AN-739
Application Note
(Formerly CER-113)

A SYNTHETIC SPECTRUM TUNING SYSTEM FOR TV

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A tuning system is described on the following pages which uses a complete spectrum of TV channel markers to achieve precise tuning to any channel.

MOTOROLA Semiconductor Products Inc.

INTRODUCTION

The synthetic spectrum tuning system was built by Motorola Applications Engineering to investigate the problems and feasibility of such an approach. The main objective was to anticipate meeting the future FCC tuning rules for VHF and UHF and to have a direct readout for each of the UHF stations. Other objectives were to get around the present methods of switching preset tuning voltages which must be calibrated for each tuner, and for each available station.

THEORY OF OPERATION

Figure 1 shows a block diagram of the system. Let's consider that the system is already on some channel and we want to select channel-83. An 83 is set on the station selector and the select button is depressed. The tuner flip-flop goes to the select mode state and switches the VHF and UHF tuner inputs from the air signal to the synthetic spectrum generator output. The varactor tuning voltage line is discharged to near zero and the VHF tuner is set to low band position. The tuner AGC line is disconnected from the set and a preset AGC is applied. The AFT is disabled. A positive going ramp is applied to the tuner varactor voltage line, which tunes the VHF tuner up through low band. As the tuner is tuned to each of the synthetic stations, a negative-going pulse appears at the detector output of the limiting IF, which is shaped, and then counted, by the divide by "N" counter. The tuner band switch will automatically advance to high band and to UHF when the varactor tuning voltage line reaches approximately 30 volts, and the tuning voltage will successively "ramp" each band.

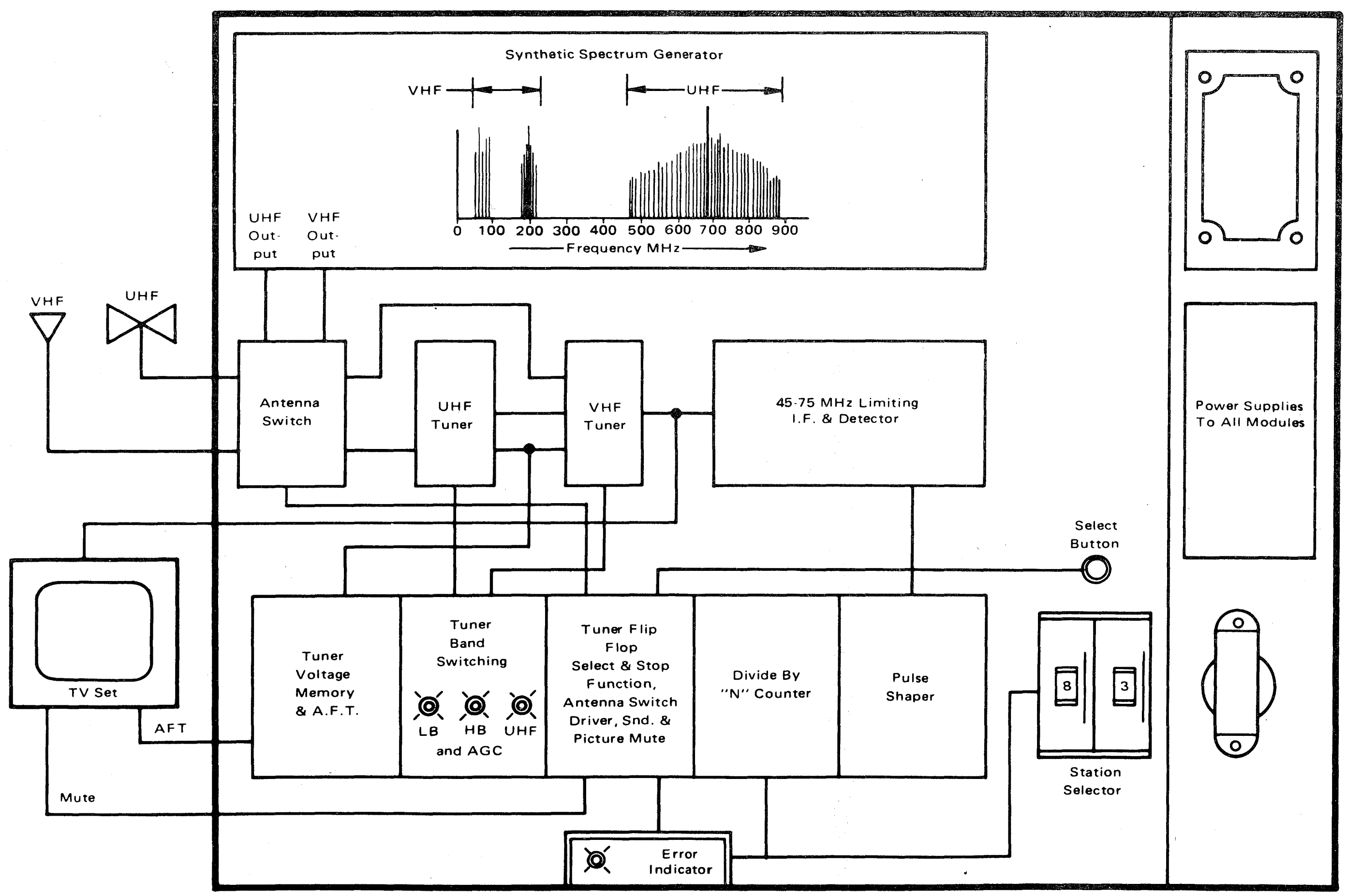


FIGURE 1 — Synthetic Spectrum System Block Diagram

When 83 pulses have been counted by the divide by "N" counter it will reset and the tuner flip-flop will return to the stop position.

The tuner voltage memory will hold the ramp at the voltage required to reach the 83rd count and the antenna switch will switch the tuners back to the air signal. The tuner AGC line is then reconnected to the TV set and the AFT is enabled.

SYSTEM OPERATION

Antenna Switch – The VHF and UHF antenna switch circuits are shown on Figure 2. With the air signal at the VHF antenna switch output, transistors Q2, Q5, Q7, Q8, and Q10 will be biased on and Q1, Q3, Q4, Q6, and Q9 will be biased off. For the VHF synthetic spectrum signal to appear at the output, the above transistors are reverse biased. The isolation in the "off" position for either half of the VHF switch is greater than 85 dB across the whole VHF band and the insertion loss is less than 1 dB. The UHF antenna switch operates in the same manner as the VHF, but contains one more stage per switch half. It was found that by keeping the signal shunt transistors Q11, Q12, Q13, and Q14 near the edge of saturation, the "off" position isolation at frequencies above 800 MHz was vastly improved.

Frequency MHz	Insertion Loss dB	Isolation dB
450	2	72
600	3	70
750	4	62
800	6	59
850	6	56
900	8	52

For the above results, the series transistors must have metal case shields and the shunt transistors must have extremely short leads.

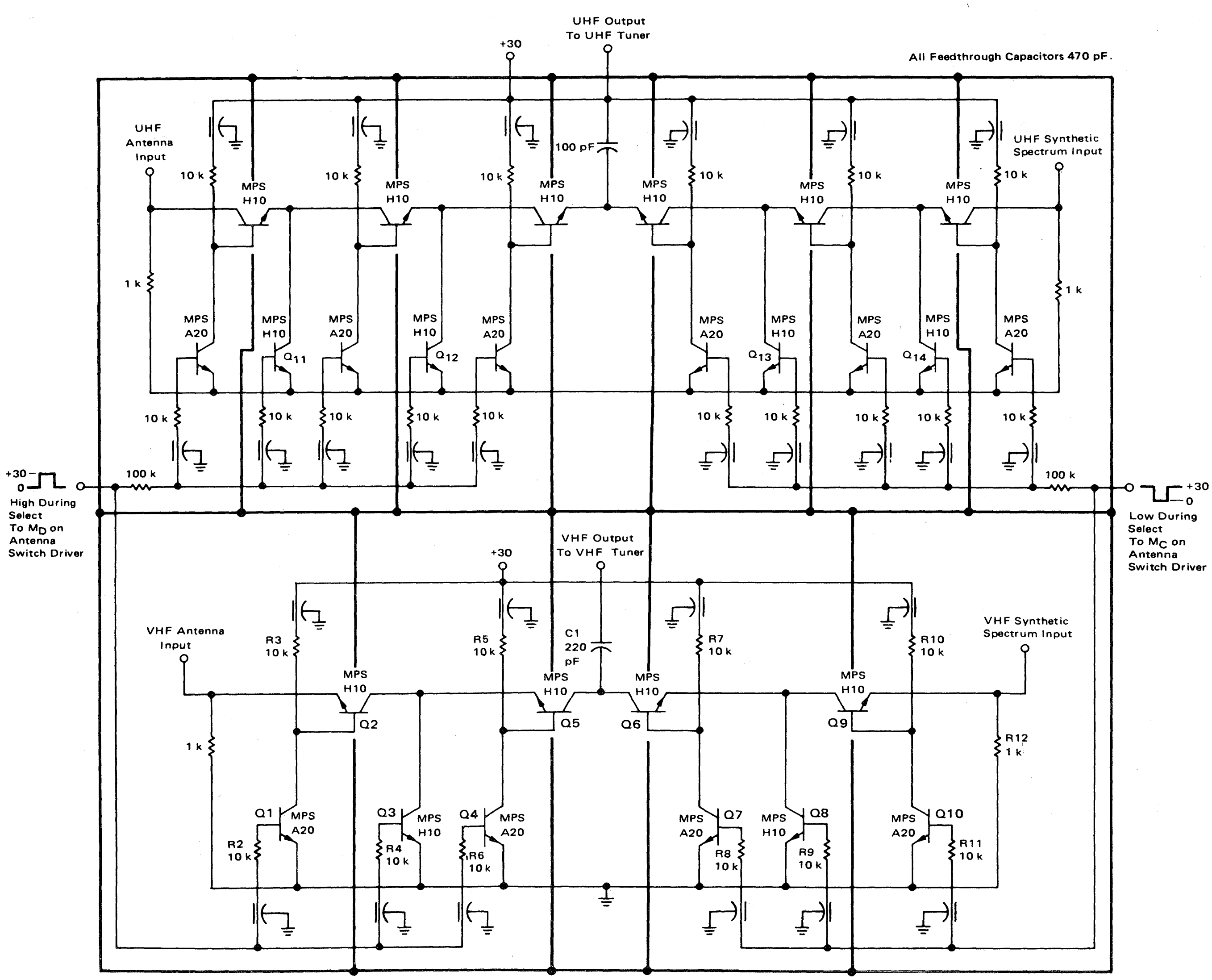


FIGURE 2 – Synthetic Spectrum Antenna Switches

Spectrum Synthesis – The synthetic spectrum generator block diagram and circuit are shown on Figures 3 and 4. The generator produces all of the VHF and UHF channels simultaneously and on frequency. A 6 MHz crystal controlled oscillator, and saturated mode amplifier are used to produce the odd and even harmonics of 6 MHz which extend beyond 1 GHz. The output of the first filter block contains 35 harmonics of 6 MHz which are mixed with a 681.25 MHz (channel 49) carrier to produce the whole UHF band. The carrier is generated from a 136.25 MHz crystal controlled oscillator coupled to a high gain 5th harmonic amplifier. A 681.25 MHz tuned line trap is used at the UHF mixer output to bring the carrier level down to that of the generated side bands. Excessive 6 MHz side bands will be generated at the mixer output if the level of the harmonics applied to the input are too high. This will necessitate more output traps for the undesired side bands. The network formed by L1, C1, and R1 is used to compensate for the lower conversion efficiency at higher frequencies of the mixer diode. It will roll-off the low frequencies and peak the high frequencies, which will help keep the levels of the side bands constant across the whole UHF band without any holes in the response pattern.

To generate the high band VHF channels, the 35 harmonics of 6 MHz out of the first block of filters are filtered down again to 3 harmonics of 6 MHz or 6, 12, and 18 MHz output. These are mixed with a 193.25 MHz (channel 10) carrier, producing channels 7, 8, 9, 10, 11, 12, and 13. The mixer output is trapped at 6 MHz below channel 7 and 6 MHz above channel 13. This reduces the undesired sidebands to 60 dB below the center carrier. The 193.25 MHz carrier is trapped enough so as to bring it down to the level of its sidebands.

Low band VHF is a product of mixing a 6 MHz sine wave with a 61.25 MHz (channel 3) carrier producing channels 2, 3 and 4. The mixer output is trapped 6 MHz below channel 2 and 6 MHz above channel 4.

Channel 5 and 6 are generated by separate common collector L-C oscillators because of the extra 4 MHz gap between 4 and 5. Second harmonic traps of carrier frequencies can be avoided by biasing the low band circuit transistors in the area where f_T is less than 150 MHz.

Logic Modules – The functions of each of the logic modules shown on Figure 5 will be discussed in general because the circuit design used is straight forward.

The select and stop function is a set-reset flip-flop composed of Q8 and Q9. In the station select position, Q9 is on; Q8 is off. SCR1 is used with the select switch to provide a clean pulse to put the flip-flop in the select position. A small delay is provided by C2 so that the VHF tuner gets into low band before the tuner varactor line starts to ramp. Capacitor C3 is used to set the flip-flop in the select mode when the power is turned on. Transistors Q7 and Q16 are used to preset a count of one in the divide by "N" counter after the select button has been depressed. This in effect produces a pseudo channel 1 so that the channel selector will read out the true channel numbers since there is no channel 1 generated by the spectrum generator.

The tuner voltage memory consists of a 1 μF mylar capacitor, charged and discharged through a neon lamp,

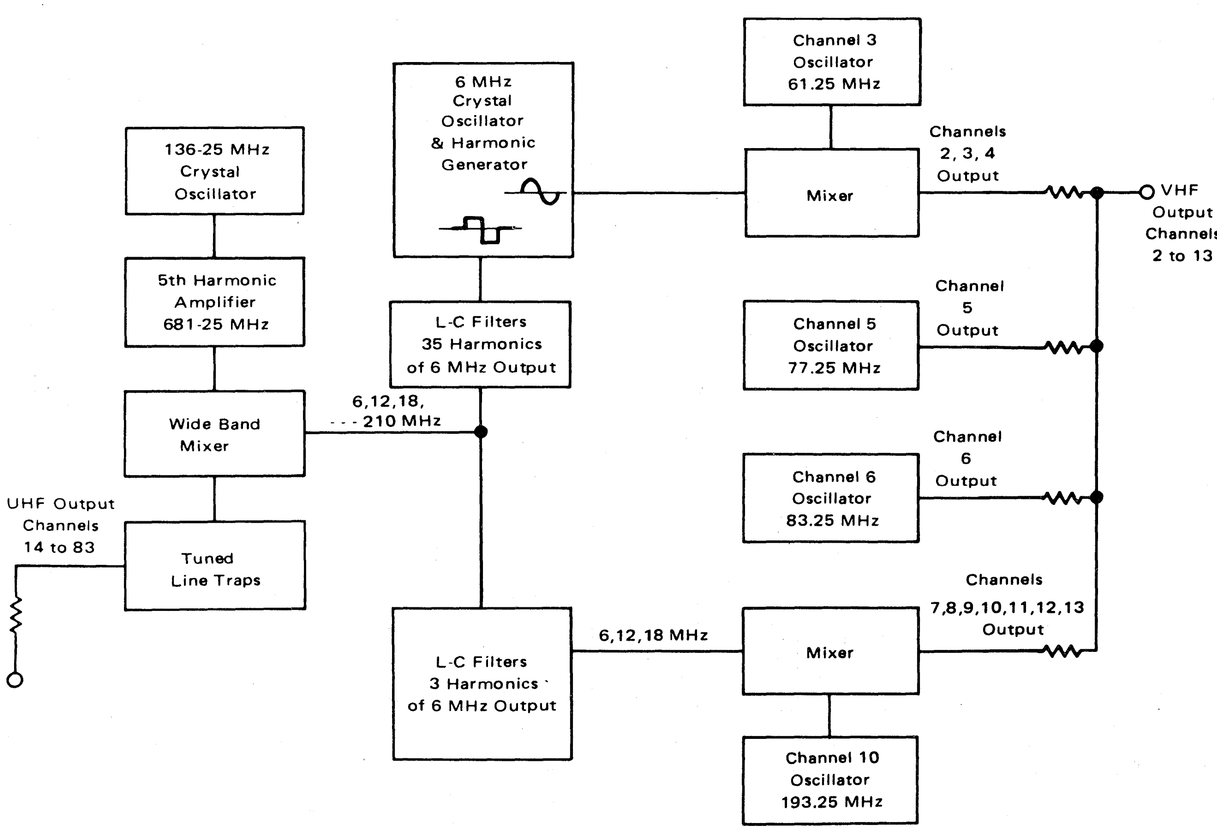


FIGURE 3 – Synthetic Spectrum Generator Block Diagram

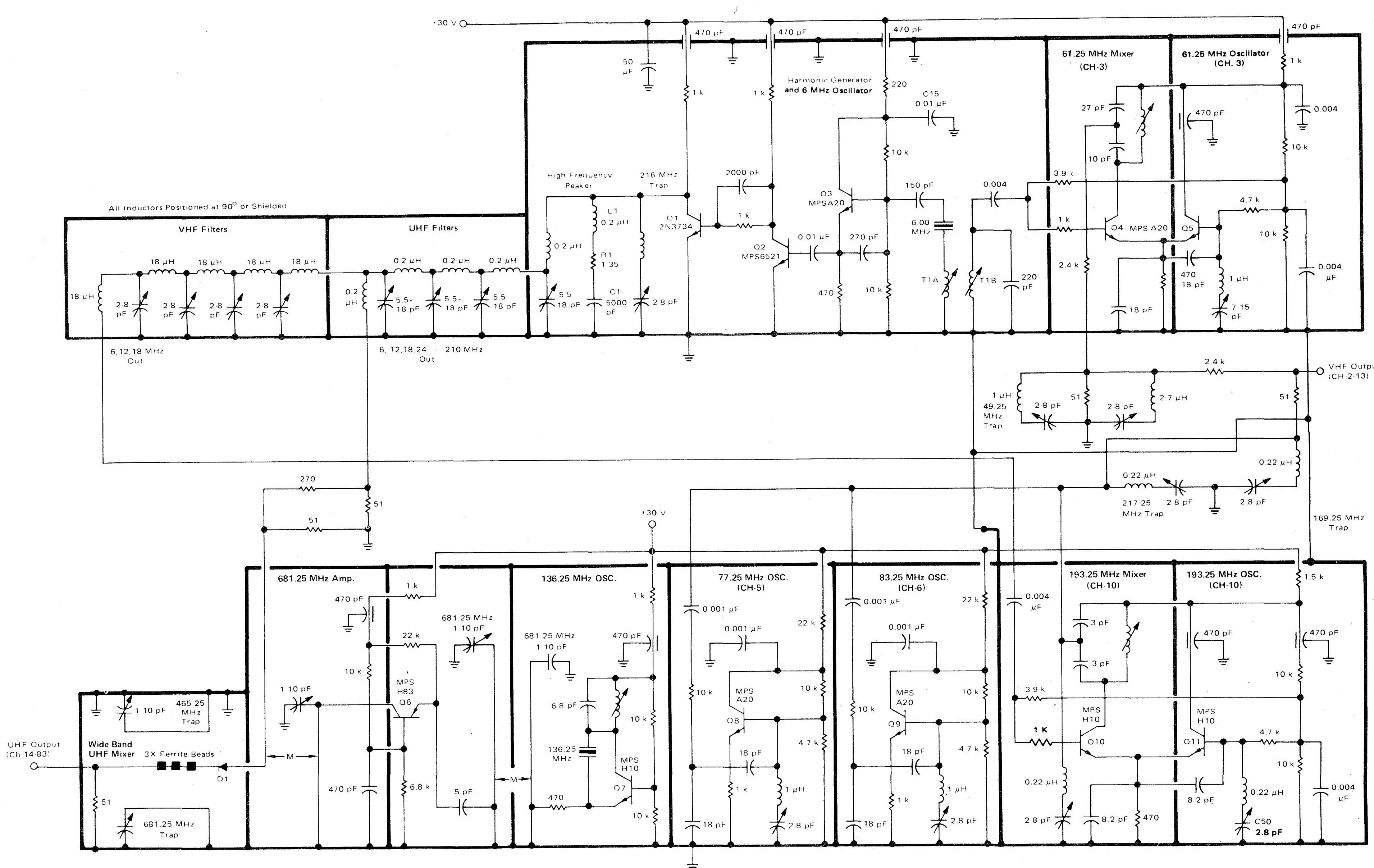


FIGURE 4 – Synthetic Spectrum Generator Channels 2 through 83

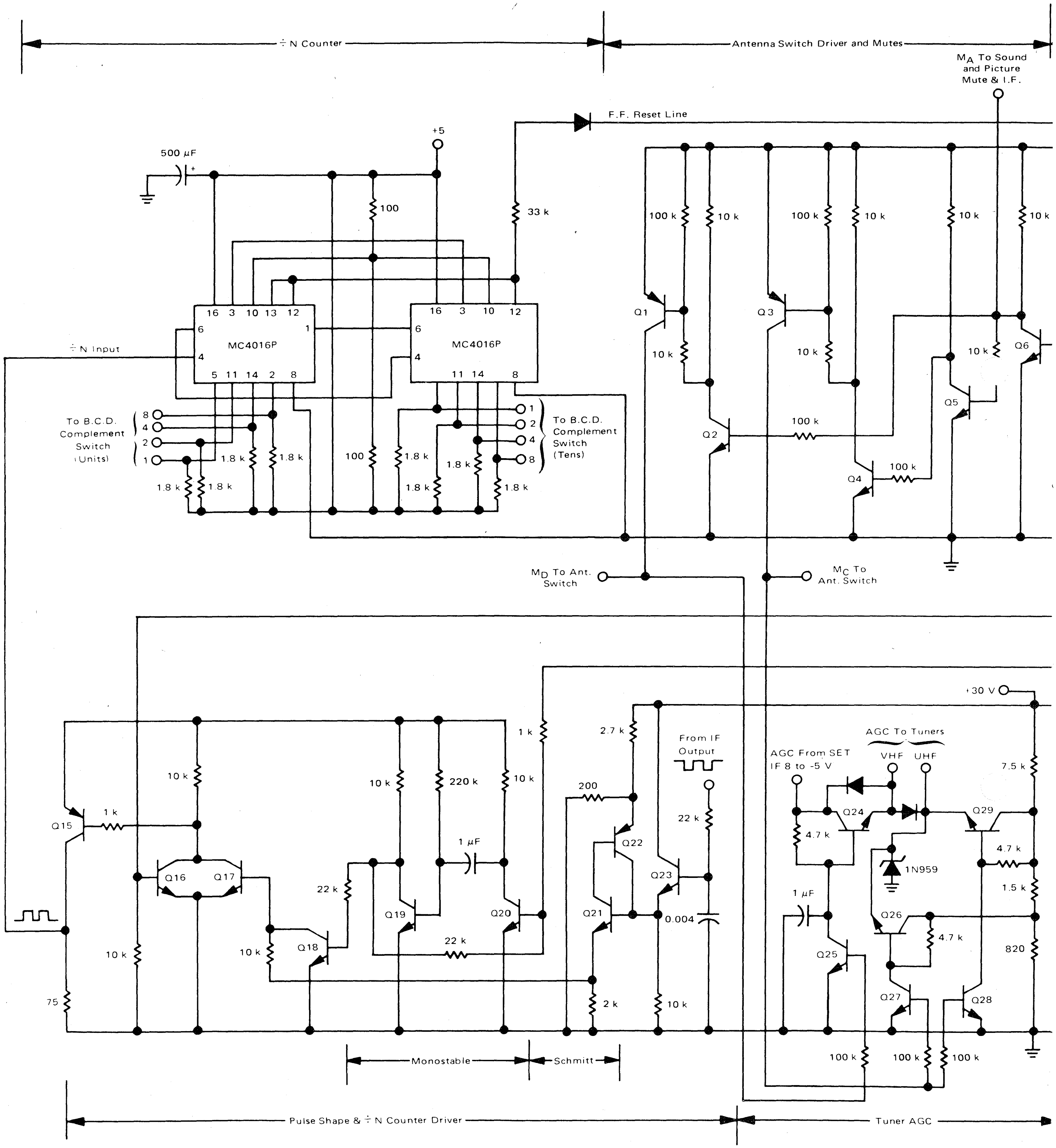
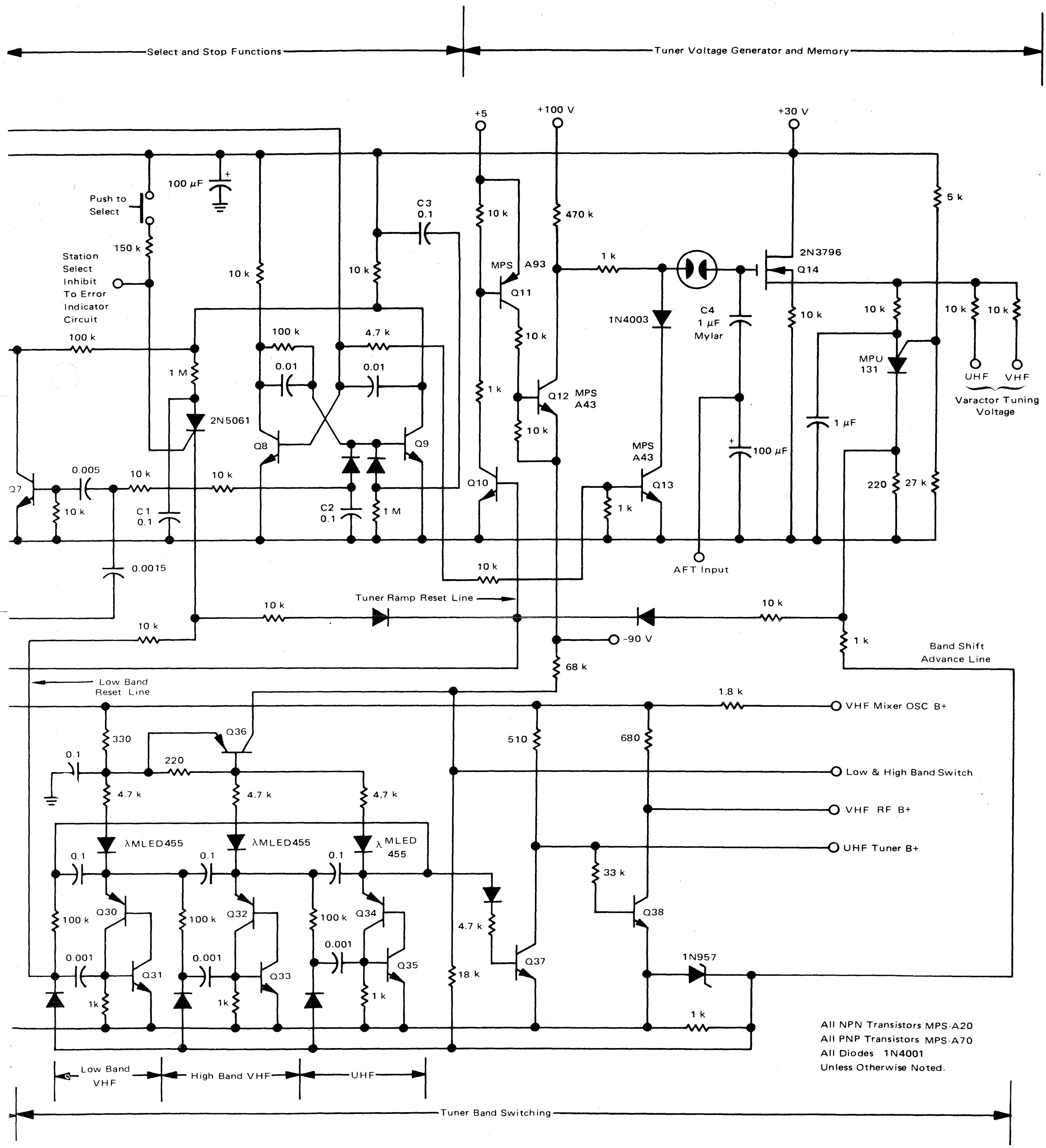


FIGURE 5 – SYNTHETIC SP


Select and Stop Functions
Tuner Voltage Generator and Memory
+5
+100 V
+30 V
100 µF
Push to Select
150 k
Station Select Inhibit To Error Indicator Circuit
10 k
C3 0.1
10 k
470 k
MPS A93
Q11
1 k
2N3796
Q14
5 k
100 k
1 M
2N5061
4.7 k
0.01
0.01
10 k
1N4003
C4 1 µF Mylar
10 k
10 k
10 k
MPU 131
UHF VHF
Varactor Tuning Voltage
Q12 MPS A43
1 k
Q8
Q9
10 k
1 µF
MPS A43
100 µF
Q7
0.005
10 k
10 k
Q10
Q13
220
27 k
10 k
C1 0.1
C2 0.1
1 M
1 k
0.0015
10 k
AFT Input
Tuner Ramp Reset Line
10 k
10 k
-90 V
1 k
Band Shift Advance Line
68 k
Low Band Reset Line
1.8 k
VHF Mixer OSC B+
Q36
330
510
680
0.1
220
Low & High Band Switch
4.7 k
4.7 k
4.7 k
VHF RF B+
λMLED455
λMLED455
λ MLED 455
UHF Tuner B+
0.1
0.1
0.1
33 k
Q30
Q32
Q34
Q38
100 k
100 k
100 k
4.7 k
0.001
0.001
0.001
Q31
Q33
Q35
18 k
Q37
1N957
1k
1k
1 k
1 k
All NPN Transistors MPS-A20
All PNP Transistors MPS-A70
All Diodes 1N4001
Unless Otherwise Noted.
Low Band VHF
High Band VHF
UHF
Tuner Band Switching

and a source-follower MOSFET. The neon lamp provides an extremely high impedance to the MOSFET when in the off-state. The MPU131 programmable unijunction transistor provides a band-shift advance and ramp-reset pulse when the tuning voltage line reaches 29 volts.

The tuner band switch circuit contains a band position memory using Q30 through Q35, and the proper tuner voltage drives for each band. The three light emitting diodes are used only for a visual display of band position, and are optional.

A preset VHF and UHF-AGC bias is used during station selection. The voltage range is fairly wide, but the extremes can cause poor IF limiting on weak synthetic channels or severe overload on the strong channels. Both conditions will cause a miscount in the divide by "N" counter. The television set AGC is reconnected by Q24 when the flip-flop is reset in the stop mode.

The detected pulses from the limiting IF are filtered and buffered by Q23. The buffered pulses are fed into a Schmitt trigger Q21 and Q22 to strip off undesired noise which appears as the tuners are tuned into and out of synthetic channels. Transistors Q15 and Q17 form a pulse driver for the divide by "N" counter. A monostable circuit Q19 and Q20 is used to hold the input of the divide by "N" counter low while the varactor tuning voltage line is being reset during a band change.

IF OPTIONS

The limiting IF shown on Figure 6 was constructed solely for the purpose of this display. The television IF can be used with minor modifications of bandwidth and AGC, and can be switched in only during the selection of a station. The IF used consists of an MC1349P high gain amplifier and an MC1330P low level detector. It has an overall voltage gain of 88 dB and a 6 dB bandwidth of 1.75 MHz when transistors Q1 and Q2 are on. The switched-in narrow bandwidth is needed in order to get distinct pulses out of the detector while counting across the UHF spectrum. Diodes D1 and D2 are used to prevent over-driving of the MC1330 input when tuning past a strong synthetic signal. High frequency off-station noise is filtered out by C1, and would have to be switched in and out, if the television IF was used.

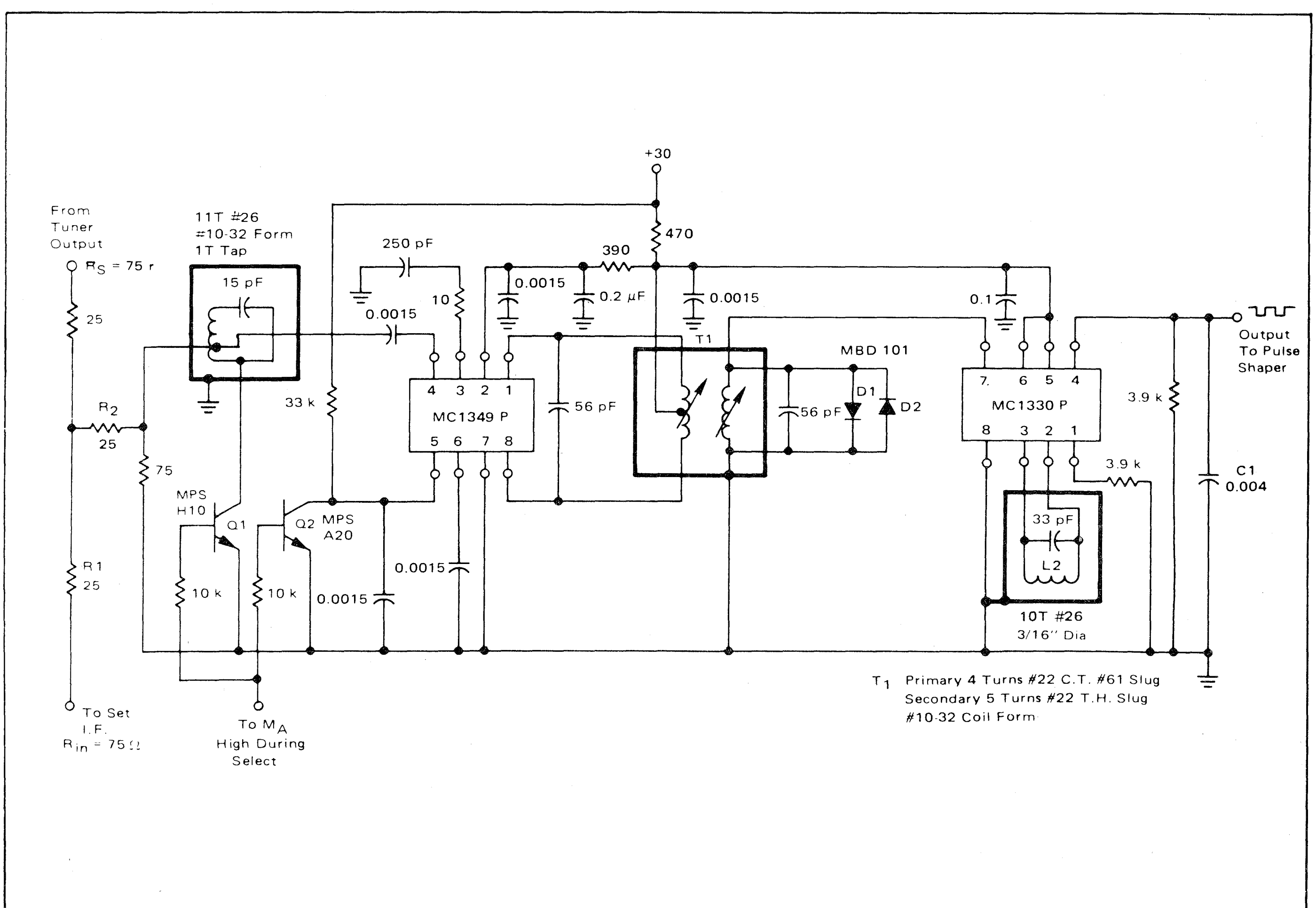


FIGURE 6 – Synthetic Spectrum Limiting I-F.

ERROR DETECTIONS

Figure 7 shows the circuit diagram of the error indicator. Its functions are to give a visual indication and inhibit the select button when an illegal number is set on the channel selector. Transistors Q1 through Q7 are wired in series to form a seven input, "AND" gate. They will all conduct when a zero or one is set on the station selector causing Q11 to turn on. When Q11 turns on, the emitters of Q12 and Q13 are held near ground which turns on the astable multivibrator they form causing the light emitting diode to flash. At the same time, the cathode of D3 would be held low, which will clamp the gate drive away from the 2N5061 SCR.

Transistors Q8 and Q9 form an AND gate and will turn on Q10 which turns on Q11 when the numbers 90 through 99 are set on the channel selector. Diodes D1 and D2 form an OR gate causing Q9 to turn on when 4 through 9 is set in the ones switch. When 84 through 89 is set on the channel selector, Q8 and Q9 will both conduct.

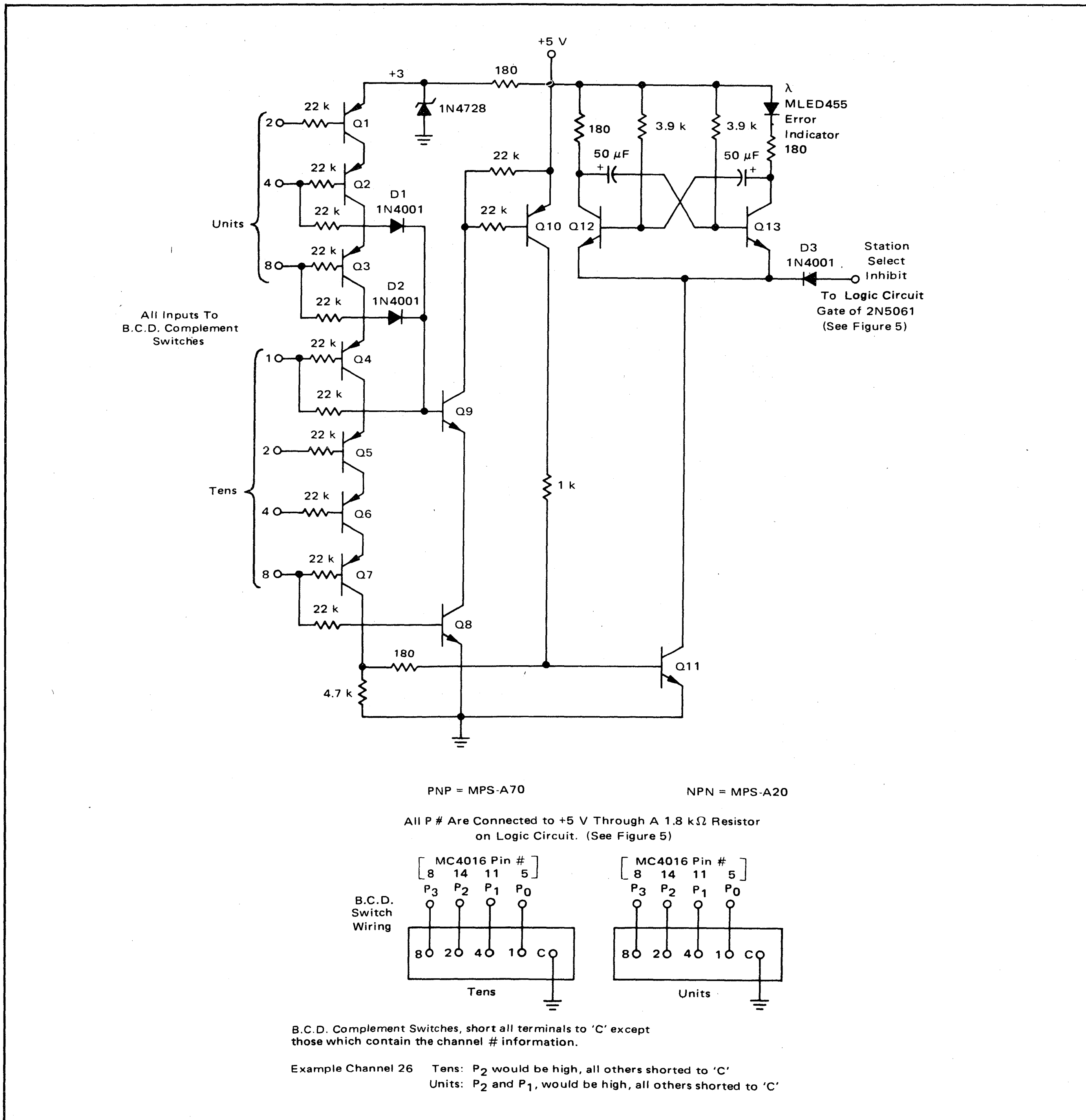


FIGURE 7 – Synthetic Spectrum System Error Indicators

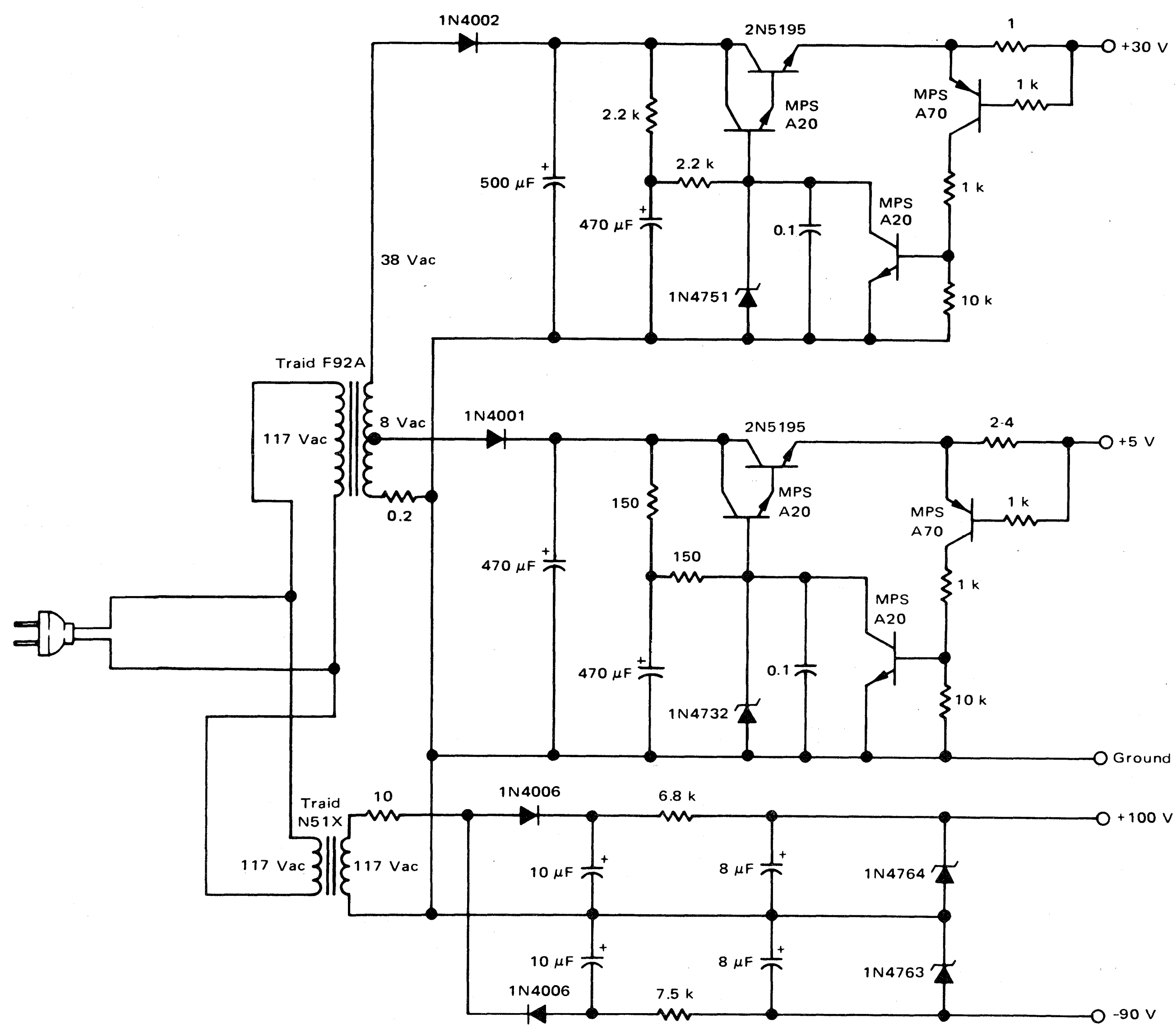


FIGURE 8 – Synthetic Spectrum System Power Supplies

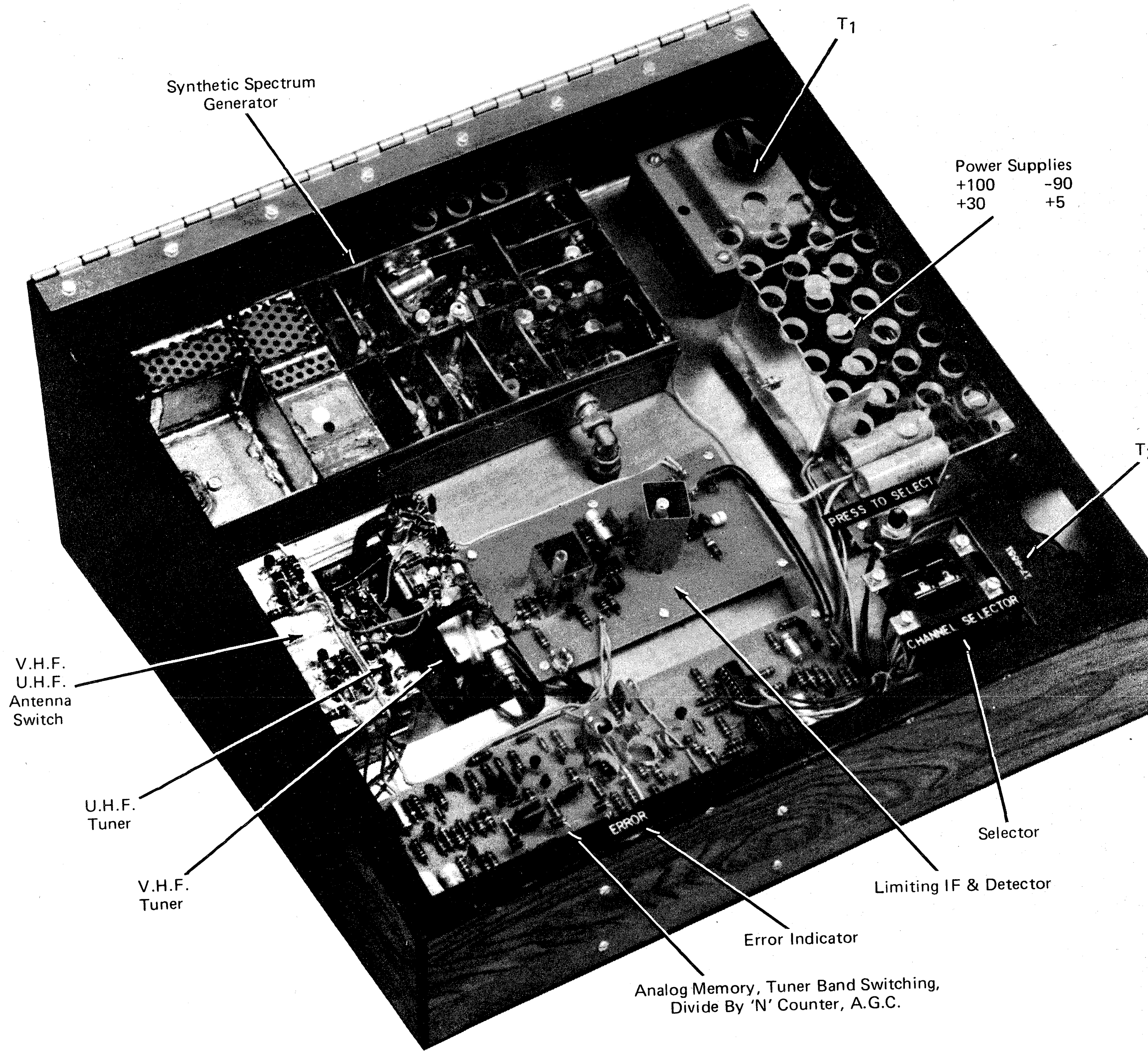
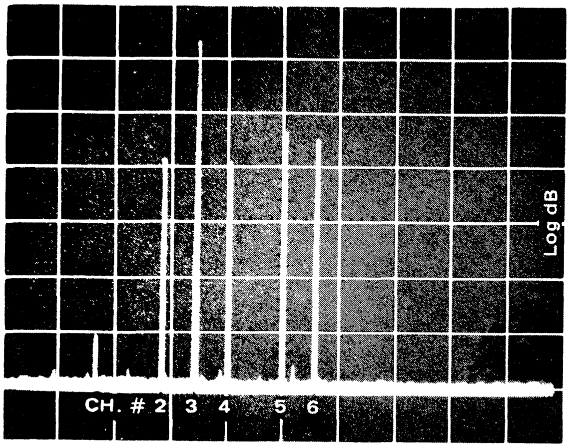


FIGURE 9 – Synthetic Spectrum System Layout

CONCLUSIONS

The system described here was constructed to show that the concept of counting a synthetic spectrum can be applied to consumer television. The circuits used are all a "first" to get the system working. There are numerous ways to simplify each module and reduce the total cost. It is hoped that this presentation will provide enough background for those interested to be able to decide whether or not to carry it further.

SYNTHETIC SPECTRUM GENERATOR OUTPUTS



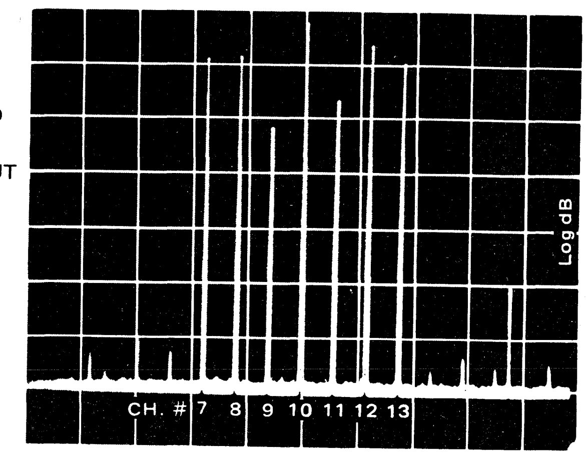
10 MHz/cm

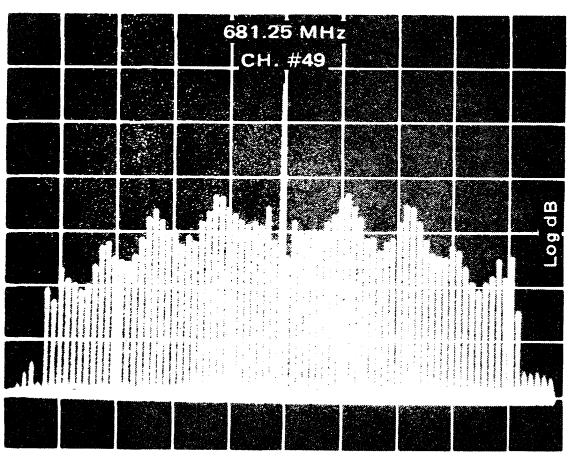
VHF LOW BAND

CHANNEL #	mV OUTPUT
2	.47
3	5.8
4	.51
5	1.08
6	.96

VHF HIGH BAND

CHANNEL #	mV OUTPUT
7	4.4
8	4.4
9	.8
10	12.4
11	2.6
12	8.5
13	2.0





50 MHz/cm

UHF

CHANNEL #	mV OUTPUT
14	.040
49	2.8
59	2.7

CREDITS

The varactor tuners used were furnished by Sickles Division of General Instrument Corporation. VHF #832-6, UHF #232-4.

The crystals were supplied by International Crystal Manufacturing Company in the FM-2 case.

The station selector thumbwheel switches are from Eeco Electronic Engineering Company. Part #177612G BCD 1-2-4-8 complement only.

The television set was furnished by Motorola Consumer Products Division, chassis #TS-938.

The system concept was stimulated by an IEEE paper in the fall of 1971 by Don Wilson of Warwick Electronics Inc.

MOTOROLA Semiconductor Products Inc.

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