

2 Circuit Description

This Section describes the operation of the basic circuit blocks found in the T2000 radio. Refer also to the circuit diagrams in Section 7 of this Manual.

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2.1 Design Overview

The T2000 radio is made up of two modules, the RF module and the control module. The RF module consists of an RF PCB unique to each frequency band with common plug-in IF and TCXO/Tx audio PCBs, determining the frequency stability and reference frequency. The control module consists of a logic PCB and a control head PCB. Each control module is unique to each T2000 model, i.e. T2010, T2015, T2020, T203X, T2040 or T2050.

The following circuit blocks are located in the RF module:

- The synthesiser, containing the
 - Tx/Rx VCO
 - plug-in TCXO and Tx audio PCB
 - Tx/Rx switching.
- The regulators and audio power amplifier.
- The receiver, containing the
 - front end
 - mixer
 - noise blanker
 - mute circuit
 - RSSI
 - plug-in IF PCB.
- The exciter, RF power amplifier and power control circuit.

The following circuit blocks are located in the control module:

- The microprocessor control circuitry.
- Audio processing.
- Control head.
- Options connectors (refer to Section 5.9, “Options Interface Specifications”).

2.2 Synthesiser

Synthesiser IC201 (MC145158) receives channel and reference frequency information from the microprocessor via a three line serial interface:

- DATA - synthesiser data: A counter: 7 bits
M counter: 10 bits
Ref. counter: 14 bits
- CLK - synthesiser clock
- ENABLE - synthesiser latch.

Once the data has been latched in, the synthesiser IC processes the incoming signals; f_{in} from the prescaler IC and f_{ref} from the temperature compensated crystal oscillator (TCXO) operating at 12.8MHz. The TCXO signal is divided by the reference counter to provide 5kHz, 6.25kHz or 12.5kHz at the phase detector. IC201 generates the modulus control at the appropriate time to change the dividing factor for the prescaler. The phase detector outputs are summed and fed via the integrator to the control line. The VCO frequency increases with a positive change in control line voltage.

The synthesiser produces a signal called LCK-DET which is fed to the exciter after some processing to prevent transmission when the synthesiser is out of lock. The LCK-DET signal is also fed to the I/O bus of the control circuitry, where the signal is used for features such as scanning. The time lapse between the synthesiser latch pulse and the lock detect line going low is typically 15ms (maximum is 20ms).

The T2000 uses a dual point modulation system which allows the radio to be modulated at frequencies below the loop filter cut-off frequency (approximately 400Hz). In this system, modulation is supplied to both the VCO and TCXO. When both the reference and VCO are modulated below the cut-off frequency of the loop filter, the phase detector cannot detect a difference between f_{in} , and f_{ref} and will not generate corrective signals. The modulation bandwidth is therefore dependent only on the audio and coupling circuits.

2.3 Audio & Regulators

The nominal supply voltage of the T2000 is 13.8VDC but satisfactory operation is possible from supply voltages of between 10.8 and 16V. Power for the radio is switched via the volume control and switch on the control head.

Overvoltage protection is provided in the form of an 18V zener diode. This will suppress transient spikes but prolonged overvoltage will cause the device to fail short circuit.

On the RF PCB, two regulated power supply rails of 8V and 5V are provided as well as a 30V supply from an inverter. The 30V supply is used to feed the synthesiser loop filter and the receiver front end tuning. A switched 8V line is used to enable the transmitter and disable the receiver.

13.8V is applied directly to the RF and audio power amplifiers, with the audio power amplifier rated for a standard output of 4Wrms into 4 Ω , at a nominal supply voltage of 13.8V.

2.4 TCXO/TX Audio PCB

The TCXO/Tx audio PCB provides the temperature compensated 12.8MHz reference frequency for the synthesiser and a times-three multiplier in the receiver. The PCB also contains the Tx audio limiter, deviation level potentiometer and low pass filter. The TCXO fine frequency adjustment is provided by a ten turn potentiometer. Narrow or wide band deviation and TCXO frequency stability with temperature are determined solely by this PCB.

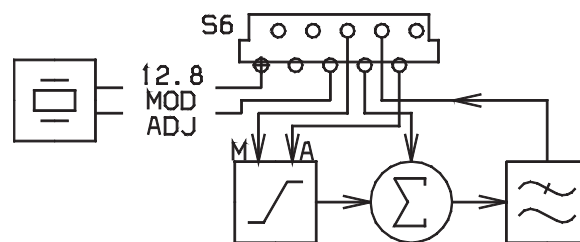


Figure 2.1 T2000 TCXO/TX Audio PCB Block Diagram

2.5 IF PCB

The 10.7MHz signal from the RF PCB feeds Q104, passes through a crystal filter (X101) and is amplified by Q111 and Q112 before passing through a 10.7MHz ceramic filter to a mixer/oscillator (Q113). This 455kHz mixer output is further filtered and amplified by CF102, CF103 and Q114, then passes back to the RF PCB where it is demodulated by IC101. The RSSI function is internal to IC101.

The demodulated signal is filtered and compensated on the IF PCB before passing to the logic PCB via the RF PCB. Narrow band or wide band response is determined solely by the IF PCB.

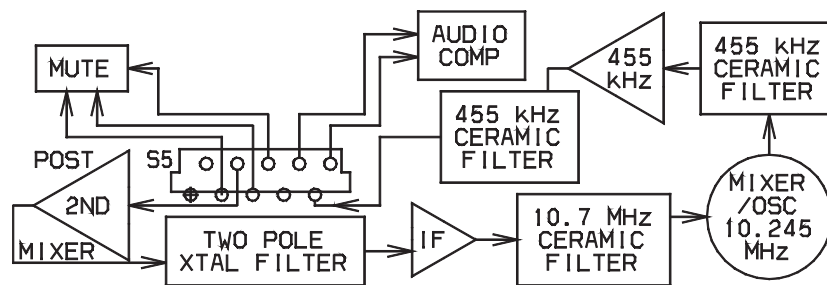


Figure 2.2 T2000 IF PCB Block Diagram

The processed transmit audio passes to the RF PCB where it is split into a VCO modulation path and a TCXO modulation path. The TCXO path passes through a potentiometer to enable the dual point modulation to be correctly adjusted, and then returns to the TCXO/Tx audio PCB.

2.6 T2000-100 & -400 RF PCB

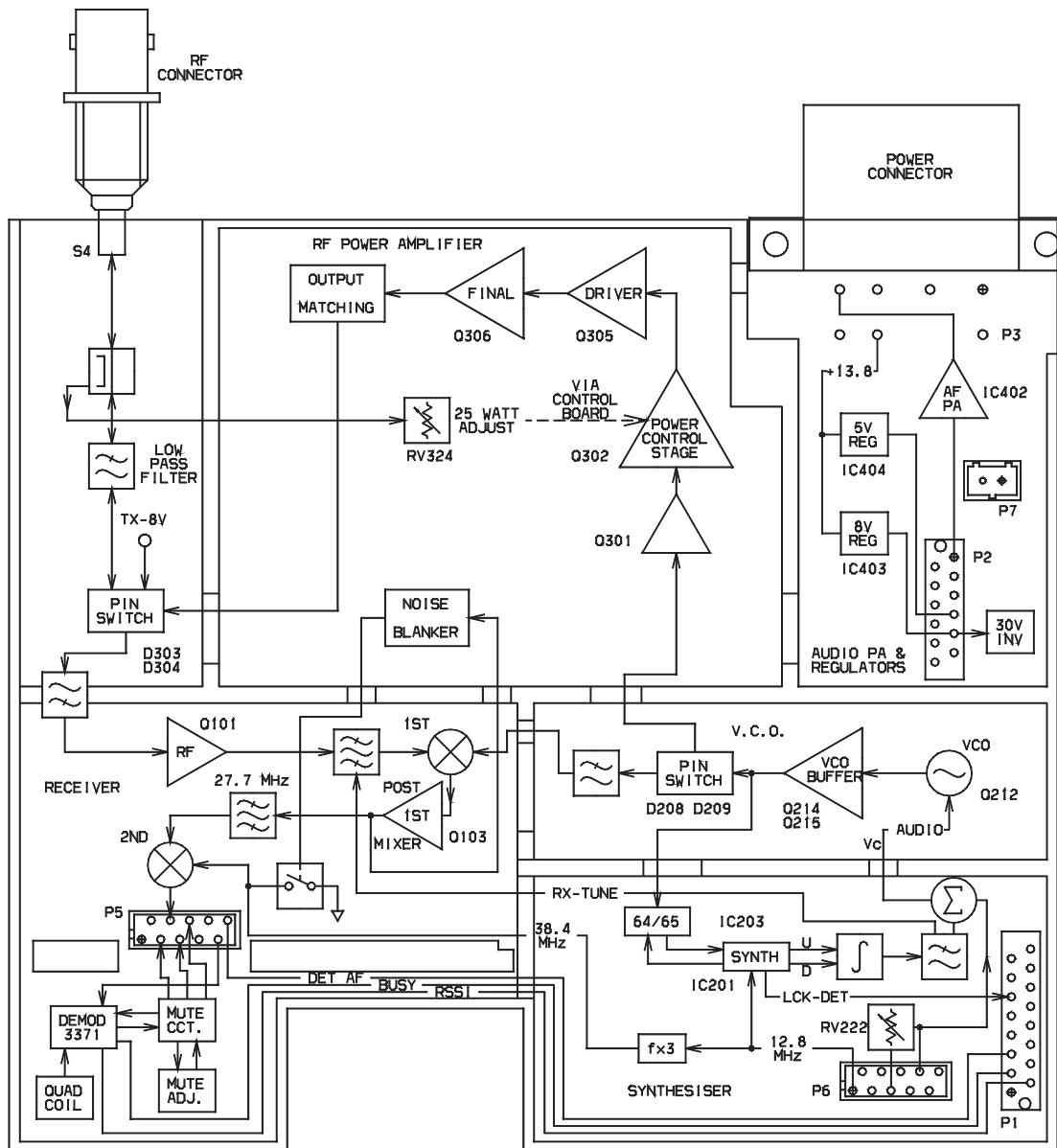


Figure 2.3 T2000-100 & -400 RF PCB Block Diagram

2.6.1 T2000-100 & -400 Receiver

The incoming signal from the antenna via the PIN switch passes through a high pass filter to the RF amplifier, Q101. The 50Ω output from the amplifier is coupled to a varicap tuned triplet which provides the spurious response rejection necessary for the first mixer. An attenuator is provided at the output to allow for fine adjustment of the front end gain.

The VCO output is fed to the first double balanced mixer via a low pass filter to reduce harmonic content. The VCO signal is 27.7MHz below the RF signal and the first mixer output (at 27.7MHz) feeds the first post-mixer buffer, Q103. The output of Q103 feeds both a delay line and the noise blanker circuit.

L114 and L116 form a 50Ω delay line which provides the spurious response rejection necessary for the second mixer. L114 and L116 also provide the delay necessary for the noise blanker to detect and clamp noise pulses. The local oscillator signal of 38.4MHz for the second double balanced mixer is provided by the 12.8MHz reference via a tripler circuit, and the 10.7MHz output feeds the plug-in IF PCB. Each sub-block within the front end has been designed with 50Ω terminations for ease of testing and fault finding.

2.6.2 T2000-100 & -400 Exciter

The VCO output from the PIN switch is amplified to 900mW by a two stage broad band exciter (Q301 and Q302) with approximately 22dB of gain. Q301 is operating into compression to prevent changes in VCO drive affecting output power.

This output power is controlled by varying the collector voltage on Q302, via Q303, Q304 and the feedback loop from the PA. The power settings (maximum, high and low) are under microprocessor control and are set for each channel by programming.

R308, R309, R310 and R313 form a 2dB attenuator, reducing the output to approximately 550mW and also providing good isolation between the exciter and PA.

2.6.3 T2000-100 & -400 Power Amplifier

The 550mW exciter output is amplified to 30W by Q305 and Q306. Q305 has a small amount of bias applied (via R319, D302, R322 and R315) to provide stability at low power levels.

The T2000-100 power amplifier has no tuning, and when the output power is set to 25W the variation across the 50MHz switching range should be less than ±2W.

The high level RF signal passes via the Tx/Rx PIN switch, the low pass filter and directional coupler to the antenna connector. The power level is sensed by D301 on the directional coupler and this voltage is fed back to the power control operational amplifier via RV324. RV324 on the RF PCB sets the high power and RV507 on the logic PCB will adjust the low power.

2.7 T2000-200 RF PCB

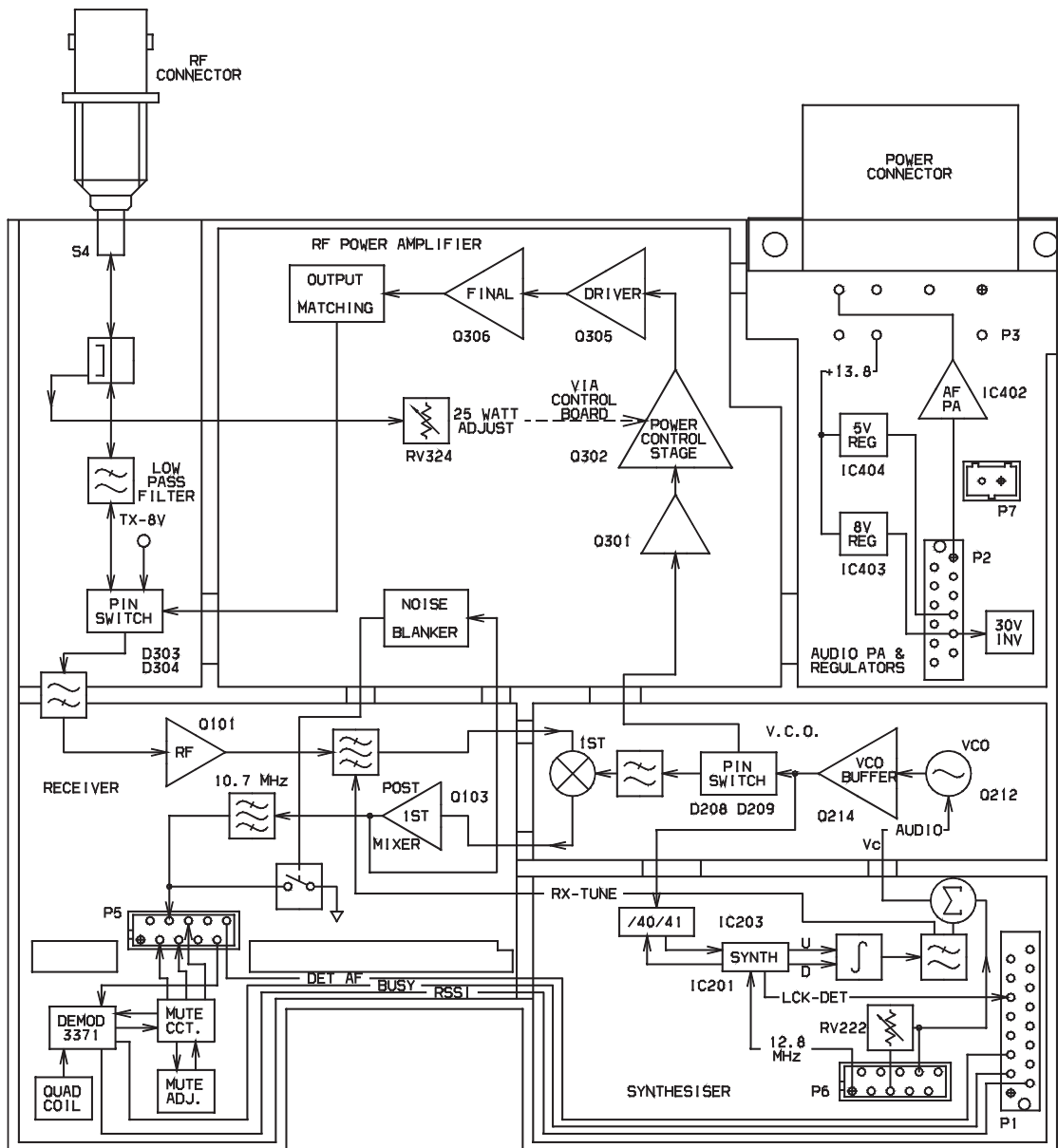


Figure 2.4 T2000-200 RF PCB Block Diagram

2.7.1 T2000-200 Receiver

The incoming signal from the antenna via the PIN switch passes through a high pass filter to the RF amplifier, Q101. The 50Ω output from the amplifier is coupled to a varicap tuned triplet that provides the spurious response rejection necessary for the first mixer. An attenuator is provided at the output to allow for fine adjustment of the front end gain.

The VCO output is fed to the first double balanced mixer via a low pass filter to reduce harmonic content. The VCO signal is 10.7MHz above the RF signal and the first mixer output (at 10.7MHz) feeds the first post-mixer buffer, Q103. The output of Q103 feeds both a delay line and the noise blanker circuit.

L114 and L116 form a 50Ω delay line that provides the delay necessary for the noise blanker to detect and clamp noise pulses and also provides a high impedance point for the signal to be clamped.

The 10.7MHz output feeds the plug-in IF PCB through R128, R129 and R132 which provide the attenuation equivalent to the second mixer of the T2000-300, T2000-400, T2000-500 or T2000-600.

Each sub-block within the front end has been designed with 50Ω terminations for ease of testing and fault finding.

2.7.2 T2000-200 Exciter

The VCO output from the PIN switch is amplified to 500mW by a two stage broad band exciter (Q301 and Q302) with approximately 2dB of gain. Q301 is operating into compression to prevent changes in VCO drive affecting output power. This output power is controlled by varying the collector voltage on Q302, via Q303, Q304 and the feedback loop from the PA. The power settings (maximum, high and low) are under microprocessor control and are set for each channel by programming. R308A, R308, R309 and R310 provide approximately 1dB of attenuation and isolation between the exciter and power amplifier.

2.7.3 T2000-200 Power Amplifier

The 500mW exciter output is amplified to 30W by Q305 and Q306. The T2000-200 power amplifier has no tuning, and when the output power is set to 25W the variation across the 22MHz switching range should be less than $\pm 2W$.

The high level RF signal passes via the Tx/Rx PIN switch, the low pass filter and the directional coupler to the antenna connector. The power level is sensed by D301 on the directional coupler and this voltage is fed back to the power control operational amplifier via RV324. RV324 on the RF PCB sets the high power and RV507 on the logic PCB will adjust the low power.

2.8 T2000-300 RF PCB

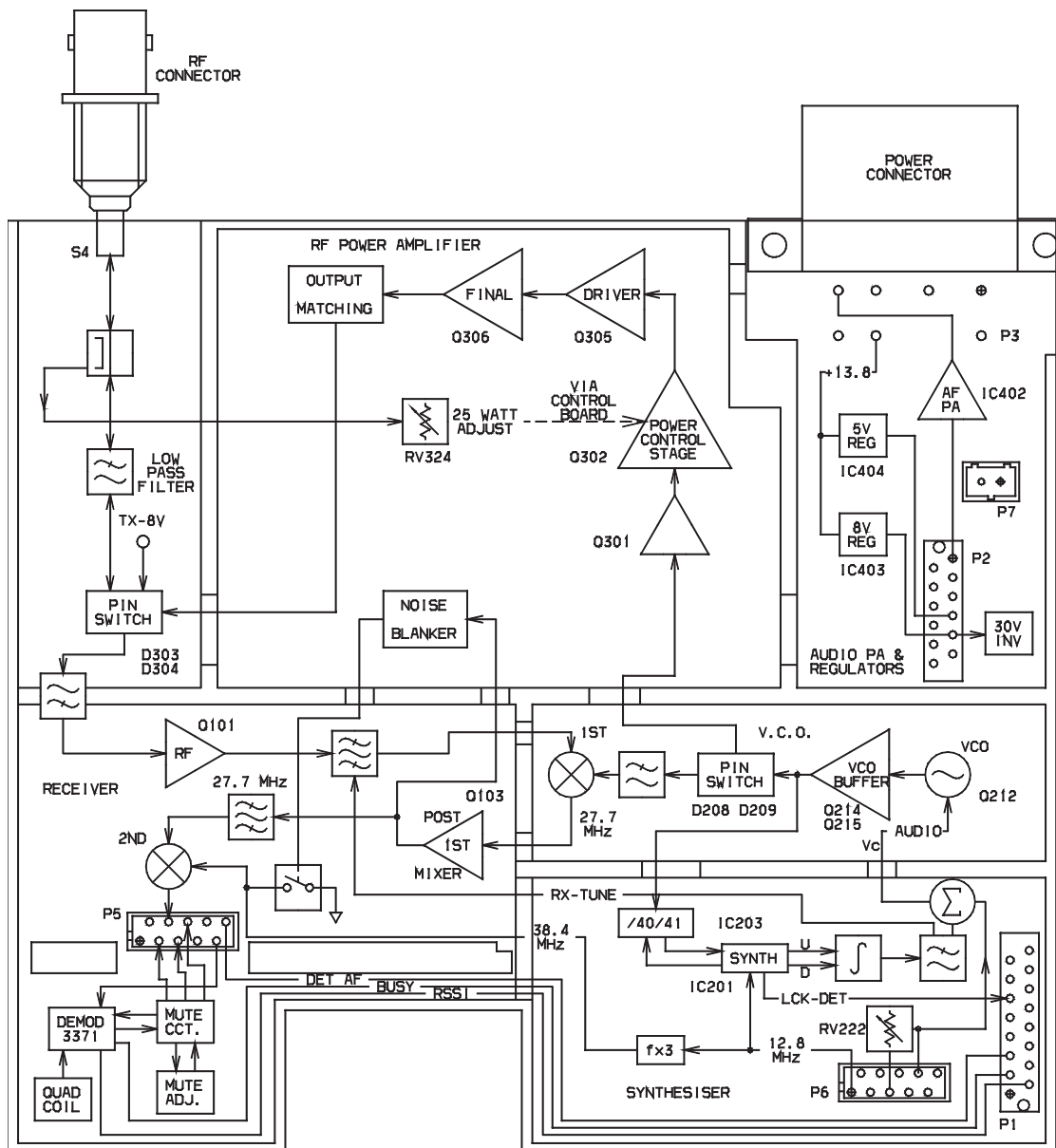


Figure 2.5 T2000-300 RF PCB Block Diagram

2.8.1 T2000-300 Receiver

The incoming signal from the antenna via the PIN switch passes through a high pass filter to the RF amplifier, Q101. The 50Ω output from the amplifier is coupled to a varicap tuned triplet which provides the spurious response rejection necessary for the first mixer. An attenuator is provided at the output to allow for fine adjustment of the front end gain.

The VCO output is fed to the first double balanced mixer via a low pass filter to reduce harmonic content. The VCO signal is 27.7MHz above the RF signal and the first mixer output (at 27.7MHz) feeds the first post-mixer buffer, Q103. The output of Q103 feeds both a delay line and the noise blanker circuit.

L114 and L116 form a 50Ω delay line which provides the spurious response rejection necessary for the second mixer. L114 and L116 also provide the delay necessary for the noise blanker to detect and clamp noise pulses. The local oscillator signal of 38.4MHz for the second double balanced mixer is provided by the 12.8MHz reference via a tripler circuit, and the 10.7MHz output feeds the plug-in IF PCB.

Each sub-block within the front end has been designed with 50Ω terminations for ease of testing and fault finding.

2.8.2 T2000-300 Exciter

The VCO output from the PIN switch is amplified to 1W by a two stage broad band exciter (Q301 and Q302) with approximately 22dB of gain. Q301 is operating into compression to prevent changes in VCO drive affecting output power.

This output power is controlled by varying the collector voltage on Q302, via Q303, Q304 and the feedback loop from the PA. The power settings (maximum, high and low) are under microprocessor control and are set for each channel by programming.

R308, R309, R310 and R313 form a 2.7dB attenuator, reducing the output to approximately 550mW and also providing good isolation between the exciter and PA.

2.8.3 T2000-300 Power Amplifier

The 550mW exciter output is amplified to 30W by Q305 and Q306. Q305 has a small amount of bias applied (via R319, D302, R322 and R315) to provide stability at low power levels.

The T2000-300 power amplifier has no tuning, and when the output power is set to 25W the variation across the 38MHz switching range should be less than ±2W.

The high level RF signal passes via the Tx/Rx PIN switch, the low pass filter and directional coupler to the antenna connector. The power level is sensed by D301 on the directional coupler and this voltage is fed back to the power control operational amplifier via RV324. RV324 on the RF PCB sets the high power and RV507 on the logic PCB will adjust the low power.

2.9 T2000-500, T2000-600, T2000-700, -900 & -000 RF PCB

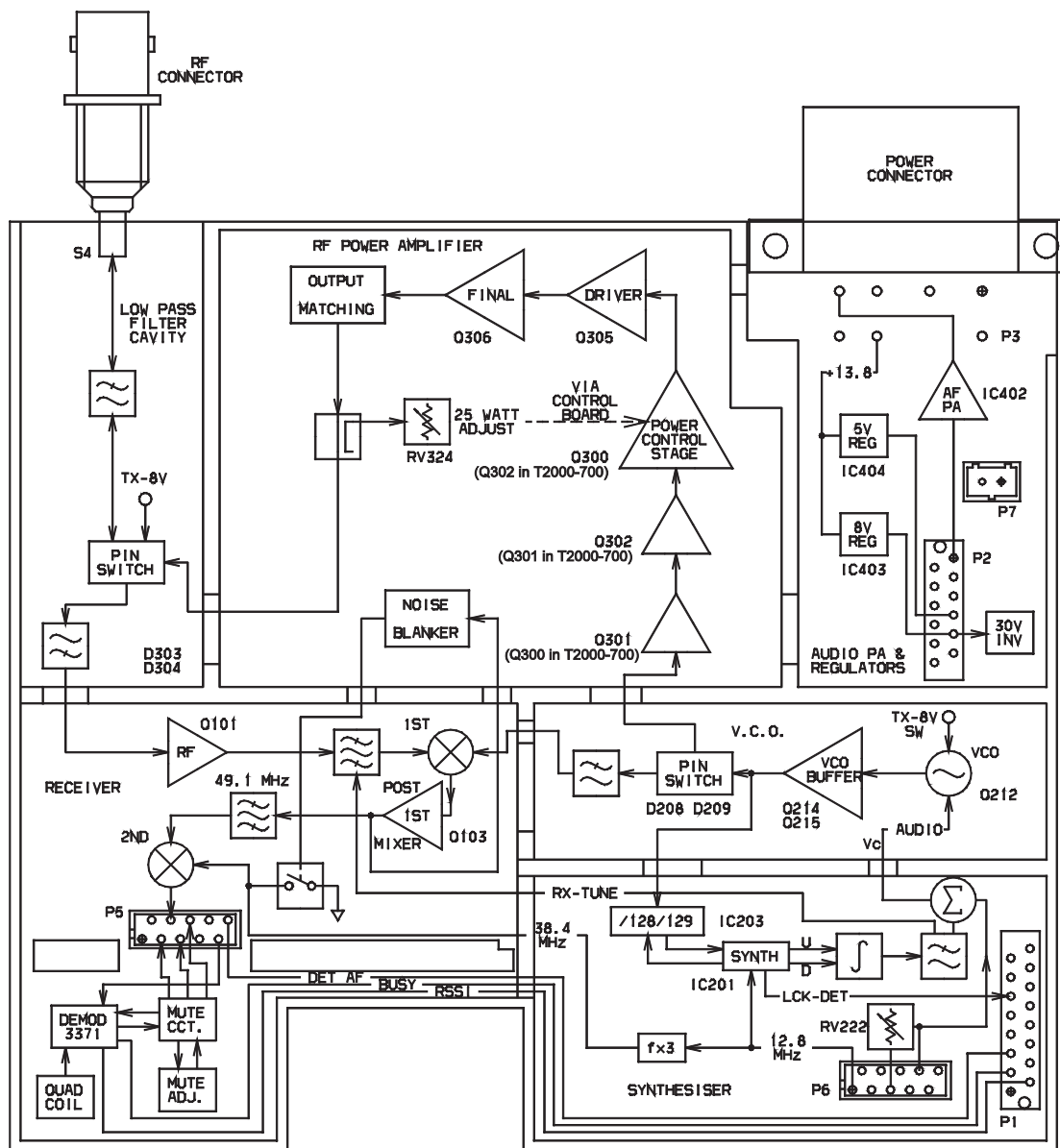


Figure 2.6 T2000-500, -600, -700, -900 & -000 RF PCB Block Diagram

2.9.1 T2000-500, -600, -700, -900 & -000 Receiver

The incoming signal from the antenna via the PIN switch passes through a high pass filter to the RF amplifier, Q101. The 50Ω output from the amplifier is coupled to a varicap tuned triplet which provides the spurious response rejection necessary for the first mixer. An attenuator is provided at the output to allow for fine adjustment of the front end gain.

The VCO output is fed to the first double balanced mixer via a low pass filter to reduce harmonic content. The VCO signal is 49.1MHz below the RF signal and the first mixer output (at 49.1MHz) feeds the first post-mixer buffer, Q103. The output of Q103 feeds both a delay line and the noise blanker circuit.

L114 and L116 form a 50Ω delay line which provides the spurious response rejection necessary for the second mixer. L114 and L116 also provide the delay necessary for the noise blanker to detect and clamp noise pulses. The local oscillator signal of 38.4MHz for the second double balanced mixer is provided by the 12.8MHz reference via a tripler circuit, and the 10.7MHz output feeds the plug-in IF PCB. Each sub-block within the front end has been designed with 50Ω terminations for ease of testing and fault finding.

2.9.2 T2000-500, -600, -700 -900 & -000 Exciter

The VCO output from the PIN switch is amplified to 2W by a three stage broad band exciter (Q300, Q301 and Q302) with approximately 28dB of gain. The first stage (Q301 in the T2000-500/600, and Q300 in the T2000-700) operates into compression to prevent changes in VCO drive affecting output power.

This output power is controlled by varying the collector voltage on Q300, via Q303, Q304 and the feedback loop from the PA. The power settings (maximum, high and low) are under microprocessor control and are set for each channel by programming.

2.9.3 T2000-500, -600, -700, -900 & -000 Power Amplifier

The 2W exciter output is amplified to 30W by Q305 and Q306. The T2000-500/600/700 power amplifier has no tuning, and when the output power is set to 25W the variation across the switching range should be less than ± 2 W.

The high level RF signal passes via the directional coupler, the Tx/Rx PIN switch and the low pass filter to the antenna connector. The power level is sensed by D301 on the directional coupler and this voltage is fed back to the power control operational amplifier via RV324. RV324 on the RF PCB sets the high power and RV507 on the logic PCB will adjust the low power.

2.10 T2000-800 RF PCB

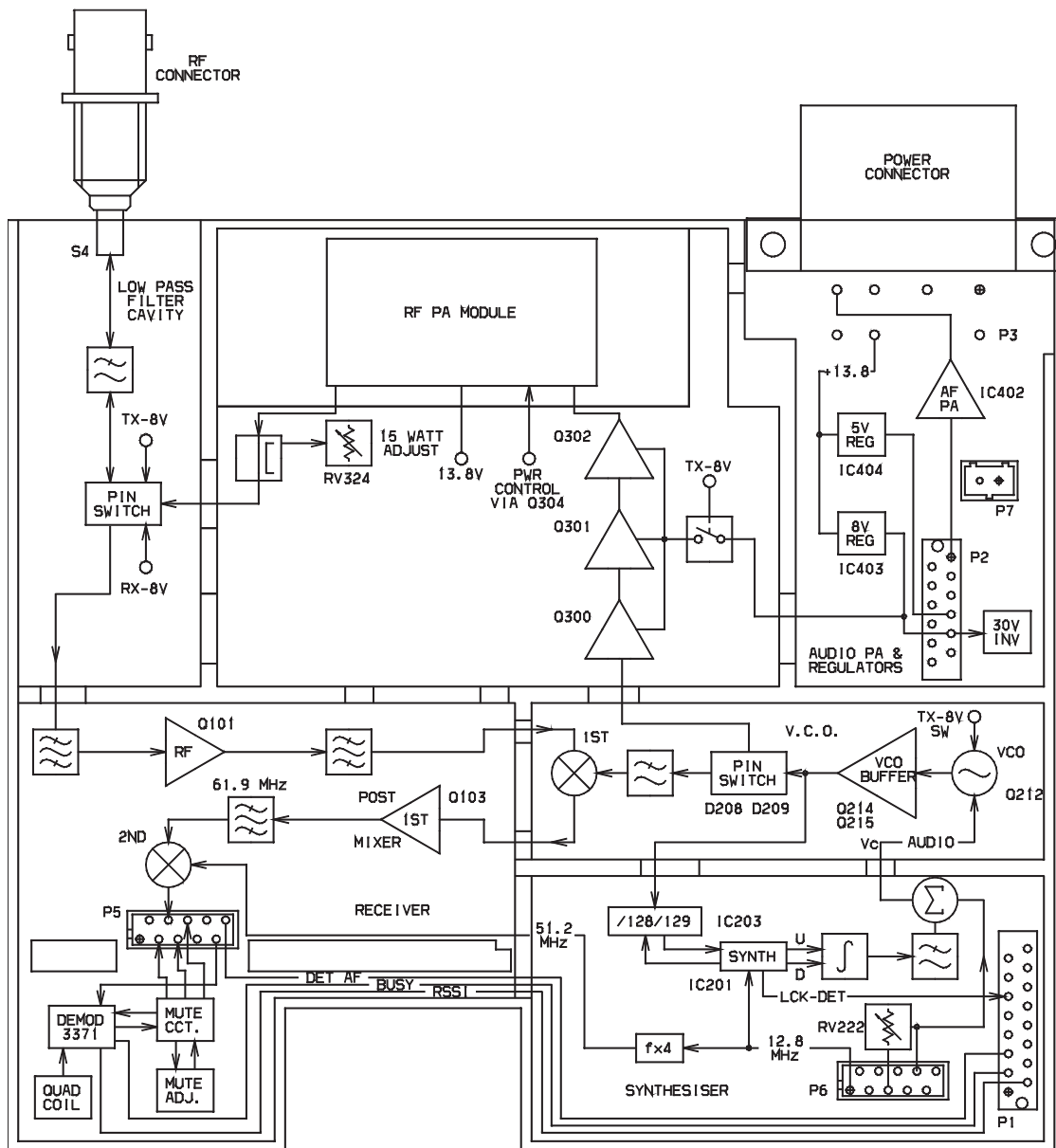


Figure 2.7 T2000-800 RF PCB Block Diagram

2.10.1 T2000-800 Receiver

The incoming signal from the antenna via the PIN switch passes through a band pass filter to the RF amplifier, Q101. The 50Ω output from the amplifier is coupled to a second band pass filter, and these two filters provide the spurious response rejection necessary for the first mixer. An attenuator is provided at the output to allow for fine adjustment of the front end gain.

The VCO output is fed to the first double balanced mixer via a low pass filter to reduce harmonic content. The VCO signal is 61.9MHz below the RF signal and the first mixer output (at 61.9MHz) feeds the first post-mixer buffer, Q103. The output of Q103 feeds a band pass filter.

L114 and L116 form a 50Ω band pass filter which provides the spurious response rejection necessary for the second mixer. The local oscillator signal of 51.2MHz for the second double balanced mixer is provided by the 12.8MHz reference via a times 4 multiplier circuit, and the 10.7MHz output feeds the plug-in IF PCB.

Each sub-block within the front end has been designed with 50Ω terminations for ease of testing and fault finding.

2.10.2 T2000-800 Exciter

The VCO output from the PIN switch is amplified to 0.5W by a three stage broad band exciter (Q300, Q301 and Q302) with approximately 21dB of gain. Q300 is operating into compression to prevent changes in VCO drive affecting output power.

This output power is controlled by varying the voltage on IC405 pin2, via Q303, Q304 and the feedback loop from the PA. The power settings (maximum, high and low) are under microprocessor control and are set for each channel by programming.

2.10.3 T2000-800 Power Amplifier

The 0.5W exciter output is amplified to 20W by IC405. The T2000-800 power amplifier has no tuning, and when the output power is set to 15W the variation across the 70MHz switching range should be less than ±1W.

The high level RF signal passes via the directional coupler, the Tx/Rx PIN switch and the low pass filter to the antenna connector. The power level is sensed by D301 on the directional coupler and this voltage is fed back to the power control operational amplifier via RV324. RV324 on the RF PCB sets the high power and RV507 on the logic PCB will adjust the low power.

2.11 Control Module

The primary task of the control section in the T2000 is to control the state of the radio at all times, based both on user input, and activity of the internal circuitry. To achieve this, the control section monitors the radio's operation and responds to any changes with various control signals.

The input shift registers are read by the microprocessor approximately 100 times per second. The output shift registers are updated only when a control signal is required to change, and the miscellaneous I/O is continually scanned.

In the majority of cases, a control output will change only in response to an input stimulus, e.g. a control head key being pressed, receiver busy, etc. Some outputs may be affected by more than one input or a sequence of events; this is particularly so in the case of the mute gate control line. Its operation may be affected by a number of external conditions and even some generated in the microprocessor.

For operation of the T2000 Series II control heads, refer to Figures 2.8 to 2.10.

2.11.1 T2010 & T2015 HC05 Logic PCB

Transmitter speech from the microphone is preamplified and fed into an automatic level control circuit which also has two mute facilities (one for options and one for the microprocessor). The speech is pre-emphasised and high pass filtered to reduce CTCSS components, then passes via the RF PCB to the limiter on the TCXO/Tx audio PCB.

DCS/CTCSS signals are generated by the microprocessor and are filtered by a low pass filter before being passed to the level potentiometer on the TCXO/Tx audio PCB. A five tone Selcall module is available which is directly interfaced to the microprocessor. Selcall tones are fed to the limiter on the TCXO/Tx audio PCB.

Receiver audio from the IF PCB passes through a low pass filter where it is split into signalling and speech paths. Five tone signals are coupled to the five tone module. DCS/CTCSS passes through a low pass filter and limiter before arriving at the microprocessor. Speech is de-emphasised and passed through one or two high pass filters, depending on the signalling used. Processed speech passes through the mute to an amplifier where speech and progress tones are summed. The signal then passes via the volume control to the audio power amplifier on the RF PCB.

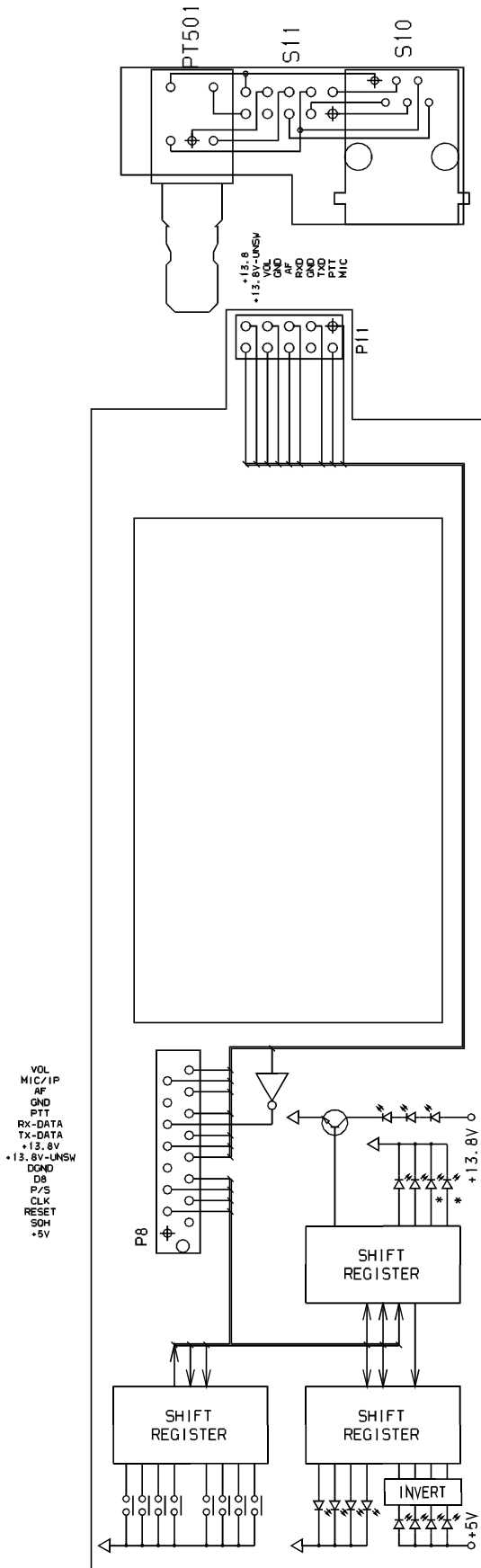


Figure 28 2010 & T2030 Control Head Block Diagram

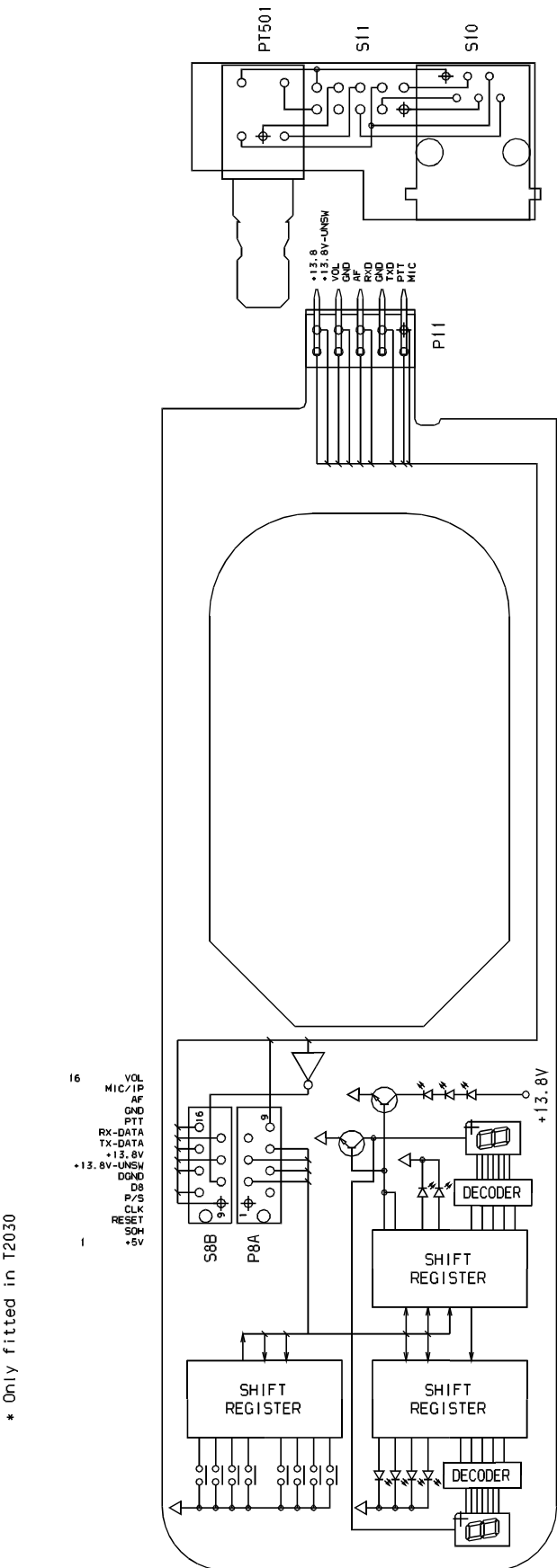


Figure 29 T2015 & T2060 Control Head Block Diagram

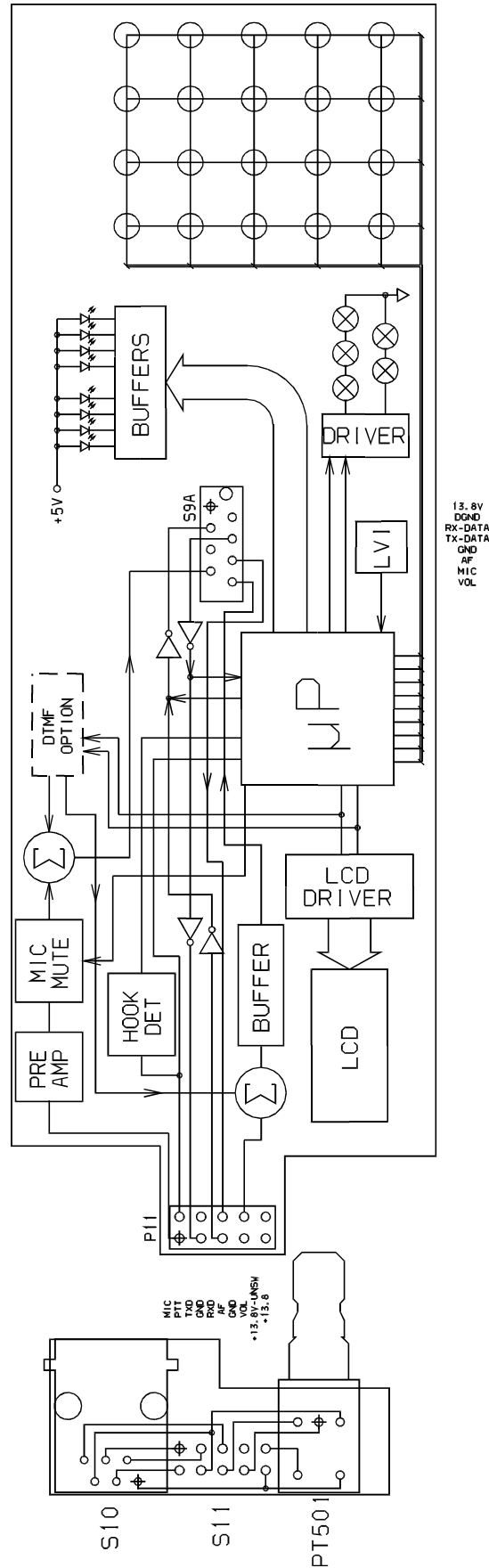


Figure 2.10 T2020, T2040 & T2050 Control Head Block Diagram

2.11.2 T2020, T203X, T2040, T2050 & T2060 HC11 Logic PCB

Transmitter speech from the microphone is preamplified and fed into an automatic level control circuit which also has three mute facilities (one for options and two for the microprocessor). The speech is pre-emphasised and high pass filtered to reduce CTCSS components. The speech passes via the RF PCB to the limiter on the TCXO/Tx audio PCB.

The FFSK modem tones pass through a level potentiometer before being fed to the limiter on the TCXO/Tx audio PCB. DCS/CTCSS signals are generated by the microprocessor and are filtered by a low pass filter before being passed to the level potentiometer on the TCXO/Tx audio PCB.

Five tone Selcall and DTMF modules are both available to directly interface to the microprocessor. Selcall tones are fed to the limiter on the TCXO/Tx audio PCB and DTMF tones are summed at the automatic level control.

Receiver audio from the IF PCB passes through a low pass filter where it is split into signalling and speech paths. Five tone signals are coupled to the five tone module. DCS/CTCSS passes through a low pass filter and limiter before arriving at the microprocessor. FFSK modem signals pass through a buffer amplifier before the modem input.

Speech is de-emphasised and passed through one or two high pass filters, depending on what signalling is used. Processed speech passes through the mute to an amplifier where speech and progress tones are summed. The signal then passes via the volume control to the audio power amplifier, on the RF PCB.

