

TS-660 SPECIFICATIONS/CIRCUIT DESCRIPTION

[GENERAL]

Frequency Range:	15 meter band 21.0000 ~ 21.4500 MHz * 12 meter band 24.5000 ~ 24.9999 MHz (Receive only) 10 meter band 28.0000 ~ 29.7000 MHz 6 meter band 50.0000 ~ 53.9000 MHz
Mode:	FM (F3), SSB (A3j), CW (A1), AM (A3)
Frequency Stability: (At room temperature)	Within ± 200 Hz during the first hour after 1 minute of warmup Within ± 30 Hz during any 30 minutes after warmup
Antenna Impedance:	50 Ω
Power Requirements:	12 ~ 16 VDC (13.8 VDC nominal) Transmit (max.) 4 A (SWR: Less than 1.5) Receive 1 A
Semiconductor Complement:	ICs 35 FETs 22 Transistors 156 Diodes 217 Display tube 1
Dimensions (projections excluded):	241 (9-1/2") W x 94 (3-11/16") H x 236 (9-5/16") D mm
Weight:	4.9 kg (10.8 lbs)

[TRANSMITTER SECTION]

RF Output Power:	SSB, CW, FM 10 W AM 4 W
Carrier Suppression:	Better than 40 dB
Sideband Suppression:	Better than 50 dB
Spurious Radiation:	21 ~ 28 MHz band Better than 40 dB 50 MHz band Better than 60 dB
Maximum Frequency Deviation (FM):	± 5 kHz
Microphone Impedance:	500 Ω ~ 50 k Ω
Audio Frequency Response:	400 ~ 2600 Hz (-6 dB)

[RECEIVER SECTION]

Sensitivity:	SSB, CW 0.25 μ V for 10 dB S/N AM 1 μ V for 10 dB S/N FM 1 μ V for 30 dB S/N 0.4 μ V for 12 dB SINAD
Image Ratio:	Better than 60 dB
IF Rejection:	Better than 70 dB
Selectivity:	SSB, CW, AM 2.4 kHz (-6 dB), 4.2 kHz (-60 dB) FM 15 kHz (-6 dB), 32 kHz (-60 dB)
	Optional Filter
	AM filter YK-88A 6 kHz (-6 dB), 11 kHz (-60 dB)
	CW filter YK-88C 500 Hz (-6 dB), 1.5 kHz (-60 dB)
	YK-88CN 270 Hz (-6 dB), 1.1 kHz (-60 dB)
Squelch Sensitivity (FM):	0.32 μ V (at threshold)
Audio Output:	1.5 W
Audio Output Impedance:	8 ~ 16 Ω

Note: Circuit and ratings may change without notice due to developments in technology.

* Will transmit on the new 12 meter band. A lead wired for preventing accidental transmission before government amateur authorization.

RECEIVER CIRCUIT

There are two antenna terminals on the TS-660 : one for 50 MHz ANT 1 and one for 21-28 MHz ANT2. The 50 MHz antenna terminal can be switched to operate the full 21-50 MHz range by means of a rear-panel changeover switch S2. When ANT 1 is used for All-BAND operation, ANT 2 is automatically grounded.

The receiver system is single conversion with an IF of 8.830 kHz. The FM is dual conversion with a 2nd IF of 455 kHz.

At the RF stage, the 50 MHz and 21-28 MHz inputs are independent, but become common from the mixer stage. The 50 MHz antenna signal enters through the transmission LPF (Filter unit, L7-9) and then to the VHF antenna coils. For HF bands (21-28 MHz), the signal enters the RF unit HF antenna coils directly. Changeover between these transmission and reception antenna paths is accomplished by diode switches. However, relays are used for band changeover. Input signals are stepped up by the RF unit antenna coils ; VHF L3, 4 and HF antenna coils (L9-11) and RF amplified by VHF Q1 : 3SK73, or HF Q5 : 3SK73.

Either VHF or HF signal then enters the common mixer (Q3, 4 : 3SK74). A 50 MHz signal enters through matching transformer (T12) and helical resonator (L6). Each H.F. BAND has its own BPF (Band Pass Filter) : (21 MHz L17–19, 24.5 MHz L20–22, 28 MHz L23–25).

In this double balanced mixer, the input signal is mixed with the PLL (phase locked loop) VCO (voltage controlled oscillator) output to derive an 8.83 MHz IF (intermediate frequency) signal. Transformers T2, T3, ceramic filter CF-1 (with a bandwidth of about 50 kHz), and T4 couple this IF signal from the mixer output to the first IF amplifier FET (Q7 : 3SK73).

T5 couples this signal into the noise blanker gate (D22–25) and T6 couples the gate output to the RIF (RX IF), which runs to the IF unit input. The signal to the FM unit is applied from T6 via buffer amplifier (Q7 : 2SC1815). The noise blanker signal is obtained at the output of the 1st IF amplifier (Q7) through FET buffer amplifier (Q10 : 2SK19). This noise signal is amplified by Q11–13 : 2SC460 and detected by D28, 29. Finally the switching driver Q8 : 2SC1815 drives the NB gate to eliminate or reduce pulse-type (ignition) noises.

The signal entering the IF unit from the RF unit is first filtered by the MCF (Monolithic crystal Filter) and then amplified by two IF amplifier stages (Q10, 11 : 3SK73). SSB and CW signals are product detected by D25–28 : 1N60 and fed to the audio preamplifier (Q22 : 2SC2240) via SSB, CW and AM squelch switch transistor (Q43 : 2SC2240).

The AM mode is derived from the output of Q11 through buffer amplifier (Q15 : 2SC1815) and detected by diode (D49 : 1N60). This is amplified by Q25 : 2SC1815 and fed to the squelch switch transistor Q43. SSB and CW or AM mode selection is performed by diode switches (D40, 41). In all cases excluding FM, a squelch signal is taken from the AGC line and amplified by Q39 : 2SC1815 and Q40 : 2SK40. Q41 : 2SA1015 is adjusted by the squelch control. This biases Q42 : 2SC1815 OFF at no signal, and ON when signal is present, to bias Q43 : 2SC2240 on when signal is present.

In the FM mode, the RF unit FMI output is delivered to the FM unit, where the signal is input to Q5 : MC3357, a monolithic IC containing the second conversion oscillator, mixer, limiting amplifier, quadrature discriminator, active filter, squelch, scan control, and mute. Q4 : 2SC2240 buffers the detected output and returns this audio signal (via the FAF line) to the IF unit, D42 switch.

FM signal meter drive (FSM) is derived through amplifiers Q6,7 : 2SC1815 (Y), transformer T3, and rectifiers D5,6 : 1N60.

Audio signals for each mode are preamplified by Q22, volume controlled, then power amplified by the audio output IC (Q23 : HA1366W).

Item	Rating
Center frequency (fo)	8831.5 kHz ± 250 Hz
–6 dB bandwidth	6 kHz
Attenuation bandwidth	11 kHz
Guaranteed attenuation	80 dB or more
Ripple	2 dB or less
Loss	3 dB ± 2 dB
Input and output impedance	600Ω//15pF
Temperature	–10°C~+50°C

**Table 1 AM Crystal filter YK-88A
(L71-0223-05) Option**

Item	Rating
Center frequency fo	8830.7kHz
Center frequency deviation	fo ± 150Hz at 6dB
6dB bandwidth	± 250Hz or more
60dB bandwidth	± 900Hz or less
Ripple	2dB or less
Loss	6dB ± 2dB
Guaranteed attenuation	80dB or more within fo ± 2kHz to ± 1MHz
Input and output impedance	600Ω/15pF

**Table 2 CW Crystal filter YK-88C
(L71-0211-05) Option**

Item	Rating
Center frequency fo	8830.7kHz
Center frequency deviation	fo ± 50Hz at 6dB
6dB bandwidth	± 125Hz or more
60dB bandwidth	± 600Hz or less
Ripple	2dB or less
Loss	8dB ± 2dB
Guaranteed attenuation	80dB or more within fo ± 2kHz to ± 1MHz
Input and output impedance	600Ω/15pF

**Table 3 CW Crystal filter YK-88CN
(L71-0221-05) Option**

Item	Rating
Nominal center frequency (fo)	455 kHz
3 dB bandwidth	±5 kHz or more
6 dB bandwidth	±7.5 kHz or more
60 dB bandwidth	±16 kHz or less
Guaranteed attenuation	Within 455±100 kHz 45 dB or more
	Within 0.1~1.0 MHz 30 dB or more
Ripple	(Within 455±5 kHz) 3 dB or less
Loss	5 dB or less
Input and output impedance	1.5 kΩ

**Table 4 Ceramic filter CFT455F2
(L72-0309-05)**

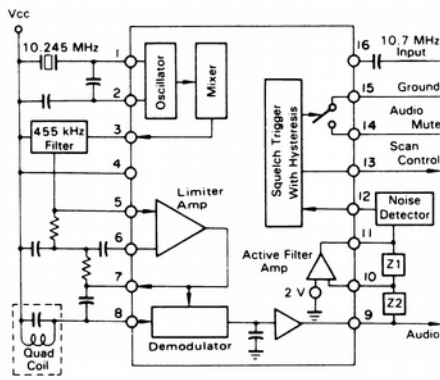


Fig. 1 MC3357P Block diagram

TRANSMITTER CIRCUIT

As in the receiver system, the transmitter is single conversion in the SSB, CW and AM modes and dual conversion in the FM mode.

In SSB and AM modes, the MIC audio signal is amplified in the switch unit by Q1 : 2SC2240, Q2, 3 : 2SC1815, and applied to the balanced modulator (D29–32 : 1N60) on the IF unit, where an 8.83 MHz DSB signal is generated. In SSB mode, this is buffer-amplified by Q17 : 2SK19, and passed through the 8.83 MHz MCF (Monolithic Crystal Filter) exiting as an SSB signal SSB mode. In the AM mode Q17's output is switched through either R91 82Ω or YK-88A AM filter (option) when installed. SSB, CW and AM mode signals are then amplified by the transmitter IF amplifier (Q18 : 3SK73) and are output via the TIF line from the IF to the RF unit.

In the FM mode, the audio signal from the Switch unit microphone amplifier (Q1 : 2SC2240) goes to the FM unit via the FMC line. In the FM-1 unit, the MIC signal is amplified and limited by Q1 : TA7061AP, an OP AMP, and is applied to varicap diode D1 : 1S2208 to modulate crystal X1.

The 8831.5 kHz carrier output generated by oscillator Q2 : 2SC460 and amplified Q3 : 3SK74 is fed via the FMT line to the RF unit (connector 6) and into the transmitter balanced mixers (Q15, 16 : 3SK74).

SSB, CW and AM or FM signal selection is performed by diode switching (D29, 30).

The various mode signals are mixed with the VCO output for each band by the transmitter balanced mixers (Q15, 16) and this output is routed to one of two paths ; one for 50 MHz and the other for 21–28 MHz. Signal path selection is performed by diodes D31, 32. The 50 MHz signal is filtered by helical coils L37 and then amplified by transmitter amplifier Q17 : 3SK73.

This is then further filter by helical coils L38 and amplified in two stages (Q18, 19 : 2SC2086).

This 50 MHz signal is relay selected (RL1) and is fed to the DRV (DRIVE) terminal and then to the Final unit. 21–28 MHz signals are first Band Pass Filtered, then amplified by wide-band amplifiers Q21 : 2SC1815 and Q22 : 2SC2086. These 50 MHz or 21–28 MHz signals are fed to the Final unit via relay RL1.

The signals input to the Final unit are amplified by a wide band push-pull driver amplifiers (Q1, 2 : 2SC1971), and then amplified by wide band push-pull final amplifiers (Q3, 4 : 2SC1972) to the 10W output level. This RF output is Low Pass Filtered for each band in the Filter unit. ALC detection is provided by Q1, and protection is provided by Q2 (both 2SC1815) before the LPF section.

Item	Condition	Symbol	Rating			Unit
			TYP	MIN	MAX	
Output voltage	$V_i = 15V$ $I_o = 350mA$	V_o	9.00	8.65	9.35	V
MAX output current	$V_i = 15V$	I_o, MAX	750	—	—	mA

Table 5 NJM78M09A (V30-1107-16) Electrical Characteristic

	VCBO	VEBO	VCEO	IC	PC	Tj	Tstg	Ta
Condition			R = $\infty\Omega$		Tc = 25°C			25 $\pm 3^\circ C$
MAX rating	35V	4V	17V	2A	12.5W	+150°C	-55~ +175°C	

Table 6 2SC1971 (V03-1971-16) Max Rating

	VCBO	VEBO	VCEO	IC	PC	Tj	Tstg	Ta
Condition			R = $\infty\Omega$		Tc = 25°C			25 $\pm 3^\circ C$
MAX rating	35V	4V	17V	3.5A	25W	+175°C	-55~ +175°C	

Table 7 2SC1972 (V03-1972-16) Max Rating

PLL CIRCUIT

The TS-660 uses a system of three Phase-Locked Loops to obtain the final VCO (voltage controlled oscillator) output frequency. A 16 MHz master oscillator is employed, from which all other standard fixed frequencies are derived. Frequency control is achieved by a 10 Hz step digital VFO feeding an 8 bit microcomputer (μ PD8048C), which controls the divide ratio of each PLL circuit.

Fig. 2 shows the PLL circuit block diagram. VCO 1 consists of a PLL circuit operating between 6–4 MHz in 2 kHz steps, using a 2 kHz reference frequency and a divide ratio of $1/N1=1/3000-1/2001$. The divider used is a TC9122P. The divide ratio is set as a 13 bit BCD signal. Next, this 6–4 MHz signal is divided by 1/200 to become a 30–20kHz signal in 10 Hz steps. It is then mixed with the 8 MHz standard frequency by MIX 1 and this becomes a 7.97–7.98 MHz output signal, with a bandwidth of 10 kHz provided by a Monolithic Crystal Filter.

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This signal enters the VCO 2 PLL circuit through MIX2.

Table 8 shows the frequency relationships within the first PLL.

VCO 2 operates between 6–7 MHz in 10 kHz steps using a 10 kHz reference frequency and a divide ratio 1/N2 of 1/197–1/98. The divider used is an MC14569B and the divide ratio is set as an 8 bit binary input, as shown in **Table 9**.

As previously mentioned, VCO 2 is controlled in 10 kHz steps. While VCO 1 operates in 10 Hz steps. The mix of the VCO 1 signal 7.97–7.98 MHz in 10 Hz steps by MIX 2 yields a VCO 2 operating range of 6–7 MHz in 10 Hz steps by the sum of 1/N1 and 1/N2 divide ratios.

This signal is then mixed with the CAR frequency, filtered, and fed into MIX 4. Here, one of two standard frequencies are mixed. For the 21 and 24 MHz bands, 4 MHz is injected. For the 28 and 50 MHz bands, 32 MHz is injected. Therefore, the output for the 21 and 24 MHz bands becomes 18.83–19.83 MHz and for the 28 and 50 MHz bands 46.83– 47.83 MHz. This signal is fed into the final PLL circuit through MIX 5.

PLL-3 actually contains three VCO's. The 21 and 24 MHz bands share VCO 3-1 with a 1 MHz coverage.

The 28 MHz band VCO 3-2 covers a 2 MHz range. The 50 MHz band VCO 3-3 covers a 4 MHz range.

This PLL employs an MC4044P phase comparator and a 1 MHz reference frequency, along with a conventional SN74LS163AN TTL-type divider. **Table 10** shows the frequency relationships within the Final Loop circuit.

Display	VCO1 (MHz)	1/N1	f3 (kHz)	f4 (MHz)
0.0 0	6.000	1/3000	30.000	7.970000
0.0 1	5.998	1/2999	29.990	7.970010
⋮	⋮	⋮	⋮	⋮
5.0 0	5.000	1/2500	25.000	7.975000
⋮	⋮	⋮	⋮	⋮
9.9 8	4.004	1/2020	20.020	7.979980
9.9 9	4.002	1/2001	20.010	7.979990

↑
Not displayed

Table 8

The RIT (Receiver Incremental Tuning) function uses an 8 MHz VXO (Variable X-TAL Oscillator) circuit which is switched in place of the 8 MHz standard input signal to MIX 1. During CW transmission, the 800 Hz carrier shift is performed by this VXO.

IF shift is easily accomplished, since the carrier frequency is mixed in the PLL circuit.

When the CAR frequency is VXOed, both the IF input (to the MCF), and Product Detector CAR input shift, moving the IF input signal across the MCF Pass Band width. In the TS-660, there are two carrier crystal oscillator circuits. In CW, SSB, and AM TX, CAR 1 operates at 8.8315 MHz. In the FM and AM RX modes, the carrier frequency into PLL MIX 3 is lowered 100 kHz by CAR 2 : 8.7315 MHz. Simultaneously, the divide ratio 1/N2 is changed to raise the VCO 2 frequency 100 kHz. So the final VCO output remains the same.

Displayed frequency	VCO2	1/N2	1/N2(binary)							
			MSB				LSB			
50.000.0	6.000	1/197	1	1	0	0	0	1	0	1
50.010.0	6.010	1/196	1	1	0	0	0	1	0	0
⋮	⋮	⋮	⋮							
50.500.0	6.500	1/147	1	0	0	1	0	0	1	1
⋮	⋮	⋮	⋮							
50.980.0	6.980	1/99	0	1	1	0	0	0	1	1
50.990.0	6.990	1/98	0	1	1	0	0	0	1	0

Table 9

BAND	f1 (MHz)	VCO3 (MHz)	f2	1/N3	Divide ratio			
					D	C	B	A
21	18.83~19.83	29.83~30.83	11	1/11	0	1	0	1
24	"	32.83~33.83	14	1/14	0	0	1	0
28	46.83~47.83	36.83~37.83	10	1/10	0	1	1	0
39	"	37.83~38.83	9	1/9	0	1	1	1
50	"	58.83~59.83	12	1/12	0	1	0	0
51	"	59.83~60.83	13	1/13	0	0	1	1
52	"	60.83~61.83	14	1/14	0	0	1	0
53	"	61.83~62.83	15	1/15	0	0	0	1

Table 10

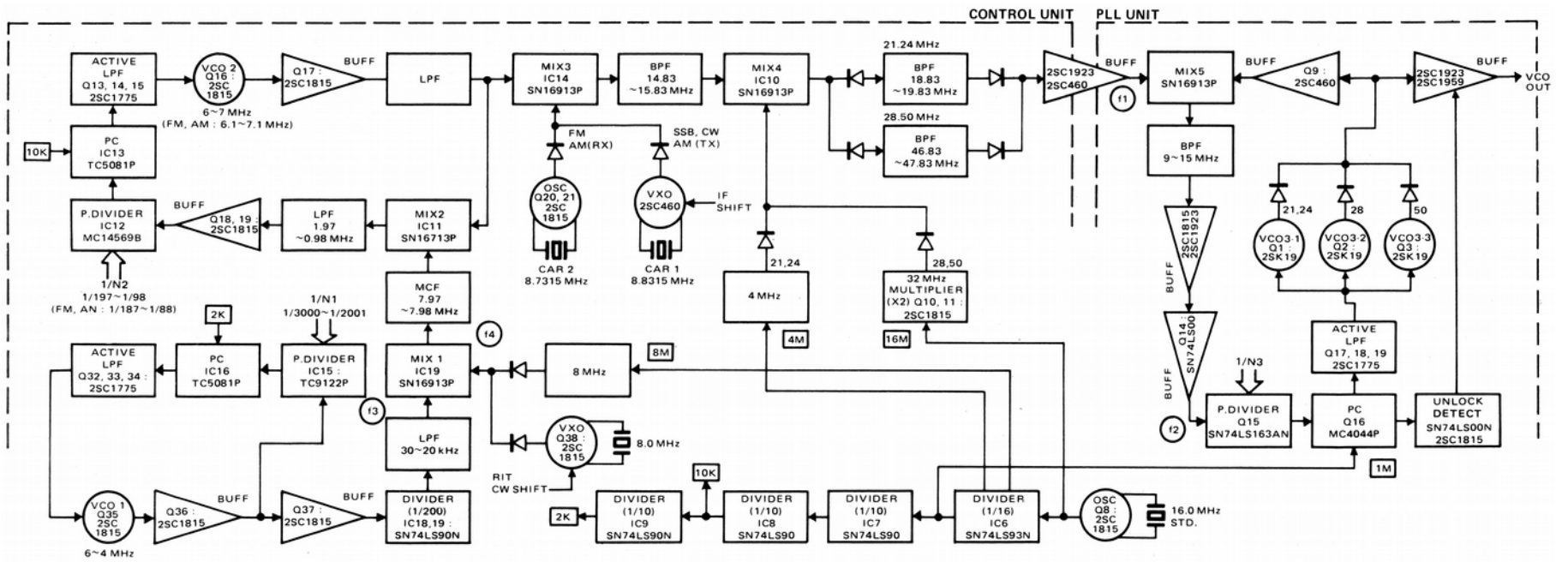


Fig. 2 PLL Block diagram

CONTROL CIRCUIT

● Rotary encoder input circuit

In the encoder unit a 250-slit rotary tuning disk and two photo-interrupters generate two clock signals with a 90° phase difference. This is fed to the Control unit via the EN1, 2 lines. These are waveform shaped by Schmitt trigger gate IC23 (TC4049BP), then multiplied by four through IC21, 22 (TC4011BP) so that a signal of 250 pulses/rotation becomes 1,000 pulses/rotation.

This is input to the microcomputer INT terminal (Pin 6) via one-half of flip-flop IC20-2 (TC4011BP).

The encoder's direction of rotation is identified by phase difference of its two output signals. flip-flop IC20-1 delivers this to microcomputer input T1 (Pin 39). Timing and waveforms are shown in **Fig. 3**.

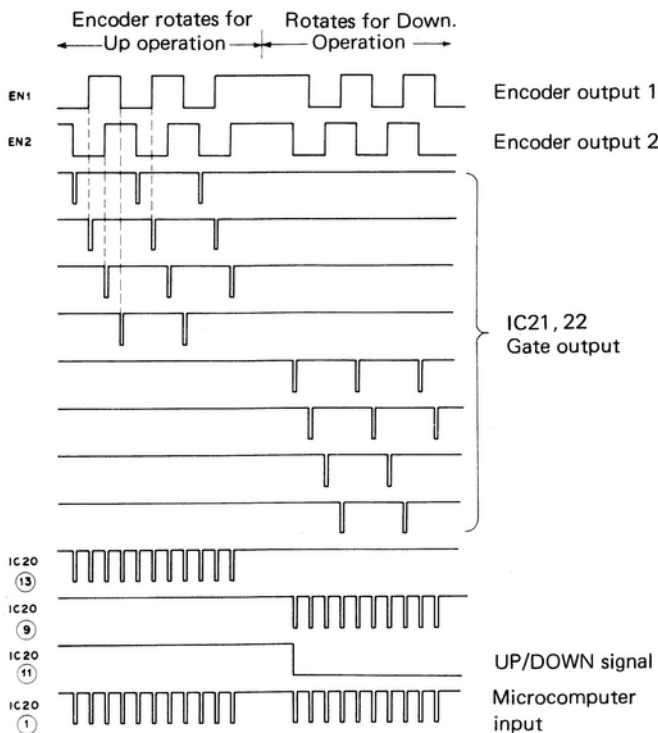


Fig. 3 Encoder output to micro-processor input timing and waveforms

● MIC Frequency shift circuit

The TS-660 permits frequency shift control by microphone-mounted switches. To generate the frequency shift control clock, the TS-660 incorporates a dedicated clock oscillator. The oscillator consists of an astable multivibrator combining two NAND gates (IC24-1 : TC4011BP). Frequency shift is controlled by the interval in which the switch is held down, and is switchable between step-by-step and continuous shifting. Shift speed is determined by CR time constant C149 (0.022μF) and R158 (150kΩ) to be approximately 100 Hz to achieve a shift speed of about 1 kHz/sec.

The 1-step shift function involves direct input to the microcomputer to terminal via IC2 (SN74LS151N) and is separate from the Timing circuit.

The interval from the step-by-step to continuous shift is determined by R160 (82kΩ) and C151 (10μF).

● Buzzer circuit

In the TS-660, a tone is generated to confirm BAND change, UP/DOWN frequency operation or MEMORY STORE by means of a driver circuit and a ceramic oscillator. When any of these operations occur, a pulse of several μsec. is output from IC1 terminal P73 (Pin 16). This pulse is multiplied by 10 by a one-shot multiplier circuit IC24-2 (TC4011BP) and RC R6 (83kΩ) and C1 (1μF), and a tone is generated by switching on the power supply to the ceramic transducer.

● Switch input circuits

All front-panel switch signals (FUNCTION, MEMORY, CH, M, S HOLD, BAND, etc.) are fed to the control unit and then compiled by diode matrix D7-10, 13-17, 19-22. This information is fed to the microcomputer via two data selector ICs.

IC2 (SN74LS151N) is a 1 bit x 8 ch data selector handling MODE, MIC, BAND UP/DOWN and S HOLD signals. IC3 (TC4019BP) is a 4 bit x 2 ch data selector handling FUNCTION, MEMORY and CH data input.

● Microcomputer power supply circuit

The microcomputer 5V power supply (IC5 : μPD8048C) has two 5V input terminals : a VCC terminal (No. 40) for microcomputer operation and developed on the Control unit, and a VDD terminal (No. 26) for internal RAM back-up fed from the external main power source. Therefore, the VDD 5V is applied only during back-up to hold the memory.

