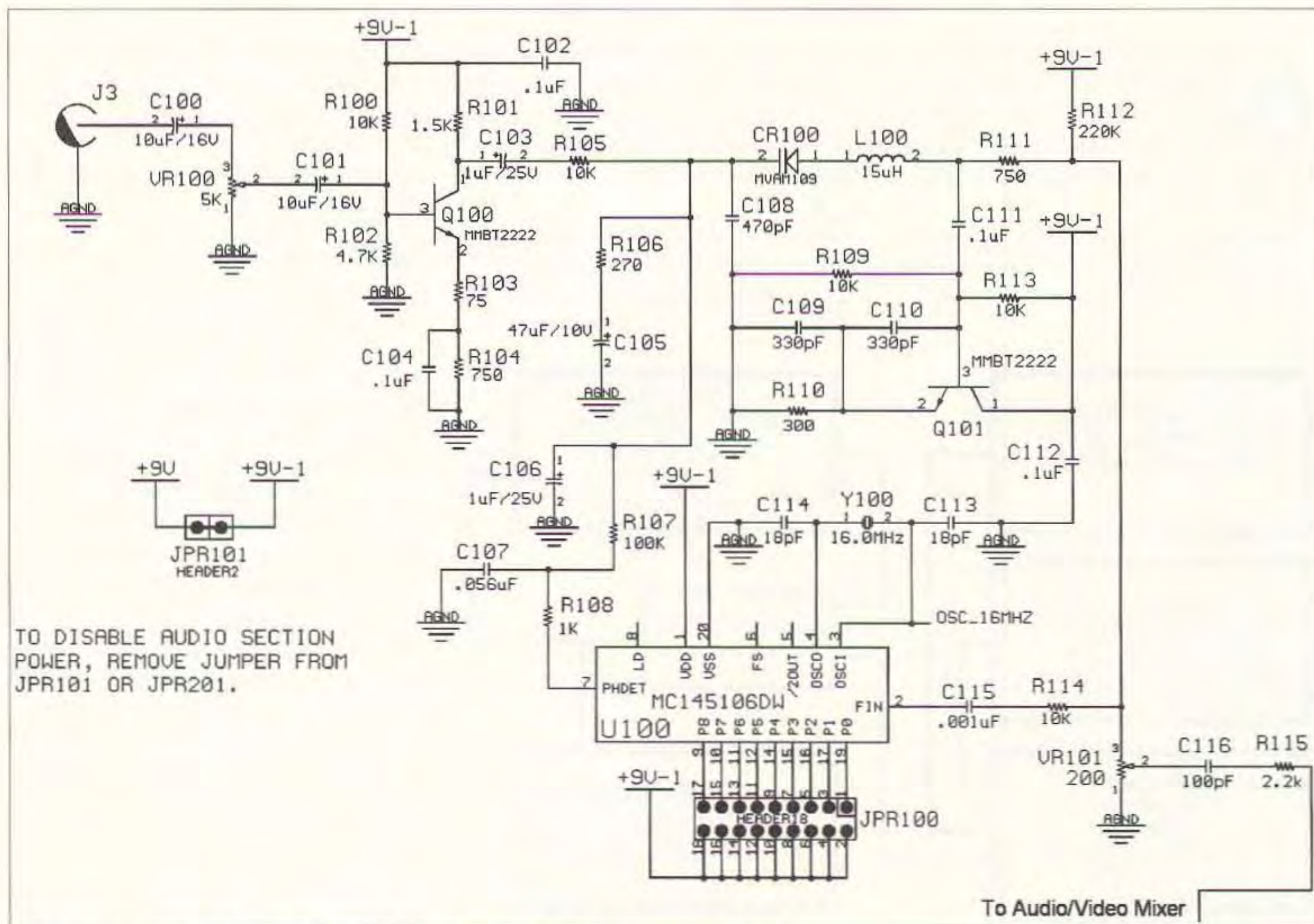


Fig. 2. First audio subcarrier. In all schematics, resistance is in Ω and capacitance in μF .

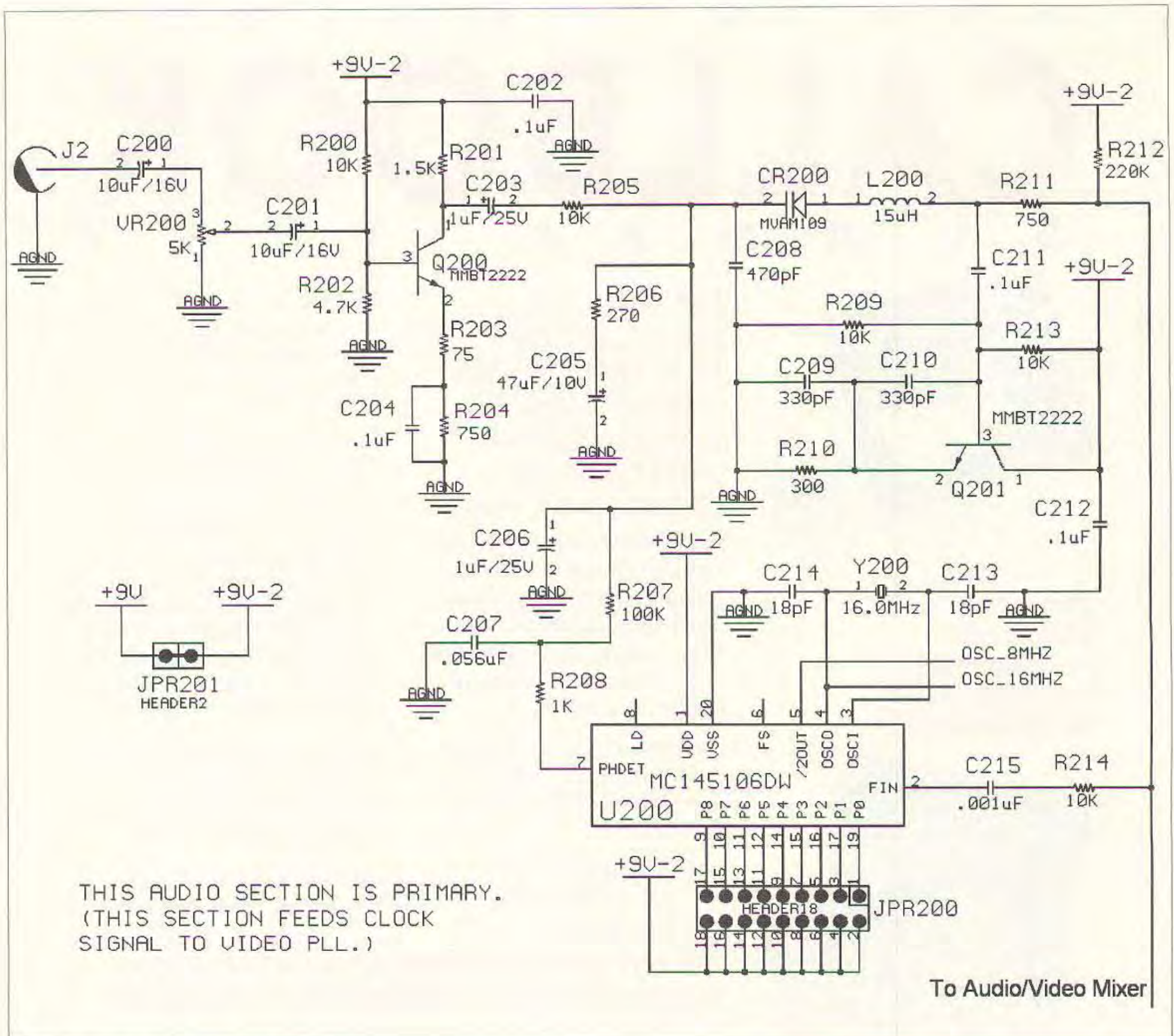


Fig. 3. Second audio subcarrier.

needed was a small inductor—a short piece of wire—to set the general oscillation frequency. The downside? It cost \$25 each in quantities of 25 or more.

Charlie board

The most obvious problem with the prior boards had been the inability to

create reliable quantities of VCOs. The second problem was inherent in the SP5070: a fixed prescaler divide ratio with a PLL using a set divide and comparison ratio. What all that jargon means is that I could have only as many frequencies as I could find crystals to create them. This meant one or two frequencies using readily available crystals; any other frequencies would be special-order, big-bucks crystals. The third problem was finding a good audio design with parts that could actually be purchased in *reasonable* quantities.

The entire process seemed to be a guided evolution. I just didn't know who was doing the guiding. I'd been searching for something but didn't know what I was looking for.

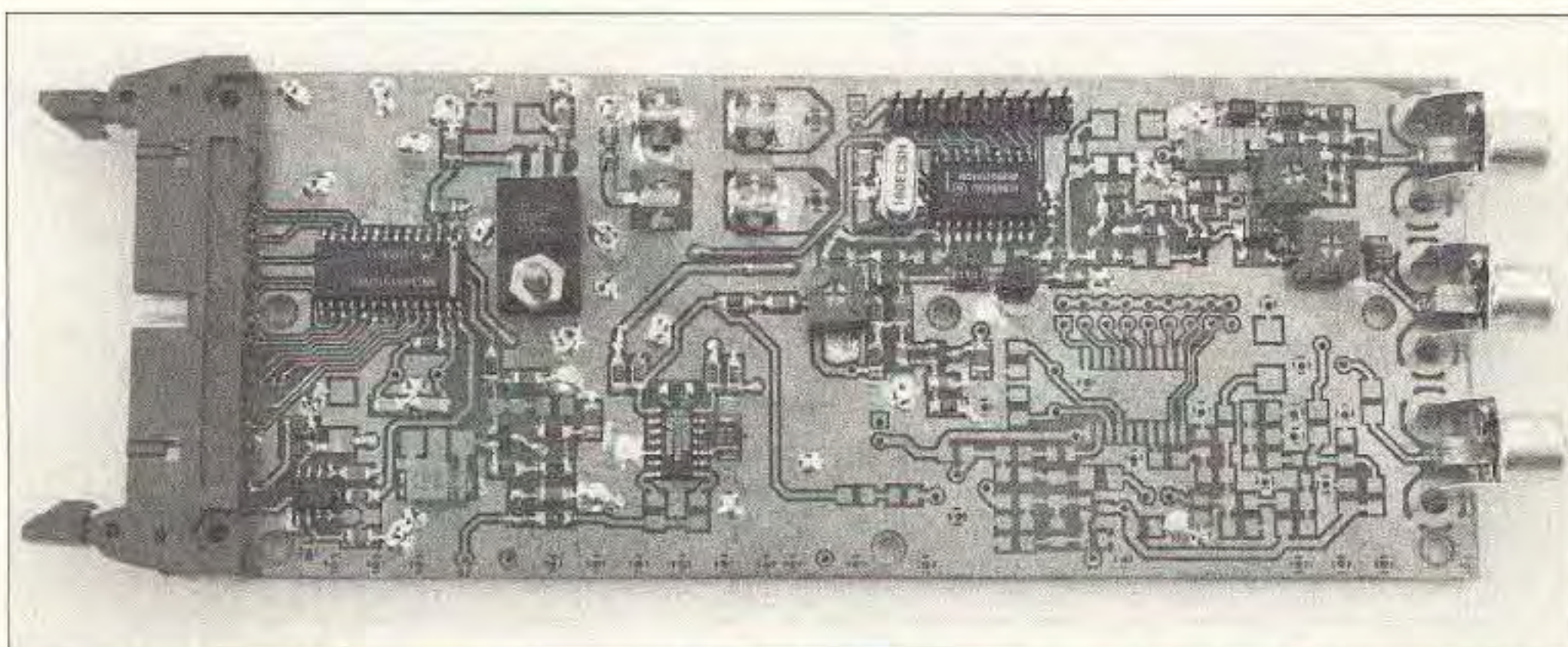


Photo B. Audio/video section of completed Delta transmitter (only one audio section used).

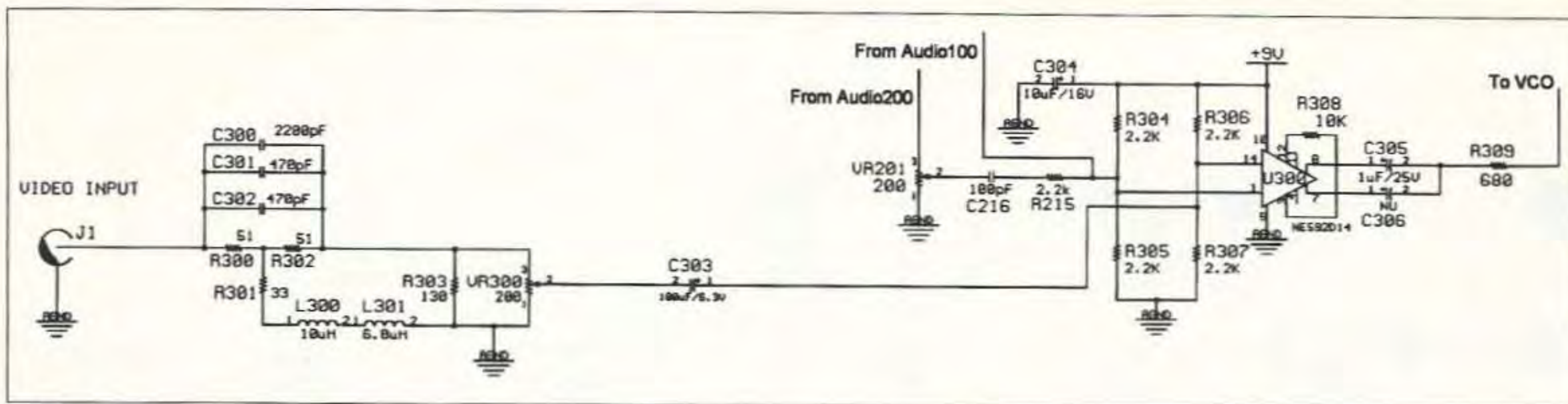


Fig. 4. Mixer.

Another HATS member gave me a copy of a magazine, and inside was a small ad: VCOs for under \$10. I figured I had nothing to lose and gave them a call. Yes, they would sell smaller quantities, but the price was higher than the TriQuint part. These nice folks offered to match TriQuint's price to be "designed in." My VCO creation problems were over.

I was working on another project at my *real* job, which required me to look in a data book I had never paid much attention to. This wonderful book was the *Motorola CMOS Special Applications Handbook*. Inside were more PLLs than I had found in the previous two years. What made it especially nice were two parallel programmable PLLs. This meant I would not need a microcontroller to run an I2C bus or serial interface to the PLL. I could use a DIP switch. I would no longer have a one-chip solution; it would take

two chips—but I gained hundreds of frequency selections.

The problem with the audio design was not so much its design as the parts I was trying to use. Although the varactor diode was a "preferred part" it also had a 20+ week lead time in minimum quantities of 5,000. Would you believe the part I needed was one page back from the part I couldn't get? It wasn't much bigger, cost half as much, was in stock for immediate shipment, and I could buy it in quantities of one. Yes, *one*.

Gee, wouldn't it be nice if someone else did all the bleeding for you? Well, how about burnt fingers and a couple square feet of mangled copperclad? Forthwith and hereafter, I present a design which shall be known as "Delta," containing the bits and pieces of knowledge I have gained/lost over the past three years in pursuit of a design for an ATV transmitter.

Frequency Range	860–1300 MHz, 2300–2500 MHz (Use only in authorized frequencies)
Channel selection steps	.25 MHz, 1 MHz
Output power	50 mW–2.5 W(+)
Video input level	1V p-p into 75 ohms
Video pre-emphasis	CCIR 405-1
Video modulation	Direct FM (up to 20 MHz bandwidth)
Audio input level	1V p-p into 5k ohm
Audio modulation	Direct FM (subcarrier(s) summed with video)
Audio subcarrier frequency	4–6.2 MHz
Audio step size	10–31.25 kHz (dependent on crystal selection)
Input connectors (3)	RCA
Output connector (1)	SMA
Input voltage	10.5–15 VDC

Table 1. Specifications.

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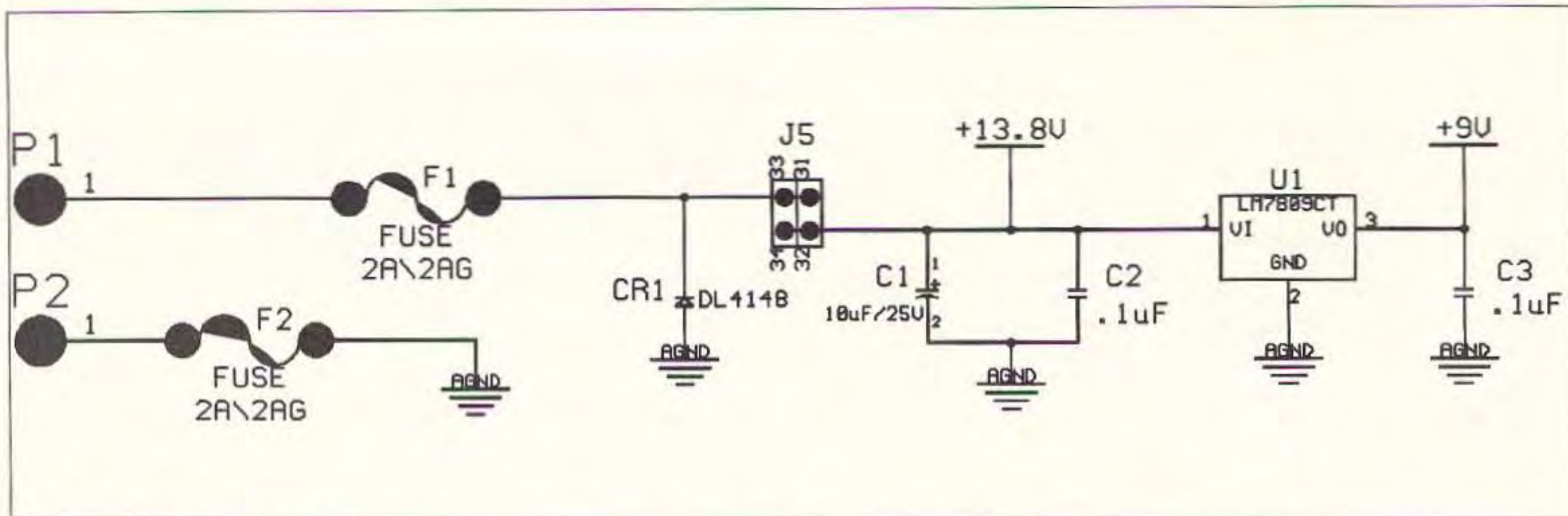


Fig. 5. Power input section.

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Delta board

Some new features:

- Two audio channels with separate PLLs (stereo, or mono and one control frequency) and use of one, two, or three crystals for oscillation reference
- Board can separate into three modules—audio/video control, video, and amplifier module (high power: 2.5 W or low power: 50 mW)—for R/C and portacam use
- Uses a smaller, cheaper VCO with more available frequencies
- You get 900 MHz, 1.2 GHz, and 2.4 GHz with same board design

- Replacement of DIP switch (the contacts bounced in RC aircraft), power switch, and lock indicator with header strip allowing quick frequency changes using pre-made “keys” (uses 34-pin header, floppy disk cable)

- Unused audio sections can be powered down for power conservation

Don't be scared by the schematic. The way printed-circuit software works is that if you want an option it has to be on the schematic. There are lots of options here! The nice thing about this board is that you only need to stuff parts in the sections you want to use. The component numbers are broken up into

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Photo C. Can I touch it? Am I holding it just right? Daughter Meredith holds ready-to-go Delta—just add power.

functional groups: the 100s and 200s are the two audio subcarriers; the 300s are the two audio subcarriers; the 300s are the video amp section; the 400s are the main PLL and its circuits; the 500s are the VCO and buffer amp; and the 600s are the high-power amplifier for 1.2 GHz or the low-power amplifier for 900, 1200, and 2400 MHz.

The sections that will always be used are: the power input section (fuses and voltage regulator); the video amp section (NTSC pre-emphasis, combines video with audio channels); the main PLL with prescaler; and the VCO with buffer amp and pads. It wouldn't be ATV if it didn't have the video stuff. For those of you who want sound with your video the two audio channels can create stereo, or mono and a control frequency, or just mono.

The schematic as written is specifically for 1.2 GHz operation due to the frequency limitations of U600 (1240-1300 MHz). The VCO (U500) can operate from 860-1300 MHz. By using U601 (500-2500 MHz) in place of U600, you now have a dual-band transmitter with an output of 50 mW. The VCO and prescaler can be exchanged for other devices in the same size (parts list has device numbers) and will then transmit in the 2.4 GHz band with a 50 mW output. Additional amplifiers can be added outside of this assembly to allow as much power as the owner can afford.

What do you want to do?

After you have created/bought the printed circuit board the next step is to determine what you want the board to do and purchase parts accordingly. Will it be a base station transmitter? A portable camera with a link transmitter? Used in an R/C model? What frequency(s) do you want to use? Do you need one audio channel? Stereo? Two selectable mono audio channels set to different frequencies? How much output power is required? All of the above? Better make another board, or perhaps two.

Assembly

The air core inductor (L500) is made from #26 AWG magnet wire wrapped ten times around a form (piece of bare #12 AWG solid copper wire). Wrap the wire around the form in a tight single layer. Remove from the form, and, using a hobby knife blade (an X-ACTO™ #10 works for me), spread the windings apart by the thickness of the knife blade. Do this gently: you don't want to nick the wire or your fingers. One pass on each side of the coil will spread the wire uniformly. Remove insulation (carefully scrape with knife blade or use insulation solvent) for approximately one-half inch close to coil ends. Trim and form leads to fit pads on circuit board.

Remove some of the material from around the outside row of pins on connector J5. This will allow more room for the solder iron tip and make inspection easier. After soldering in J5, use an ohmmeter to check continuity between each pin and its destination. Also check for shorts between adjacent pins and to ground. The jumper headers can also be trimmed to ease soldering. Insert the headers and tack them in place from the bottom of the board. Carefully trim the plastic from the outside edges of the header until the component side pad is visible. Finish soldering the header in place. All through-hole parts should be installed first, and checked for shorts and continuity.

If you are using a commercially-made board, assembly is easiest if you solder the parts from smallest to largest, with the through-hole parts assembled last. If you have made your own board and did not do plated-through holes (they are beyond the capabilities of most hobbyists) you will want to do all of the through-hole parts first and then the surface-mount ones. Surface-mount parts have all of their electrical connections on one layer—the layer you can see. Through-hole parts connecting to traces on the bottom are easily inspected, but the traces on top are difficult to solder without leaving some space under the part, to

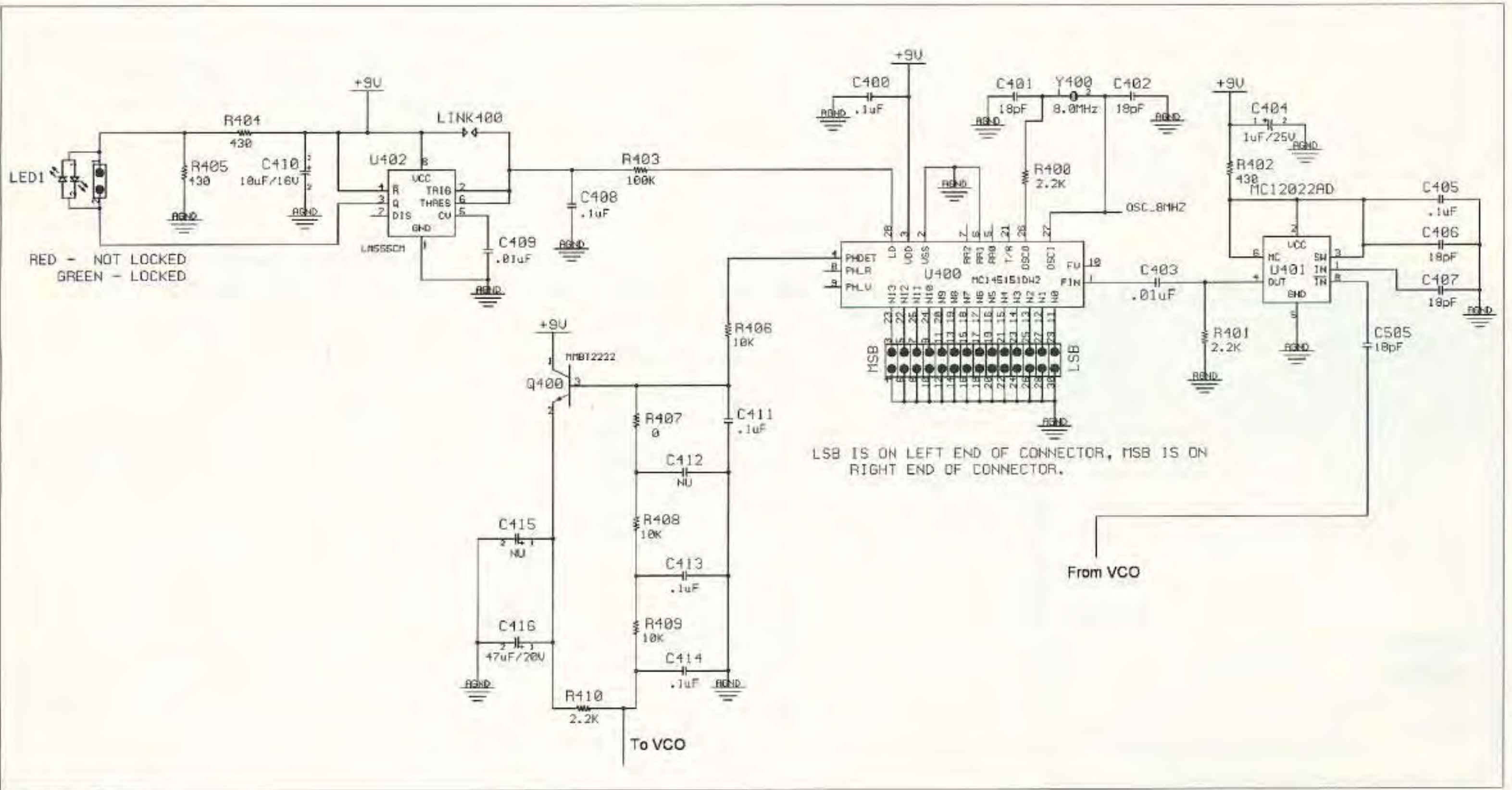
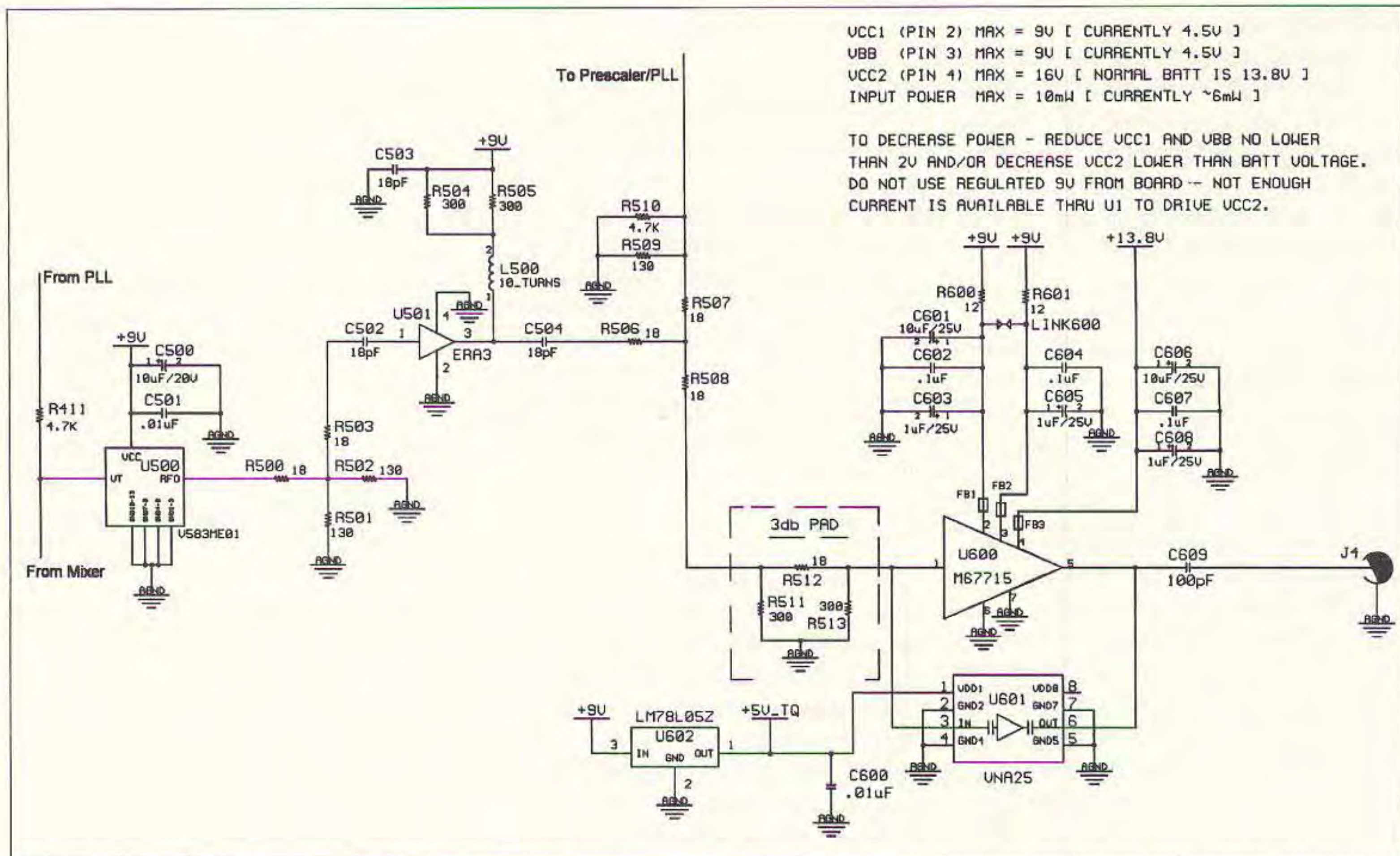


Fig. 6. Main PLL.



UCC1 (PIN 2) MAX = 9V [CURRENTLY 4.5V]
 UBB (PIN 3) MAX = 9V [CURRENTLY 4.5V]
 UCC2 (PIN 4) MAX = 16V [NORMAL BATT IS 13.8V]
 INPUT POWER MAX = 10mW [CURRENTLY ~6mW]

TO DECREASE POWER - REDUCE UCC1 AND UBB NO LOWER THAN 2V AND/OR DECREASE UCC2 LOWER THAN BATT VOLTAGE. DO NOT USE REGULATED 9V FROM BOARD -- NOT ENOUGH CURRENT IS AVAILABLE THRU U1 TO DRIVE UCC2.

Fig. 7. High- and low-power amp. VCC1 (pin 2) max = 9 V (currently +4.5 V). VBB (pin 3) max = same. VCC2 (pin 4) max = 16 V (normal battery is 13.8 V). Input power max = 10 mW (currently ~6 mW). To decrease power, reduce VCC1 and VBB no lower than 2 V and/or decrease VCC2 lower than battery voltage. Do not use regulated 9 V from board—there is not enough current available through U1 to drive VCC2.

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heat the lead and the pad. It also helps if you install the parts with larger quantities first. This makes it easier to tell where the single parts go because there are fewer places to look.

If you're making the high-power version, do not install U600 until the board has been tested and all functions are working. It's much easier and safer to test small signals than large signals.

Why three crystals?

The board needs one crystal to operate in standard mode. A 16 MHz crystal at Y200 provides reference frequencies to both audio oscillators, and using the /2 output of the audio PLL provides the 8 MHz reference for the video PLL. The board artwork connects Y100 and Y200 together and provides the /2 signal from U200 to the video section. By having the option of three crystals, I can separate the crystals from each other by removing a section of the trace connecting the two audio PLL crystal inputs together and have the video using an 8 MHz crystal (250 kHz steps at 1.2 GHz, 1 MHz steps at

2.4 GHz), one audio channel using 16 MHz (31.25 kHz steps), and the other audio using 10.24 MHz (10 kHz steps—but maximum frequency is 5.12 MHz). Any crystal can be used in the audio channels, provided the divide ratios work out to a whole number with no remainder, or the PLL will oscillate and be unable to lock.

Divide ratios of PLLs

Formulas for the MC145106:
 PLL reference frequency:
 (ref. crystal input freq.)(divide by 2)(divide by 2e9 or 2e10)
 Oscillator frequency:
 (oscillator output freq.)(divide by N)
 with N being the binary inputs P0 to P8.

EXAMPLE:

16 MHz crystal installed, 5.25 MHz oscillator output frequency desired.
 16 MHz input divided by 2 = 8 MHz.
 8 MHz divided by 512 (2e9) = 15.625 kHz.
 15.625 kHz, or 0.015625 MHz, is our step frequency.



Photo D. Portable system configuration used during this year's March of Dimes Walkathon. Note Delta board to left of TV, above rear wheel.

5.25 MHz divided by (N) must = 15.625 kHz or 0.015625 MHz.

Therefore 5.25 MHz divided by 0.015625 MHz = 336.

$$336 = 256 + 64 + 16.$$

Inputs P8, P6, and P4 should be connected to the positive voltage supply. All of the P0-P8 pins have internal pull-down resistors and are at ground potential and inactive unless connected to the positive supply. Each audio section is independently powered, allowing unused sections to be turned off.

Formulas for the MC145151

PLL reference frequency:

(ref. crystal input freq.)(divide by reference address divide ratio value) = phase detect frequency

The reference divide ratio is set by connecting RA0-RA2 to ground per the manufacturer's table. The artwork sets this ratio at 2048. Other ratios would require "cuts and jumps" to connect the appropriate pins to analog ground (AGND).

Oscillator frequency

(oscillator output freq.)(divide by prescaler ratio)(divide by N)

with N being the binary inputs N0 to N13.

The prescaler ratio is set to 64 by artwork connections to VCC on pins 3 and 6. This ratio will allow 0.25 MHz steps on the 900 MHz and 1.2 GHz bands. For usage on the 2.4 GHz band, a different prescaler chip (MC12032A) should be used and pin 6 connected to VCC giving a divide ratio of 128.

EXAMPLE:

8 MHz crystal installed, reference address divide ratio of 2048 is used. Prescaler divide ratio is set at 64. 1280 MHz oscillator output frequency desired.

8 MHz input divided by 2048 = 0.00390625 MHz.

0.00390625 MHz is our phase detect frequency.

1280 MHz divided by (64) = 20 MHz.

Then 20 MHz is divided by 0.00390625 MHz = 5120.

$$5120 = 4096 + 1024.$$

Inputs N12 and N10 should be connected to AGND. This is the opposite of the MC145106! The MC145151 has its input pins and reference address pins pulled up by internal resistors and are at positive voltage potential and inactive unless connected to ground. I guess these chips were done by two different groups—one group that preferred pull-down and the other group preferring pull-up. I have designed the artwork where a closed connection indicates the selection of that pin on the PLL to its active state. For those of you familiar with logic levels this will drive you nuts. Please remember the two PLL chips are opposite if you must use a voltmeter to troubleshoot your frequency keys.

Applying power

Do *not* power up the transmitter without connecting an antenna or dummy load to the output. This is a good practice to get into, even if the board would not be damaged. Antennas should be pointed away from organic life. Exposure to high-frequency energy can cause permanent damage, especially to eyes.

The board should be tested prior to installation of the high-power amplifier. The 50 mW section can be tested along with the rest of the board if your test equipment can survive the 50 mW as an input.

Connect board to power supply and verify correct voltages are being seen at all areas of the circuit. Check for hot parts: Under proper operation everything should be cool to the touch except the regulator (warm after 30 minutes) and the power amplifier (slowly warm to very warm after 30 minutes).

Troubleshooting

Most of the problems you'll encounter in building this board will be bad solder joints. The first thing to do is determine which section of the board is not functioning properly; make sure the power is turned off, and check all the solder joints in the section, touching up the joints that look suspicious. Reapply power and check to see if the section is now working. If power to that section is incorrect or the main regulator has the correct voltage on the "IN" side and no output there is a solder bridge somewhere on the board. Look for solder joints that have slopped onto their neighbors' pads or onto the power traces or ground planes.

Transmitter adjustments and alignments

Frequencies for video and audio are set by program keys and should be checked, the first time, anyway, to verify that you have understood the programming sequence. This is easily done using a spectrum analyzer with no video or audio inputs applied to the board, or a frequency counter can be used if it can be set to "peak detect" the signal. Audio frequencies can also be checked using an oscilloscope.

Video input level (VR300)

This potentiometer (pot) sets the deviation (the width) of the video signal. It should be adjusted with no signals applied to the audio inputs and VR101/VR201 set to minimum. Using a calibrated receiver (a receiver with known ATV characteristics and settings) the video input level should be set such that the video received is in color with no "bloom" (too much signal), or is not "dingy" (not enough signal). A spectrum analyzer will verify the total deviation at approximately 8 MHz. The *ARRL Radio Handbook* has suggestions on how to set video deviation.

Video mix level (VR101, VR201)

Subcarriers are a tradeoff. They rob power from the carrier—the video—to support their life. The adjustment of VR101/VR201 creates the balance between these two signals. Using a calibrated receiver, adjust until sound is heard clearly with no video damage. Play around; see what too much audio does to the video (tearing, lines of white dots), or not enough audio (I can't hear you, but you look great). Adjust the first subcarrier (the one closest to the carrier and lowest in frequency) first. If you are using the second subcarrier (most applications won't but it's there for stereo or controls) set it according to your receiver specifications for second subcarriers. Verify that the video signal remains good and audio is clear. The first subcarrier should be set approximately 10 dB down from the peak of the video signal and the second subcarrier approximately 10 dB down from the first subcarrier (this is a very good time to have a spectrum analyzer to visualize

the relationship between signals). Bessel null calculations for subcarrier power levels and deviation in relation to carriers can also be used to determine empirically the best settings for each subcarrier.

Audio input levels (VR100, VR200)

The deviation of the audio signal should be set by (once again) using a calibrated receiver. This control with a normal 1V p-p signal will be set "wide open." For audio levels above 1V p-p, such as an amplified microphone, this control should be adjusted to bring the signal back to 1V p-p. "Hot" audio sources will cause the video to "tear" due to over-deviation of the audio signal.

Author's note: Boards, parts kits, and "mostly assembled" kits should be available by the time this article is published. Information on pricing and availability will be posted on the HATS Web page at [<http://www.stevens.com/hats>]. E-mail inquiries can be sent to [

Photo E. T-shirt and hat collection from activities supported by HATS since 1994. Not shown is shirt from 1994 Tenneco Marathon—it wore out.

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