Circuit Description

1 Frequency configuration

The reference frequency of frequency synthesizer is provided by 12.8MHz crystal oscillator X1 TCXO. The receiver adopts quadric mixing mode. The first IF is 38.85MHz, and the second IF is 450kHz. The first local oscillation signal of the receiver is produced by frequency synthesizer and the second local oscillation signal selects the 3rd harmonics of 12.8MHz of crystal oscillator X1 TCXO. The signal of transmitter is produced by frequency synthesizer directly.
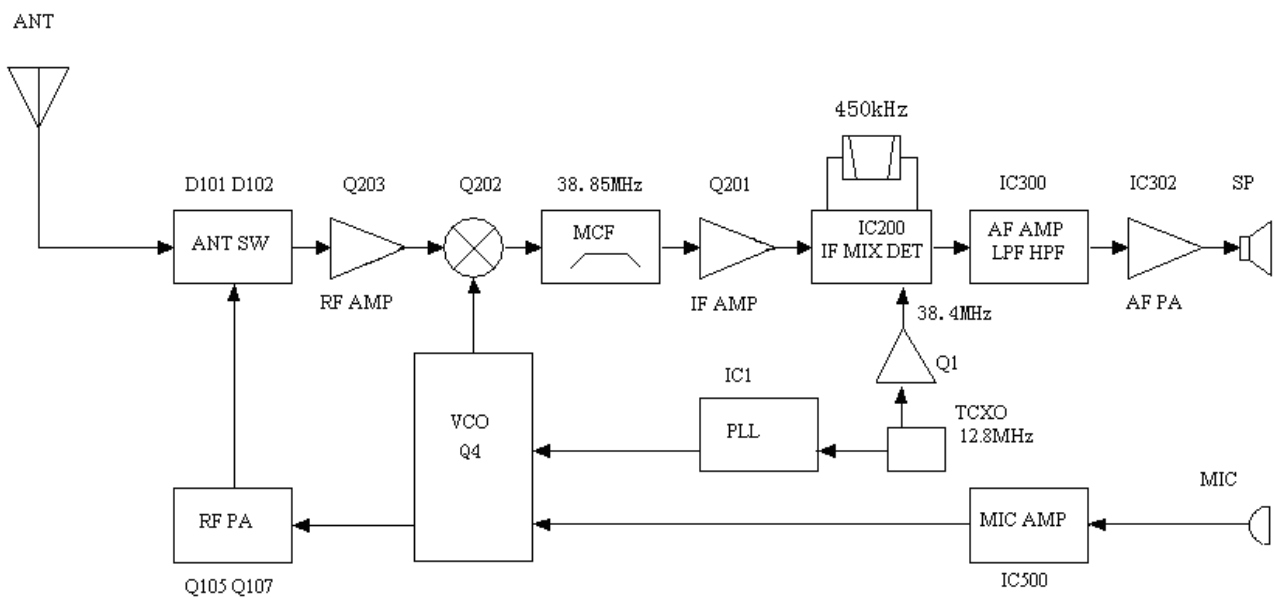

Figure 1 Frequency configuration

2 Receiver（Rx）

The receiver is double conversion superheterodyne, designed to operate in the frequency range of 136 to 174MHz,The frequency configuration in Fig 2
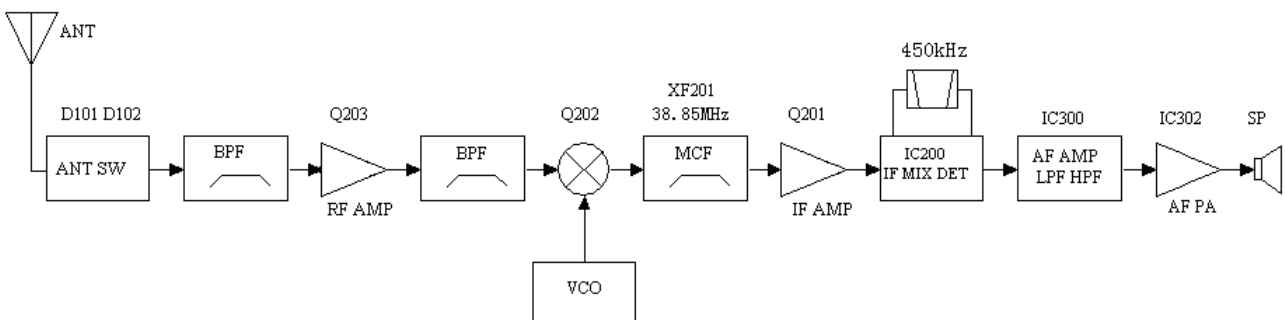
Figure 2 Receiver section configuration

Front End of Receiver

Signals from the antenna are filtered by BPF which consists of C235 C233 C604 C252 C951 C234 C255 C255 L209 L208 D201 D202 via RX/TX switch (D101 D102 and D103). After being filtered out the useless out-of-band signals, the signals are amplified by LNA consisting of Q203 and external components.

Signals from LNA are filtered again by BPF which consists of C228 C226 C238 C229 C227 C239 C947 C259 C948 L214 L204 L203 D905 and D206 before entering the 1st mixer (Q202).

The PWM wave is output by MCU composed of 58 foot and then commutated to adjustable voltage after filtering to change the capacity of varactor diode D905 D203 D206 D201 D202 to control the center frequency of BPF.

1st mixer

The first IF (51.65MHz) signal is produced after mixing of the receiving signal from LNA and the 1st local oscillation signal from frequency synthesizer. The first IF signal is filtered out adjacent channel and other useless signals by crystal filter (XF201).

IF Circuit

The 1st IF signal from crystal filter is amplified by the first IF amplifier (Q201) before processing of IC in IF(IC200，GT3136).

IF IC consists of the 2nd mixer, 2nd local oscillation, IF amplifier, limiter, frequency discriminator and noise amplifier.

Frequency (12.8MHz) produced by TCXO(X1) is amplified and then selects 3rd harmonics (38.4MHZ) as the second local oscillator signal source. The second IF signals (450kHz) are generated after signals mixing of the second local oscillation (38.4MHz) and the first IF (38.85MHz) in IC200. Audio signals are demodulated and outputted by IC200 after the second IF signals are amplified and limited in IC200 and then filtered by ceramic filter(450kHz).
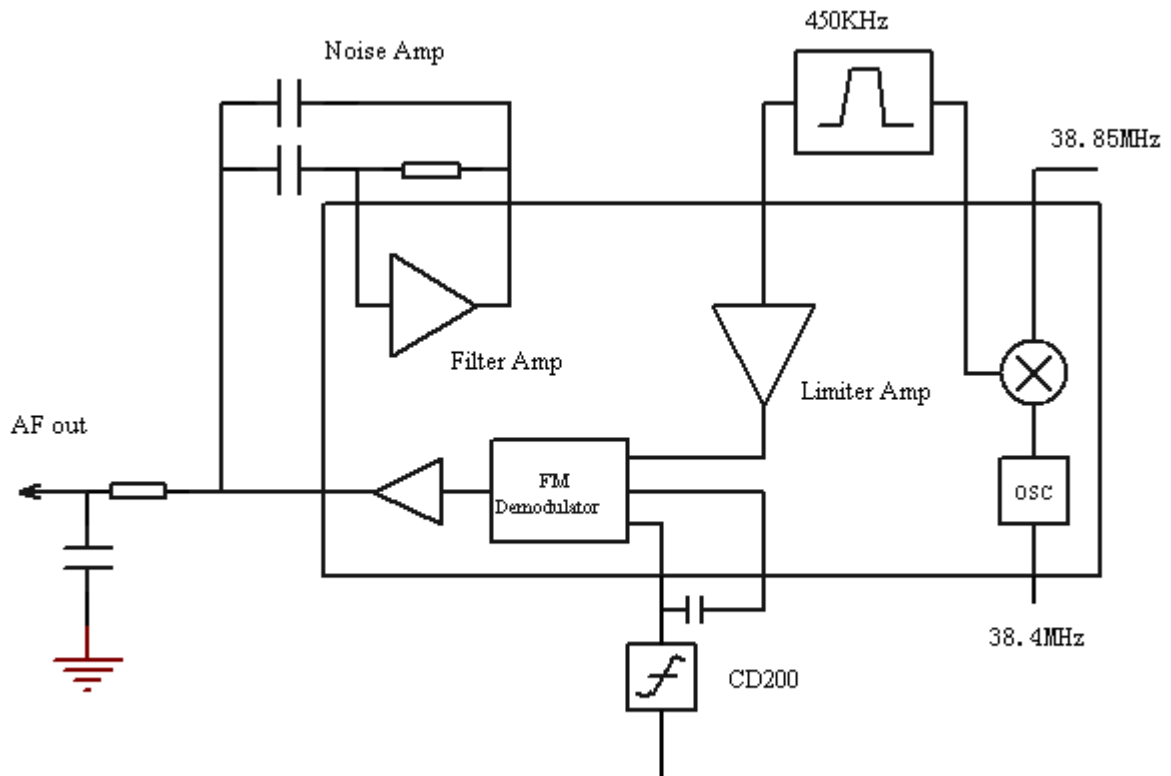
Figure 3 Schematic Diagram for IF System

Receiving Audio Signal Processing:

The audio processing circuit of receiver consists of IC300 and the peripheral circuit. Voice signals from IC200 are sent to IC301（CTCSS signaling filter circuit）and IC300-D respectively after amplified in IC300-C. After that, the signals are removed of the HF and LF components after amplification, de-emphasis and filtering by other units of IC300, and only audit components from 300 to 3000Hz can be sent to audio power amplifier (IC302) after amplified in Q300 and adjusted by volume potentiometers.
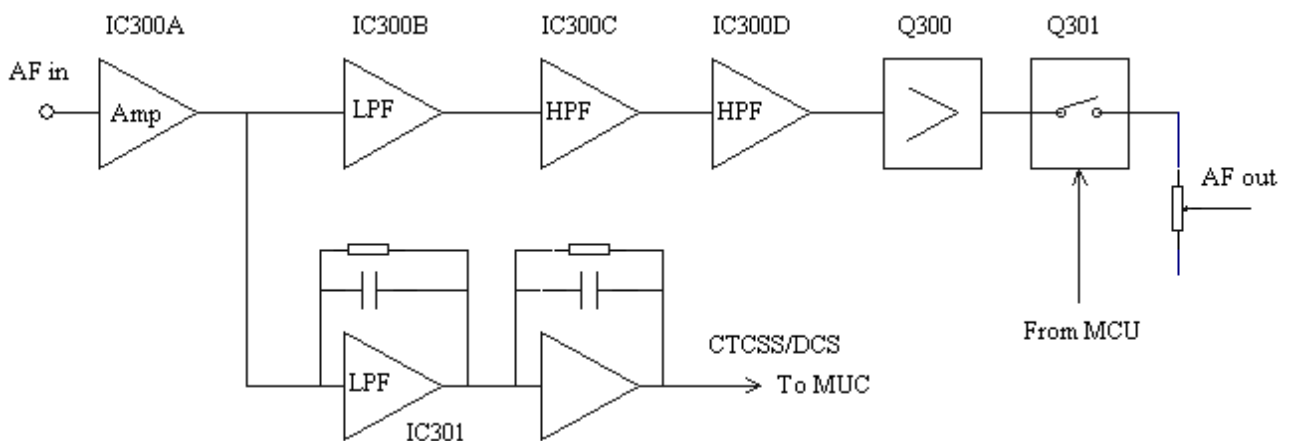

Figure 4 Schematic Diagram for Audio Processing of Receiver

Squelch Circuit

Part of the AF signal from the IC200 enters the FM IC again,and the noise component is amplified and rectified by a filter and an amplifier to produce a DC voltage corresponding to the noise level.

The DC signal from the FM IC goes to the analog port of the microprocessor(IC403).IC403 determines whether to output sounds from the speaker by checking whether the input voltage is higher or lower than the preset value.

To output sounds from the speaker,IC403 sends a high signal to the MUTE and AFCO lines and turns IC302 on through Q302 Q304 and Q305.

Audio Power Amplification

The audio power amplifying circuit consists of IC302 and the peripheral components.

The signals are amplified by audio power amplifier to drive the speaker after collecting the receiving audio signals, voice signals and warning tone signals. The warning tone has no volume limitation.

When AFCO is high level, Q304 is on, IC302 begins to work and the speaker sounds. Speaker Impedance: 16ohm

CTCSS Signal filtering

The audio signals after demodulation in IC200 may contain CTCSS (continuous tone control squelch system) or DCS（digital squelch）signals. The spectrum component of CTCSS/DCS is 67 to 250Hz. The filtering circuit composed of IC301 can filter out signals except CTCSS/DCS spectrum, which makes MCU decode the CTCSS/DCS more accurately.

3 Transmitter (Tx)
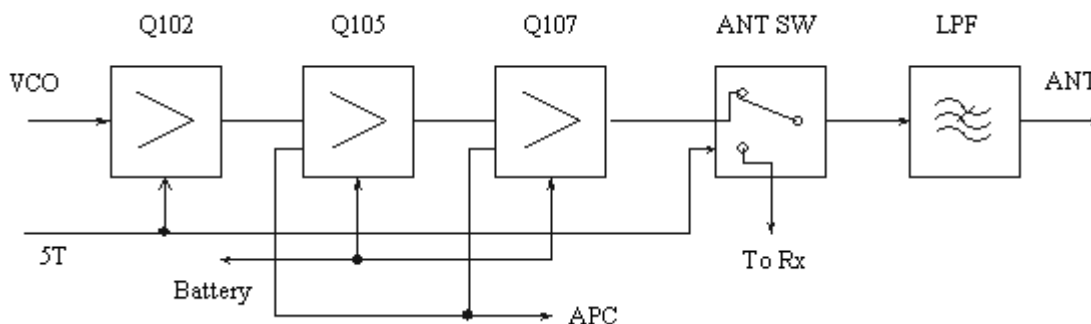Transmitter Power Amplifier

Figure 5 Schematic Diagram for Power Amplifier and Antenna Switch

The modulated RF signals from VCO are amplified by Q102 and Q105 before the power amplification in Q107.

Gate bias of Q105 and Q107 is controlled by APC circuit, so the output power of transmitter can be controlled conveniently by changing the gate bias voltage.
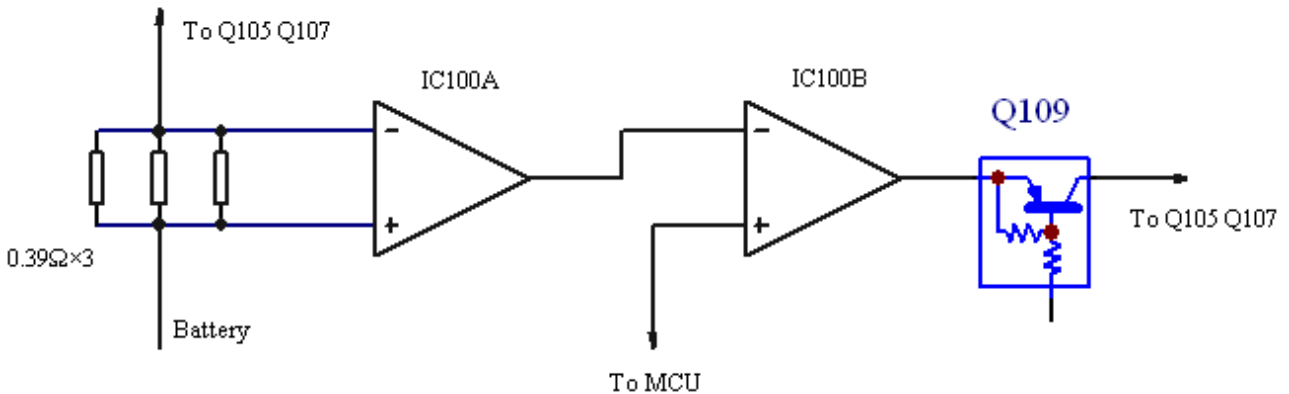
APC（Automatic Power Control）

Figure 6 Schematic Diagram for APC Circuit

R130 R131 and R132 are power amplification current detector, IC100A is power amplification current sampling amplifier and IC00B is power comparison amplifier.

The power amplification current and IC100A output will increase with oversized output power of transmitter. When the output voltage of IC100B decreases, the bias voltage of Q105 and Q107 will decrease, finally the output power of transmitter will decrease or vice versa. Thus, the output power of transmitter will keep stable under any different working condition.
MCU can set the power by changing the voltage input to IC100B.
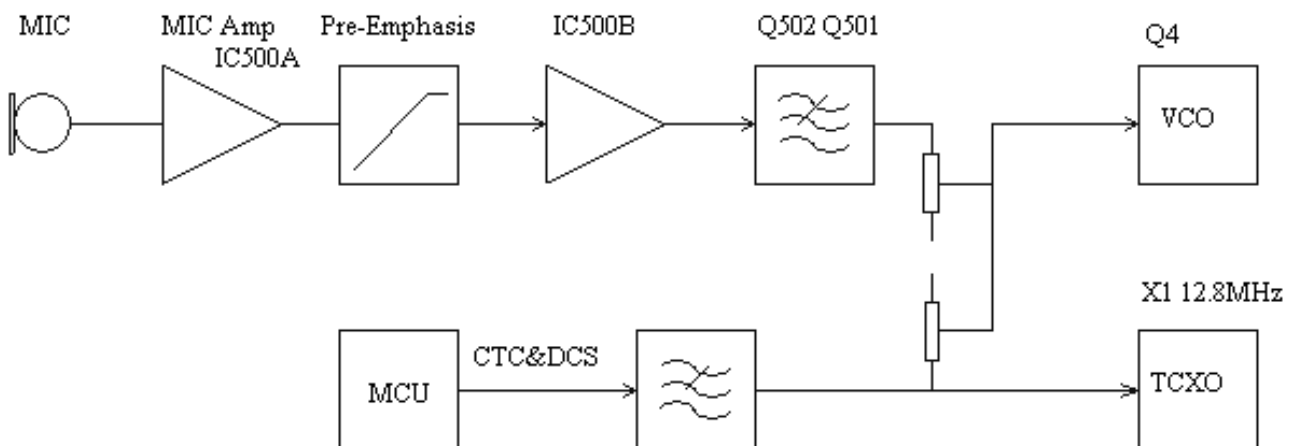
Audio Signal Processing of Transmitter

Figure 7 Schematic Diagram for Audit Circuit of Receiver

The audio signal processing circuit of Transmitter consists of IC500 and the peripheral components. Voice signals from MIC are sent to VCO for modulation together with

CTCSS/DCS after amplification, limitation and filtering.

AGC circuit consists of D500, D501 and Q503. The signal amplitude is reduced to ensure no distortion in case of oversized MIC signal.

Q504, the power switch of voice processing circuit, controlled by MCU, will give power supply to IC500 only during transmission.

J501 is the socket for external MIC, and the internal MIC will disconnect automatically when using external MIC, but the internal PTT is still effective.
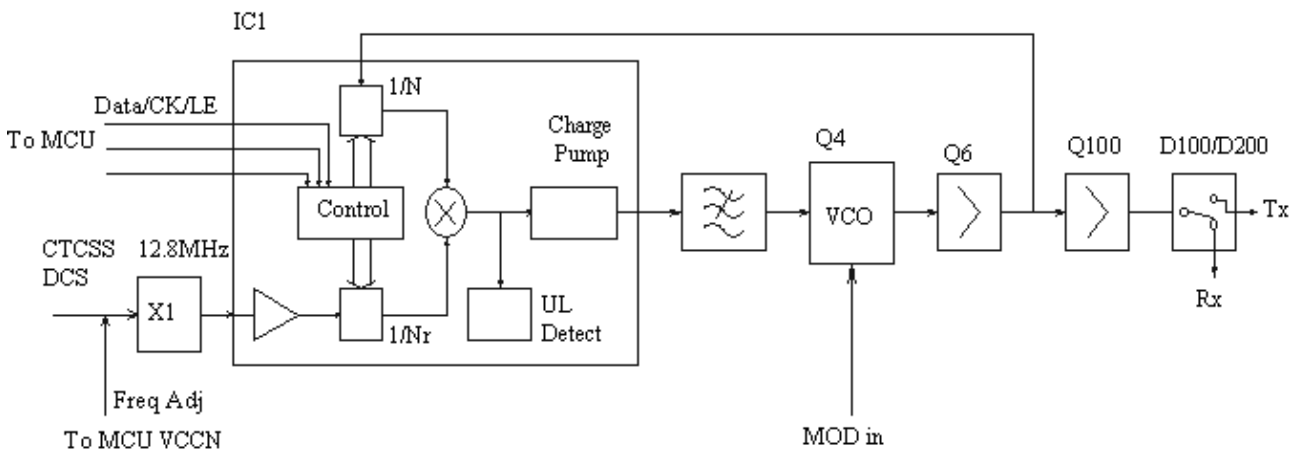
4 PLL Frequency Synthesizer

Figure 8 Schematic Diagram for Frequency Synthesizer

The CU500-1(CU510-1) adopts PLL frequency synthesizer.

Frequency synthesizer consists of reference oscillator, voltage controlled oscillator (VCO), programmable frequency divider (PFD), phase comparator and low pass filter (LPF).

RX VCO Unit consists of Q4 D2 D4 L14 C35 C41 C44 C45 .

TX VCO Unit consists of Q4 D2 D4 L14 C35 C41 C44 C45 and D1 Q5,D5 is the modulation circuit of VCO.

IC1 (MB15E03) is PLL integrated circuit and contains programmable parametric frequency divider (PPFD), programmable frequency divider (PFD), phase comparator and charge pump, etc.

Low pass filter consists of R5 R7 R9 R10 C12 C15 and C18.

Reference frequency is provided by X1 (TCXO, 12.8MHz).

Reference frequency of TCXO (Temperature-controlled Crystal Oscillator) is divided by PPFD in IC1 to produce reference frequency of 5kHz or 6.25kHz (controlled by MCU based on the set channel frequency).

The oscillation frequency of VCO is compared with reference frequency to produce error signal after divided by PFD in IC1. The error signal is filtered by low pass filter before changing the VCO frequency to the set value in VCO (it is locking).

$$N=F_{VCO}/F_R$$

N：Division Frequency
F$_{VCO}$：VCO Oscillation Frequency
F$_R$：Reference Frequency

Lock lost detection: When PLL is out of lock, IC pin14 will output low level signal to MCU，and then MCU prohibit transmitter from transmitting with a warning tone.

Q8, the power filter, can provide PLL with more purified power to reduce the noise of frequency synthesizer.

5.5 Voice Circuit

The station is equipped with Voice Prompt Function, which is very useful during night or under dark condition.
The speaker will voice the current channel number when changing the channel every time because of the voice memory chip (IC401), which stores channel voice prompts.

5.6 Power Supply:
The station use lithium battery (7.4V, 1500mAh), while transmitter amplifier circuit (Q105 Q107) and receiver audio amplifier (IC302) use battery directly for power supply, and other circuits use regulated voltage (5V and 3V).

IC404:micro-power voltage stabilizer of 3V LDO, provides power (3V) of heavy current for the station together with Q10 and Q30.
IC902:5V LDO
Q405: 5T switch (controlled by MCU)
　　5T: supply power for the front end of transmitter
Q408: 5R switch (controlled by MCU)
　　5R: supply power for the units such as RF amplification, mixing, IF processing and audio signal processing.
Q910: 5C switch (controlled by MCU)
　　5C: the power (5V), controlled by power-down mode, is the supply power of frequency synthesizer.

5.7 MCU Unit:

5.9 Schematic Diagram for MCU Unit

MCU Unit controls the operation of every unit to realize all functions of the CU500-1(CU510-1).
Communication with external PC
State data access
Control PLL for the generation, receiving and transmitting of local oscillation frequency
Access to the current channel state
Control LED status indicator
Control power supplied condition of every unit
Detect action of every function key
Produce CTCSS signal
Produce DCS signal
Produce power controlled signal
Finish CTCSS decoding
Finish DCS decoding
Squelch detection and control
Control voice prompt content

Memory (FLASH)
Channel data, voice data and other function setting data and parameter adjustment data.

CTCSS/DCS signal coding and decoding:

CTCSS/DCS signals from MCU (pin22 and pin18 output) are sent to VCO and TCXO for modulation respectively after filtering by R500 R501 C500 C501 and R504 R503 C920 C921.

CTCSS/DCS signals from receiver are sent to MCU(pin52) for decoding, and then MCU test if there are CTCSS/DCS signals with the same setting of the station to decide whether open the speaker or not.

CTCSS (continuous tone control squelch system, hereinafter referred to as CTCSS), is a kind of squelch control system with modulation on carrier and continuous sub-audio signals as pilot tone. If   CTCSS function is set, the call is available only at the same CTCSS frequency of both receiving and transmitting parties to avoid the disturbance of other signals.
The station has 39 groups of standard CTCSS frequency for your selection, such as Table 1.
CTCSS signals produced by MCU are sent to VCO for modulation after filtered the HF components over 300Hz in low pass filter composed by RC.

Table 1   CTCSS Frequency Table

No.	Frequency [Hz]	No.	Frequency [Hz]	No.	Frequency [Hz]	No.	Frequency [Hz]
1	67.0	11	94.8	21	131.8	31	186.2
2	69.3	12	97.4	22	136.5	32	192.8
3	71.9	13	100.0	23	141.3	33	203.5
4	74.4	14	103.5	24	146.2	34	210.7
5	77.0	15	107.2	25	151.4	35	218.1
6	79.7	16	110.9	26	156.7	36	225.7
7	82.5	17	114.8	27	162.2	37	233.6
8	85.4	18	118.8	28	167.9	38	241.8
9	88.5	19	123.0	29	173.8	39	250.3
10	91.5	20	127.3	30	179.9		

DCS signaling：

DCS (Digital code squelch), is a kind of continuous digital code modulated on carrier with voice signal and used for squelch control. If DCS function is set, the speaker is available only when receiving the same DCS code to avoid the disturbance of useless signals.

The station has 83 kinds of standard codes including positive and inverse code for your selection, such as Table 2.

DCS signals produced by MCU (PWM waveform) are sent to VCO and TCXO for modulation (the HF components of DCS signals are modulated by VCO, while the LF components by TCXO) after filtered the HF components over 300Hz in low pass filter composed by RC.

CTCSS/DCS signals from receiver are sent to MCU for decoding, and then MCU test if there are DCS codes with the same setting of the station to decide whether open the speaker or not.

Table 2   DCS Coding Schedule

023	114	174	315	445	631
025	115	205	331	464	632
026	116	223	343	465	654
031	125	226	346	466	662
032	131	243	351	503	664
043	132	244	364	506	703
047	134	245	365	516	712
051	143	251	371	532	723
054	152	261	411	546	731
065	155	263	412	565	732
071	156	265	413	606	734
072	162	271	423	612	743
073	165	306	431	624	754
074	172	311	432	627	

8 Description of Semiconductor Devices
The distribution of each pin goes as the table 3.

Table 3---Definition of CPU Base Pin:

Pin No.	Port Name	Pin Name	I/O	Active Level	Function
1	APCSW	P33	O	H	APC switch
2	PTT	P34	I	L	PTT switch input
3	MODE	-	-	-	Connect this pin to VCC via a 4.7K resistor(*Burn)

4	SK1	P43	I	L	SIDE KEY1 input
5	SK2	P44	I	L	SIDE KEY2 input
6	RESET	-	I	L	CUP reset (*Burn)
7	XOUT	-	O	-	MCU clock
8	VSS	-	-	-	GND
9	XIN	-	I	-	MCU clock
10	VCC	-	-	-	+3V
11	BSHIFT	P54	O	H	Beat shift switch
12	F_CS	P53	O	L	FLASH chip select output
13	F_DI	P52	O	-	FLASH data in
14	F_CLK	P51	O	-	FLASH serial clock output
15	F_DIO	P50	I/O	-	FLASH data input/output
16	NC	P27	O	-	
17	VCCN	P26	O	-	Frequency regulation output（PWM）
18	DCSTCXO	P25	O	-	CTCSS/DCS output（PWM）
19	PLL_CLK	P24	O	H	PLL clock Output
20	PLL_DAT	P23	O	-	PLL data Output
21	PLL_EN	P22	O	H	PLL enable
22	DCSVCO	P21	O	-	CTCSS/DCS output（PWM）
23	PLL_UL	P20	I	H	PLL unlock detect pin
24	RXVCO	P17	O	H	TX/RX VCO selection(H,RX)
25	BEEP_AF	P16	O	-	Local Beep Control Pin
26	RXD0	P15	I	-	Serial data
27	TXD0	P14	O	-	Serial data
28	GLED	P86	O	H	Green LED
29	RLED	P85	O	H	Red LED
30	NC	P84	O		
31	TDIN	P83	I	TRFI	TONE data input
32	ALARMC	P82	O	L	Alarm switch control（H：Controlled by Volume Switch
					L：Emergency siren maximum volume)
33	DEV2	P81	O	-	Voice deviation adjustment 2
34	DEV1	P80	O	-	Voice deviation adjustment 1
35	NARROW	P60	O	H	12.5KHz
36	MIDDLE	P45	O	H	20KHz
37	TXD1	P66	O	-	Reserved
38	RXD1	P67	I	-	Reserved
39	MIC_MUTE	P65	O	L	MIC mute　　　　L: MIC mute
40	5TC	P64	O	H	Transmitting power control
41	EXTPTT	P63	I	L	External PTT switch input
42	SAVE	P31	O	H	Battery power control H：Power save

43	5RC	P30	O	H	Receiving power control
44	ENC0	P36	I	-	Channel selector input
45	ENC1	P32	I	-	Channel selector input
46	ENC2	P13	I	-	Channel selector input
47	ENC3	P12	I	-	Channel selector input
48	VOX	P11	I	AN9	VOX level input
49	BATT	P10	I	AN8	Battery voltage input
50	AFCO	P00	O	L	Audio Amplification Power
51	SPKSW	P01	O	L	Audio amplifier control
52	DCS_IN	P02	I	AN5	CTCSS/DCS input Recording level input
53	NC	P03	I		
54	BUSY	P04	I	AN3	Busy level input
55	TOPKEY	P62	I	L	TOPKEY input
56	RXMUTE	P61	O	H	RX audio mute
57	RSSI	P05	I	AN2	Received Signal Strength Indicator input
58	PCTV	P06	O	DA0	APC/BPF control output
59	AVSS	-	I		GND
60	DTMF	P07	O	DA1	DTMF/Beep output
61	VREF	-	I		+3V
62	AVCC	-	I		+3V
63	NC	P37	O		
64	RX_W/N	P53	O	H	RX Wide/Narrow switch

Table 4 Functional description of semiconductor device

Item	Model	Function Description
IC1	MB15E03	Frequency Synthesizer
IC100	NJM2904	APC, Voltage Comparison, Driving
IC200	GT3136	Receiver 2nd Local Oscillation, 2nd IF Amplification, Limitation, Demodulation, Noise Amplification
IC300	NJM2902V	Receiver demodulated signal Amplification, Filtering
IC500	NJM2100V	MIC Amplification, Limitation, Filtering
IC302	TDA2822D	Audio Frequency Power Amplification
IC401	W25Q80	FLASH, Channel Frequency Data Storage, Function Setting Parameter, Debug Mode Parameter
IC403	R5F212BCSNFP	MCU