10 GHz Qualcomm Modifications Notes

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Introduction

During the past three (3) years over 50 sets of Qualcomm transmit and receive boards have been returned here in the northeast area for use on the 10.368 GHz amateur radio band. Ken, W1RIL, undertook much of the original work in this area. This work has been documented previously in the NEWS (Northeast Weak Signal) Group newsletters and in several of the ARRL conference proceedings. I retuned a series (approximately 20) of these boards for distribution by Bruce, N2LUV. Many of the procedures and unique tidbits gleaned from this conversion process are presented herein. The hope of this labor of love is to disseminate more modules for use here on the east coast in order to increase 10 GHz activity. Bruce, N2LUV has written several articles that integrate the power amplifier (PA) and Low Noise Amplifier (LNA) modules with a local oscillator (LO) and mixer/filter into a complete 10 GHz transceiver package. (Ref 4)

Discussion

Surplus transmit and receive boards, made available through WB6IGP and N6IZW, have helped fuel the explosion of interest by amateurs in the 10GHz band. A few years ago, the average station ran power levels of 100 milliwatts or less. Today, these modified Qualcomm units make the 1-watt level practical for most of us. We are finding that this power level allows for fairly routine contacts over 300 km (200 mi) or so, often via paths that are difficult even at 144 MHz. The excitement of DX-ing through tropo or rain scatter can best be shared by a multitude of active stations on 10 GHz. Reliable and inexpensive equipment are bringing this about.

It is my hope that you want to become part of the amateur development of a band that is proving to be one our most exciting. Think of the possibilities for our future (the Mars Pathfinder mission uses frequencies near 10 GHz.) We must justify our retention of coveted microwave bands by undertaking meaningful activities.

The following details result from tuning up Qualcomm units for 10 GHz operators in the northeast. You may not feel comfortable undertaking such a project or may not have the time. If so, completed transmit power amplifier and receiver pre-amplifier modules are available through Bruce, N2LIV. A 10 GHz transverter will require the addition of a local oscillator, image filter, IF radio, relay, and sequencing. “Brick” LOs are becoming scarce. I am working on a simple, reproducible LO multiplier chain to replace the “Brick.” Stay tuned for details.

Power Amplifier Board

The procedures presented below follow the order in which your conversion process should most likely occur in order to result in a successful re-tuning.

1. Read the articles by WB6IGP/N6IZW, W1RIL, N2LIV, and KB3XG/N3AOG (ref 1-4).

2. File or mill the heat sinks to remove the sharp edges and to provide a flat surface for mounting the SMA input and output connectors. Making you own heat sink is not recommended. It must have sidewalls and a cover to prevent feedback. The slightest gaps or discontinuities may result in low output or stability problems. Be sure that there are no broken screws in the heat sink.

3. I’ve had success with both flange mounted SMA connectors (2 or 4 hole variety) and single threaded hole SMA types (#4-36 tap.) The former are easier to use if the Teflon center insulators are long enough to completely pass through the heat sink housing in order for the Teflon to be trimmed flush with the flat surface. It is important that there be no major discontinuity between the connector and the circuit board. At this frequency, a slight air-gap could change a 50-Ohm interface into a tuning nightmare. The input connector holes will have to be located and drilled (measure the Teflon insulator to find the exact size for a tight fit) as shown in Figure 1. The original output connector hole in this case may need enlarging to mount the SMA connector

4. Mount the PA circuit board onto the clean heat sink using the hardware supplied. First, remove some of the ground plan conductor from around the input connector hole on the board so that the connector doesn’t short circuit this is a mistake I made only once!) Be careful, as Teflon boards are soft. Remove the conductor by hand with a small (1/8” or so) drill bit. Tighten the screws after they are all in place. Note that the power FETs do not need thermal conducting paste where they contact the heat sink.

5. Be sure that the power supply module is working and delivers –5.0V at all times, +10.0V on receive and _+10.0V on TRANSMIT (only when the key-line is grounded. The voltages are adjustable with the potentiometers on the board. Note that the three power regulators (Q12, Q13, Q14) will get hot during transmit and should be heat sinked. Their tabs are at the same potential and may be bolted to a common strap of aluminum or copper heat sink (¾” x ¾” solid bar stock) but this must be insulated from ground since they are at B+ voltage.

6. Reliable connections between the PA and power supply modules are imperative. Solder a separate ground wire between both boards (no clip leads here!) For convenience, lengthen the yellow (-5.0V) and red (+10.0V) wires and use the original white power connector if supplied. I have replaced these wires with 12”

long #22 Teflon coated wires and also added a long brown (or green) wire for the relative output indicator, bundling all in thin sleeves made of heat shrink tubing.

7. DC test the five FET stages on the PA board. Be sure that there is nearly –5V on each FET gate (use a high impedance digital multimeter and be careful not to short anything out!) before applying the +10V (i.e., don't ground the key line yet.) Lack of –5V may be due to a shorted trace or chip capacitor or an open to one of the FET gates.

8. If step 7 is OK, ground the key line. Measure the drain voltages of each of the five FETs. Q1 (MGF1302) should be approximately _32V, Q2 (MGFK30) approximately +3.4V and Q3 (MGFK25), Q4, and Q5 (MGFK30) each approximately +8.0V or +8.1V. Check the gate voltages. These will vary considerably with individual devices and will automatically adjust so that each FET will conduct its design value current by means of a PNP transistor feedback circuit. My measurements of thirteen (13) PA modules indicate that the gate voltages may range from –0.2V to –1.0V for Q1 or Q2 and from –0.7V to –2.0V for Q3, Q4, or Q5. (More negative values indicate higher conductance transistors that may give "hotter" performance, but I haven't verified that this is true!) Again, be careful when measuring voltages not to short any board traces putting a (+) voltage onto a gate will most likely blow a FET! If you do not obtain the voltages as noted above, repair the defective stage(s) before proceeding. You can provide the full –5V to a FET's gate by disconnecting one end of the yellow wire that passes over the FET. This will disconnect the collector of the PNP bias regulator. The FET will then be biased to cut-off and its drain should reach +10V during transmit. I have encountered a unit where the –5V did not reach the Q4 gate because of a nearly invisible break in the narrow ¼ wavelength board trace. The FET conducted enough current to smoke the 8.2-Ohm chip resistor in the drain lead but, fortunately, did not blow the FET!

9. If you are satisfied with the DC performance as noted above, prepare the PA board as per Figure 2. Be sure that the SMA center conductors do not project much above the PC board. I have seen nearly 0.5dB radiation loss for a 1/16" projection of the output connector above the board. One unit (with a home made heat sink) suffered all sorts of instability which was further aggravated by a couple of screws projecting ¼" into the cavity. These little ¼ wavelength monopoles were radiating energy from the output to the input! Such problems are prevented by careful attention at the beginning of the project and as it progresses. The 1 to 2 pf chip capacitors added near the input connector is for blocking Q1's gate voltage. It should be a high quality 0.05" ceramic (ATC or equivalent) chip capacitor unless you are willing to sacrifice overall gain.

10. Remove some of the copper from the un-energized PA board, as per figure 3, with an Exacto knife and soldering iron. I recommend adding a long Teflon insulated wire from the soldering iron (using 2 screw mounted solder lugs) to the PA boards. This is to prevent damaging the gate of one of those expensive FETS

from even the slightest current (I haven't blown one yet!) Leave this wire in place during any subsequent soldering on the board. Be careful to prevent even the tiniest piece of removed copper foil from shorting out traces or lodging between a transistor and the recessed heat sink (you may go crazy trying to solve this one!)

11. Connect the PA and power supply modules through suitable attenuators to a 10GHz power meter or spectrum analyzer and a stable drive source of approximately –10dBm. The drive should have an attenuator or an isolator to help minimize any SWR problems. Remember that you will be adding tiny pieces of copper-foil ("snowflakes") in order to increase the PA gain from initially nearly zilch to possibly over 40dB so your power indicator must be able to cope. If you have never attempted "snow-flaking" at 10GHz, it may be advisable to first practice at a lower frequency such as 1296 MHz or 2304 MHz (WA1MBA considers these "DC Bands" and K2RIW suitable IF frequencies"), where adjustments are less critical.

12. A PA with added "snowflakes" is depicted in figure 4. Units will vary somewhat. You may determine where to add a flake by probing the microstrip with a tuning tool consisting of a small (0.05") square (flake) of copper foil glued to a squared off toothpick unless you are lucky enough to have a set of tuning sticks. Different sized squares may be tried to optimize the flake size for proper tuning. Each time a snowflake is moved or permanently soldered, you must disconnect all power from the PA module. Don't forget to ground that soldering iron! The entire procedure will try your patience. Getting the first 20dB or so of gain is easy but achieving the last few dB, along with 1-watt output, can be tedious. Tuning for maximum gain with low drive will probably result in one of the power stages saturating before the 1 watt level is reached, so additional tuning may be needed (and a little gain sacrificed) after increasing the drive level. Most improvement here will occur between Q5 and the output connector. Some devices may not deliver more than 900mW (that's only 0.5dB down!) The single most influential gain adjustment is the long stub between Q2 and Q3. Careful trimming will increase overall gain 10 to 15 dB. The touchiest adjustments seem to be near the drains of the power FETS. Here, a copper "snowflake" only 0.02" square affects the output.
    Typical completed units deliver +29.5dBm (0.9 Watts) to +31 dBm (1.2 Watts) with drive requirements from –4dBm (0.03mW) to –14dBm (30 microWatts.) Gain thus ranges from +33.5dB to +45dB. It must be mentioned that a modified module is quite narrowband (which may help with filtering.) A Unit optimized for 10.368 GHz CW/SSB had to be retuned somewhat for use with a Gunnplexer at 10.250 GHz. Adding very small flakes near the drains of Q3, Q4, and Q5 doubled the power output at the lower frequency.

13. Stability can be a problem, especially with higher gain units. Over 40dB of gain in an enclosure is a lot to ask for. Adding the cover is necessary, but will probably affect both the gain and output. KB3XG substituted lossy G-10

fiberglass board for the original cover. I found that the supplied metal cover could be used if pieces of the loss rubber absorber are rearranged. Clean off the old adhesive. I used a “Glue Stick” to attach the rubber to the metal. Centering the pieces in line with the FETs gives the best results as shown in figure 5. Use four pieces. One or two extra pieces may be added near the input or output to tame a particularly stubborn module. This absorbent rubber is presumably ¼ wavelength thick at 14 GHz. And thus is not quite optimum for 10 GHz use. It appears to come in two styles: The bumpy surface type seems slightly less effective in squelching oscillations than the smooth surface type. Thus, if you have a choice and are tuning up several transmitter modules, use the smooth finish rubber on your highest gain units. The secured cover may increase or decrease the overall gain, but not more than a couple of dB, if all goes well. Output power should be nearly 1 Watt.

One or two extra pieces may be added near the input or output to tame a particularly stubborn module. For use in a transverter, the module input should be connected to an isolator or resistive attenuator to minimize instability caused by the preceding filter or mixer.

14. I have encountered transmitter boards with Part Numbers PK-3086-06, PK-3086-07, PK-3086-08, and PK-3086-09. The –08 and –09 versions have a large 15 Ohm (marked “150”) chip resistor in parallel with 2 smaller 51 Ohm (marked “510”) chip resistors in the Q3 (MGFK25) drain circuit. The –06 and some –07 versions lack the 51-Ohm resistor. Adding a 51 Ohm, 1/8 Watt chip to these earlier units will increase the drain current of Q3 (the gate will become slightly less negative to compensate), thereby allowing Q3 to saturate at a higher level and slightly improving the overall power output. Don’t expect to gain more than a fraction of a dB, but every little bit helps. You may notice that a –06 board does not have bypass chip capacitors at the decoupling stubs near the gates of Q4 and Q5. I have not found this to be a problem.

15. An external relative output meter will prove very useful. Watching the pointer swing on SSB or CW allows you to adjust IF drive levels and helps to verify that you are indeed transmitting when the other station claims not to hear you! This is particularly true for a remote controlled 10 GHz units. Use a 1mA or more sensitive meter movement with a series resistor of several hundred or more ohms. The relative output voltage is positive. The meter should have a negative ground return. I select series resistors so that the meter reads about ¾full scale with full carrier output and the PA board’s potentiometer (near the relative output detector) set to mid range.

Pre-Amplifier (LNA) Board

1. Read the preceding power amplifier section first—This LNA amplifier modification will be easier—you should modify the pre-amplifier before the PA, if you are uncomfortable with 10 GHz "snow-flaking" techniques.

2. File or mill the heat sink to remove sharp edges and allow a flat surface for the connectors. Be sure that there are no broken screws in the heat sink. The pre-amplifier board may be mounted on a homemade heat sink since the transistors do not need milled recesses. However, shielded sidewalls are recommended.

3. As with the power amplifier, RF connections may be either the flange mounted SMA types (2 or 4 hole,) or single threaded hole SMA types (#4-36 tap.) The former, with long Teflon center insulators, are easier to use. The Teflon must be trimmed flush with the flat metal surface to minimize air gap discontinuities between the connector and the circuit board. The output connector hole (s) ill have to be located and drilled (measure Teflon diameter for a tight fit,) as shown in figure 1. The input-connector hold may need enlarging. It is possible to locate the output connector so that the etched band pass filter is incorporated. I have successfully retuned a filter to 10.368 GHz by extending the traces with small copper snowflakes. However, tuning is very critical and the filter will not reject image or LO signals as well as a good external filter, particularly if you are using a 144 MHz IF. Therefore, you may as well completely remove the etched filter.

4. Mount the pre-amplifier circuit board onto the clean heat sink using the supplied hardware. But first, remove some of the ground plane conductor from around the output connector hole on the board to prevent a short circuit. Remove the conductor by hand with a small (1/8" or so) drill bit but be careful with the soft Teflon board dielectric. Tighten the mounting screws after they are all in place.

5. Be sure that the power supply module is working as in Step 5 of the Power Amplifier section.

6. Reliable connections between the pre-amplifier and the power supply modules are imperative. Solder a separate ground wire between both boards. I replaced the yellow (-5.0V) and red (+10.0V) wires with a 12" length of #22 Teflon insulated wire, and bundled these along with the ground wire in thin sleeves of heat shrink tubing. Use the white connector, once again, if supplied.

7. DC test the three (3) FET stages on the board (do not ground the power supply transmit key line). Measure the drain voltages. Q1 (FX-05) should be approximately +1.8V or +1.9V, whereas Q2 (FX-35) and Q3 (FX-35) should be approximately +2.8V or +2.9V. Check the gate voltages. These will vary considerably with individual devices and will automatically adjust so that each FET will conduct its design value current by means of a PNP transistor feedback

circuit. My measurements of fourteen pre-amplifier modules indicated Q1, and from –0.23V to –0.8V for Q2 Q3. (More negative values indicated higher conductance transistors but I haven't verified any correlation with pre-amplifier performance.) Repair any defective stages(s). I have encountered problems with corroded board traces and broken bias transistors or chip capacitors. Test the transmit function by grounding the power supply key line. The Q1, Q2, Q3 gates should go to nearly –5V and all three drains to zero (0) volts.

8. If you are satisfied with the DC performance as above, prepare the pre-amplifier board as per Figure 7. Be sure that the SMA center conductors do not project more than 1/32" or so above the board. The 1 or 2pF chip capacitor added near the input connector is for blocking Q1's gate voltage. It affects noise figure and should be a high quality 0.05" ceramic (ATC or equivalent.) The added output chip capacitors (not needed if you retain the etched band pass filter) are less critical. A cheap chip cap here will have no measurable effect on noise figure, and losing a few tenths of a dB gain may be insignificant if the unit has an excess of gain.

9. Remove copper form the un-energized pre-amplifier board as per W1RIL's diagram with an Exacto knife and a small soldering iron. As for the power amplifier, it is important to ground the soldering iron with a long insulated wire soldered to the board. Working on the board is made difficult by the shields around each FET stage. Be careful to prevent tiny pieces of removed copper foil from "hiding" on the board and causing potential shorts.

10. Connect the pre-amplifier and power supply modules (through suitable attenuators to a 10 GHz power meter or spectrum analyzer) and to a stable drive source of approximately –30dB (1 microwatt.) Do not over-drive the unit—the output stage will saturate at a few milli-watts of output, which renders tuning a fruitless exercise. The "snowflake" procedure will be less tedious than for the PA module, and thus, should be attempted first. At least you will have read about it.

11. A pre-amplifier with added 'snowflakes" is depicted in W1RIL's diagram. Units will vary somewhat. Use a procedure similar to that described in step 12 of the Power Amplifier section. Typical completed units have a gain, which ranges from +27dB to +34dB. Measured noise figures varied from 1.87dB to 2.8ddB with an average around 2.2dB. I have not attempted to optimize NF due to the lack of test equipment. It should be possible to achieve a 1.5 dB NF with careful tuning of Q1 (Dave Robinson, G4FRE/W5, achieved this level after several hours of careful tuning on a NF meter). The pre-amplifier is unlikely to self oscillate, and is considerably more broad banded than a modified PA module.

12. Adding the cover may affect the gain—typically a reduction of 1.2dB. Add small absorbent rubber pieces to the cover over each RF cavity, including the input and output connector cavities (four in all.) The rubber may be removed from the areas of the cover where they are not needed. Be sure to secure the cover with all the

bent tabs on the shielding (some may have corroded.) A moving cover will cause unstable gain and noise figure variations.

13. If desired, the pre-amplifier may be preceded by a really low noise pre-amplifier. Insert a 10GHz isolator between the two units. You will probably end up with "gain to burn," but this may be sacrificed in an attenuator, power splitter, filter, or long feed line between the pre-amplifier output and mixer. This versatility allows remote control of your Qualcomm modules, or elimination of 10Ghz relay switching by leaving the filter and mixer connected to the PA input and pre-amplifier output at all times through a power splitter (See reference 4.)

What's Next?

Considerable interest in the Qualcomm PA and LNA boards and 10GHz in general continues to exist and is growing in the northeast region [of the United States.] Many stations are upgrading 200mW stations with often just mixer front ends to these state-of-the-art modules. I will continue to modify these boards and Bruce, N2LIV, will distribute them as long as an economical supply of the raw boards exist and the demand is present.

We will be exploring the possibility of replacing the one (1) watt output K30 devices with a two (2) watt K33 device in an attempt to develop a self contained 2 watt amplifier module. Ken, R1RIL has developed a stand-alone two (2) watt amplifier board, which can be easily driven by the one (1) watt (approximately 640mW) board. If we can integrate the two (2) watt device directly onto the one (1) watt Qualcomm PA module, it will make for a more compact and concise package—not to say much less expensive.

We would like to thank Chuck Houghton and Kerry Banke for their work in making these raw boards available for development and activity.

References

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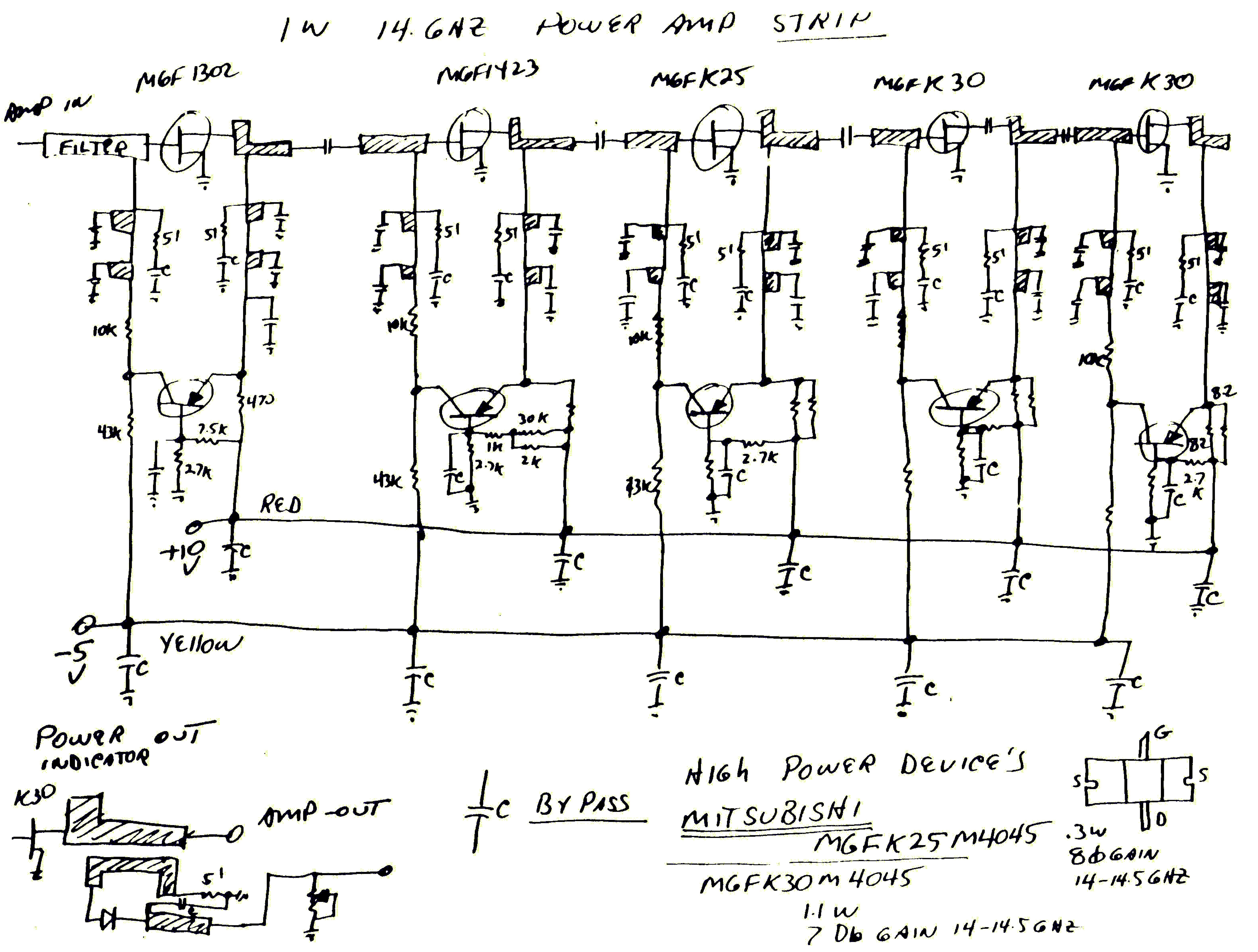
2. Ken Schofield, W1RIL, "Suggestions for Modifications of Qualcomm LNA Board for 10 GHz", Proceedings of the 21st Eastern VHF/UHF Conference, August 1995, p.65.
3. Ken Schofield, W1RIL, "Modification update of Qualcomm Omnitrack PA Board for 10GHz", Proceedings of the 21st Eastern VHF/UHF Conference, August 1995 p.65.
4. Bruce Wood, N2LIV, "Up, Up & Away to 10GHz Semi-Commercial Style", Proceedings of the 20th Eastern VHF/UHF Conference, August 1994, p.133.



1W 14.6GHZ POWER AMP STRIP
MGF1302
MGF1423
MGFK25
MGFK30
MGFK30
AMP IN
FILTER
51
C
10K
43K
470
7.5K
2.7K
30K
1K
2K
82
2.7K
RED
+10 V
-5 V
YELLOW
POWER OUT INDICATOR
K30
AMP-OUT
C BYPASS
High Power Device's
MITSUBISHI
MGFK25M4045
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G
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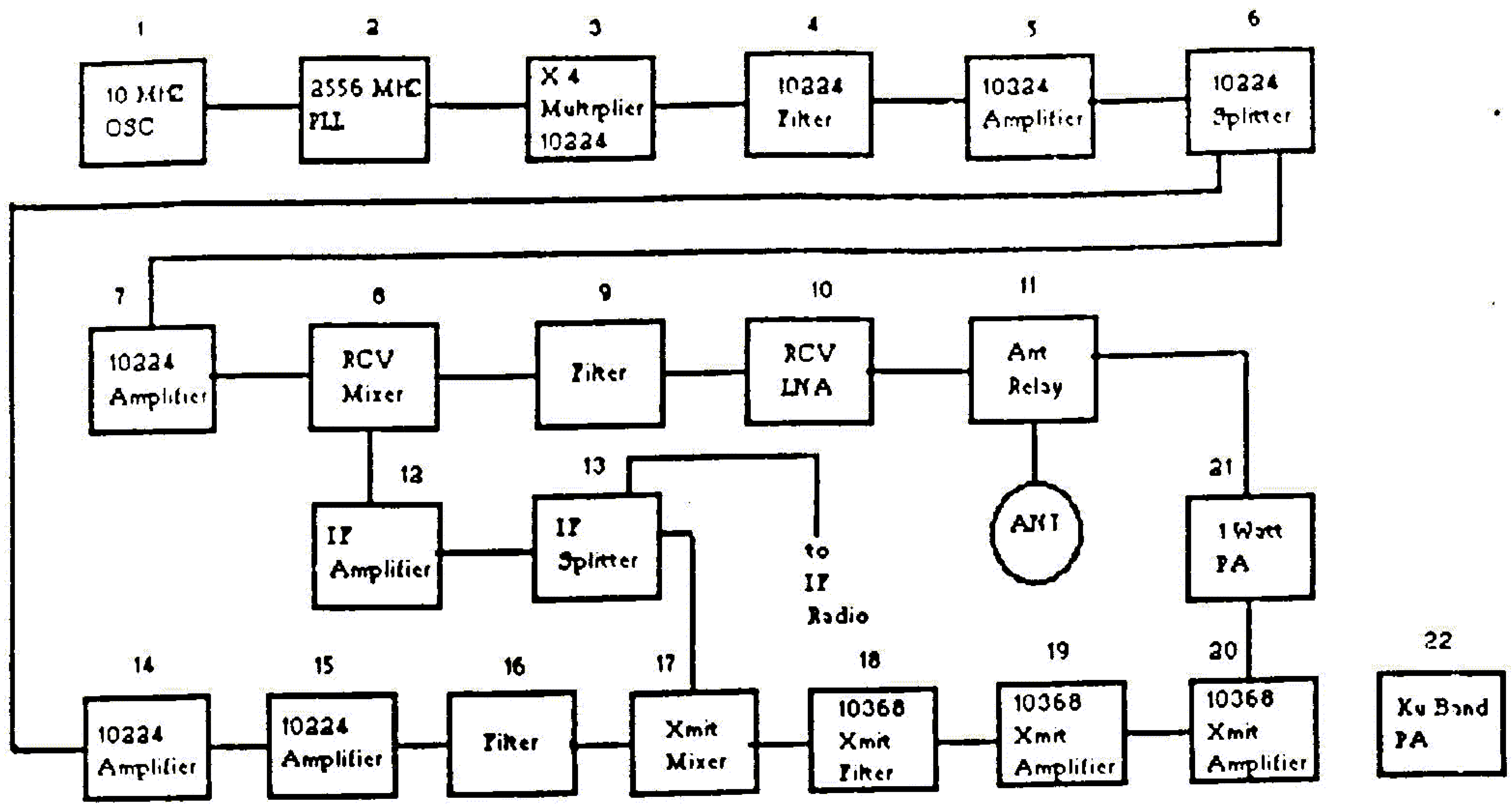
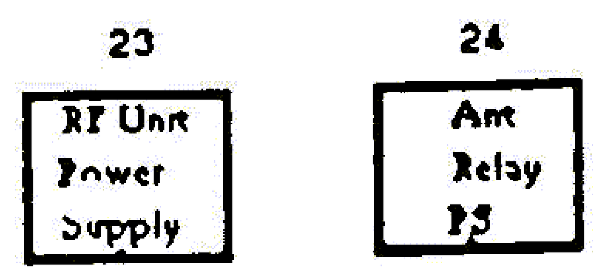
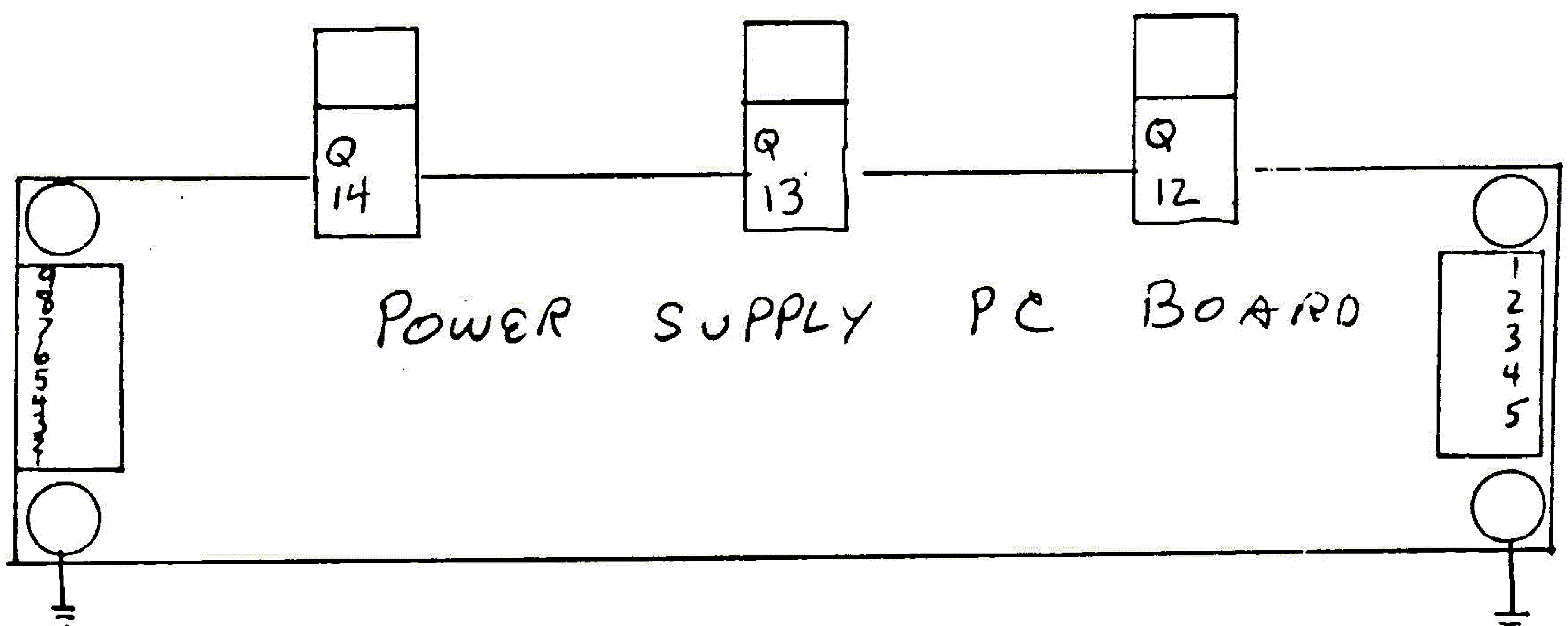




NOTE: POWER SYNTH FROM ADDED EXTERNAL 7810 REGULATOR FROM MAIN +12 to 14V INPUT



9 KEY CONTROL (GND TO TRANSMIT) ← COMMON → 4 KEY CONTROL
8 + 12V IN
7, 6 +10 (200 MA MAX) B4 ← COMMON → 1 +10 (200 MA MAX)
5, 4, 3 +10 RECEIVE (SWITCHED) B2
2, 1 -5V BIAS ← COMMON → 5 -5V BIAS B1

2, 3 +10 TRANSMIT (SWITCHED) B3

B1 -5V BIAS 5 MA MAX (KEYED OFF when KEY CONTROL = GND)
B2 +10 100 MA (KEYED ON when KEY CONTROL = GND)
B3 +10 XMTR-AMP'S (" OFF " " " = OPEN)
B4 +10 200 MA CONTINOUS (MAX 200-300 MA)