INTEGRATED CIRCUIT

TECHNICAL DATA

TC9124AP

"C²MOS" DIGITAL INTEGRATED CIRCUIT

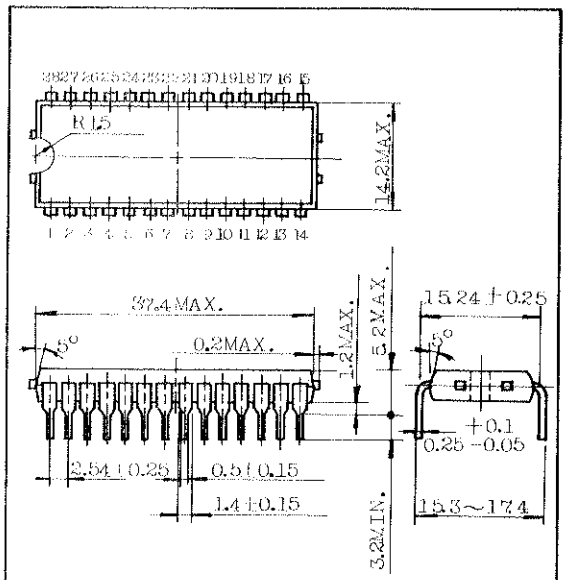
SILICON MONOLITHIC

TC9124AP FM/AM SYNTHESIZER TUNER CONTROLLER

TC9124AP is C-MOS LSI developed and designed especially for FM/AM synthesizer tuner controller, permitting composition of high performance synthesizer tuner in combination with C-MOS LSI TC9123BP for use in digital PLL.

More emphasis is placed in design on definite operability to attain high tuning function by simple key operation.
Of C-MOS construction, TC9124AP requires minor operating current, permitting easy long-term memory backup by the use of cell.

Unit in mm



Lead pitch is 2.54 and tolerance is ±0.25 against theoretical center of each lead that is obtained on the basis of No. 1 and No. 28 leads.

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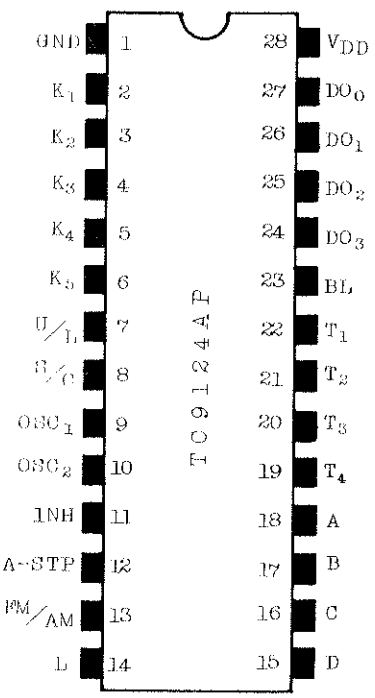
PIN CONNECTION



MAXIMUM RATINGS (Ta=25°C)

CHARACTERISTIC	SYMBOL	RATING	UNIT
Supply Voltage	V_{DD}	−0.3 ∿ 10	V
Input Voltage	V_{IN}	−0.3 ∿ V_{DD} + 0.3	V
Output Current*	I_{OUT}	40	mA
Operating Temperature	$T_{opr.}$	−30 ∿ +75	°C
Storage Temperature	T_{stg}	−55 ∿ +125	°C

(Note) The asterisk * signifies bipolar transistor open emitter sink current for DO_0 ∿ DO_3.

GENERAL DESCRIPTION OF TC9124AP FUNCTIONS

Before detailed explanation of TC9124AP, brief description will be given below of its functions and features, and reference shall be made to the latter part of this technical data for more details of each of the relevant items.

1. TC9124AP PERMITS CONTROL OF THE FOLLOWING FIVE BANDS.

DESIGNATION OF BAND	RECEIVED FREQUENCY BAND	FREQUENCY STEP	REMARKS
FM_U	87.5 ∿ 108.0 MHz	100 kHz	FM U.S.A band
FM_E	87.5 ∿ 108.0 MHz	50 kHz	FM European band (50 kHz separation)
FM_L	76.0 ∿ 90.0 MHz	100 kHz	FM Japan band
AM_1	525 ∿ 1605 kHz	1 kHz	AM 10 kHz separation
AM_2	531 ∿ 1602 kHz	1 kHz	AM 9 kHz separation

2. SETS, FULL OF VARIETIES, WITH MULTIPLE TUNING FUNCTIONS CAN BE DESIGNED:

   a. 1 step/1 push tuning with [UP] or [DOWN] key.

   b. Rapid feed tuning by continuous depression of [UP] or [DOWN] key.

   c. Automatic search tuning by [AUTO] and [UP] or [DOWN] keys.

   d. Direct data tuning with ten keys [0] through [9].

   e. Tuning by memory read-out.

3. LSI HAS MEMORY FOR TWELVE STATIONS

   a. The 12-station memory can be used randomly, irrespective of reception mode, or six stations can be assigned each for FM and AM mode.

b. Depress [WRITE] and memory number keys for memory write (two operation). For memory read-out, depress memory number key alone (open-push operation).

c. Independent of the 12-station memory, LSI has a built-in AUTO MEMORY performing automatic read/write operation when FM/AM mode change-over is executed.

d. All the memories are composed of static C-MOS RAM to fulfill low voltage and minor power consumption operation requirements.

4. CAREFUL CONSIDERATION HAS BEEN GIVEN IN DESIGN TO VARIOUS DISPLAYS

a. Digital display of received frequency (4 digits).

b. Mode display of FM, AM and CLOCK.

c. Display of auto-search tuning, memory write and direct data preset operations.

d. Display of 12-station memory read-out.

Received frequency data are dynamically outputted in BCD code from TC9124AP, and LED is driven by the external decoder/driver IC TC5002P. By selecting decorder driver IC, numerical display can use fluorescent display and liquid crystal display device.
Dimmer feature is provided that controls display frightness in two steps.

5. THOUGHTFUL CONSIDERATION HAS BEEN PAID TO AUTO-SEARCH TUNING OPERATION.

a. Scan speed in automatic search operation can be regulated with the external CR of OSC-2 to the design of set.

b. In AM_1 mode, scanning is performed in 1 kHz steps, but stop is limited to frequencies of integer times 10 kHz.

c. In AM_2 mode, scanning is executed in 1 kHz steps, but stop is limited to frequencies of integer times 9 kHz.

d. In FM mode, scanning is performed in 100 kHz steps, but the operation is not stopped in the 100 kHz step point that follows the channel just preceding the point where auto-search operation starts, to ensure complete separation from reception state to facilitate design of set.

6. LSI HAS LOCK FUNCTION THAT REJECTS ANY OPERATION KEY INPUTS.

7. Since TC9124AP has control terminal (INH) which causes all outputs to be stopped when the power supply of radio set is in "OFF" position and makes LSI's operation, including OSC oscillation, completely static, it is possible to fully back up reception state (memory content) with minor current by use of a cell or condenser for many hours when the power supply is in "OFF" position.

DESCRIPTION OF FUNCTIONS OF EACH TERMINAL

PIN NO.	SYMBOL	NAME OF TERMINAL	DESCRIPTION OF FUNCTIONS AND OPERATIONS	REMARKS
2 ~ 6	K_1 ~ K_5	Key signal input terminal	Input terminal for various operation keys, capable of issuing twenty kinds of instructions in total for assigning different operations with inputs at each timing of T_1 through T_4.	
7	U/L	Band change-over input terminal	Input terminal for assigning FM_U/FM_L in FM mode and AM_1/AM_2 in AM band, each being independently settable.	
8	S/C	Synthesizer/ clock change-over output terminal	Signal output terminal used to add clock IC and to change display mode (frequency/ clock). The output is at "H" level in synthesizer operation and at "L" in clock operation.	

PIN NO.	SYMBOL	NAME OF TERMINAL	DESCRIPTION OF FUNCTIONS AND OPERATIONS	REMARKS
9	OSC-1	Oscillator terminal 1	Terminal of oscillator for system control clock, including T_1 through T_4, connecting C, R to outside.	
10	OSC-2	Oscillator terminal 2	Oscillator termial for timing clock to determine AUTO SCAN speed, memory write time, etc., connecting C, R to outside.	
11	INH	Inhibit terminal	Inhibit control terminal at memory back-up. Normal operation at "H" input and memory state at "L" input.	
12	A.STP	AUTO STOP signal input terminal	When "H" input is applied to this terminal in automatic scanning, the Scan operation is stopped.	
13	FM/AM	FM/AM change-over output terminal	"H" output in FM mode and "L" output in AM mode. This terminal is used for FM/AM changes of prescaller and FM/AM mode display.	
14	L	Load signal output for PLL LSI	Output terminal for connection to load terminal of PLL LSI TC9123BP and for assigning data read-in timing.	
15 16 17 18	D C B A	Receiving frequency data output terminal	Data output terminal for received frequency. 4-digit BCD data are serially outputted in synchronization with the timing of T_1 through T_4. It is used for received frequency data of display driver and programmable counter of TC9123BP.	

PIN NO.	SYMBOL	NAME OF TERMINAL	DESCRIPTION OF FUNCTION AND OPERATIONS	REMARKS
19 20 21 22	T_4 T_3 T_2 T_1	Digit signal output terminal	Digit signal output for controlling all the timings, such as A ∿ D output data, K_1 ∿ K5 key input timing, DO_0 ∿ DO_3 display output, etc.	
23	BL	Display blanking output terminal	Blanking signal output for prevention of blurred display and for brightness change. Connected to BI of TC5002P.	
24 25 26 27	DO_0 DO_1 DO_2 DO3	Various mode display driver output	Driver output to display operation state of TC9124AP, such as memory read-out address, AUTO SCAN, memory write, etc. Because of its dynamic lighting in synchronization with T_1 through T_4, 16 types of display are available.	

DETAILED EXPLANATION OF FUNCTIONS AND OPERATIONS OF TC9124AP

1. I/O TIMING WITH EMPHASIS ON T_1 THROUGH T_4

In most cases with TC9124AP, input and output operate in synchronization with digit signals of T_1 through T_4. A ∿ D frequency data outputs and DO_0 ∿ DO3 display outputs are subjected to change at each timing of T_1 through T_4 and are sent out as dynamic data, while K_1 ∿ K5 key signal inputs and U/L band change-over input are synchronized in LSI for data read-in. Instructions have different meanings, depending on each timing.

Functions of each I/O terminal at T_1 through T_4 are listed in the following table.

ELECTRICAL CHARACTERISTICS (Unless otherwise specified V_{DD}=7.5V, Ta=25°C)

CHARACTERISTIC	SYMBOL	TEST CIRCUIT	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Operating Supply Voltage	V_{DD}			7	–	10	V
Operating Supply Current	I_{DD}		Output Open Scanning	–	–	-5	mA
Quiescent Supply Current	I_{DD}(1)		INH=GND	–	–	250	μA
	I_{DD}(2)		INH=GND, V_{DD}=2V	–	–	10	
Memory Back Up Voltage	V_{MB}		INH=GND	2	–	–	V

"H" LEVEL OUTPUT CURRENT

S/C Output	I_{OH} S/C		V_{OH}=6V	-1.0	–	–	mA
FM/AM Output	I_{OH} FM/AM						
BL Output	I_{OH} BL						
L Output	I_{OH} L			-0.5	–	–	
$A_0 \sim D_0$ Output	I_{OH} A0∿D0			1.0	–	–	
$T_1 \sim T_4$ Output	I_{OH} T_1∿T_4			-3.5	–	–	

"L" LEVEL OUTPUT CURRENT

S/C Output	I_{OL} S/C		V_{OL}=1V	1.0	–	–	mA
FM/AM Output	I_{OL} FM/AM						
BL Output	I_{OL} BL						
L Output	I_{OL} L			0.5	–	–	
$A_0 \sim D_0$ Output	I_{OL} A0∿D0			1.0	–	–	
$T_1 \sim T_4$ Output	I_{OL} T_1∿T_4						

$DO_1 \sim DO_3$

Output Current	I_{OUT}		V_{OUT}=6V	-30	–	–	mA
Output Leakage Current	I_{OLL}			–	–	-10	μA

FM/AM, BL, $A_0 \sim D_0$, TRI-STATE LEAKAGE

Leakage Current	"H" Level	I_{TLH}	–	–	–	10	μA
	"L" Level	I_{TLL}		–	–	-10	

U/L, $K_1 \sim K_5$

Pull Down Resistance	U/L	R_{IN} U/L	–	30	–	300	kΩ
	$K_1 \sim K_5$	R_{IN} K1∿K5		10	–	60	
Input Voltage	"H" Level	V_{IH}		5.0	–	VDD +0.3	V
	"L" Level	V_{IL}		-0.3	–	1.0	

A-STP, INH

Input Current	"H" Level	I_{IH}	V_{IN}=7.5V	–	–	10	μA
	"L" Level	I_{IL}	V_{IL}=0	–	–	-10	

INTERNAL BLOCK DIAGRAM FOR TC9124AP

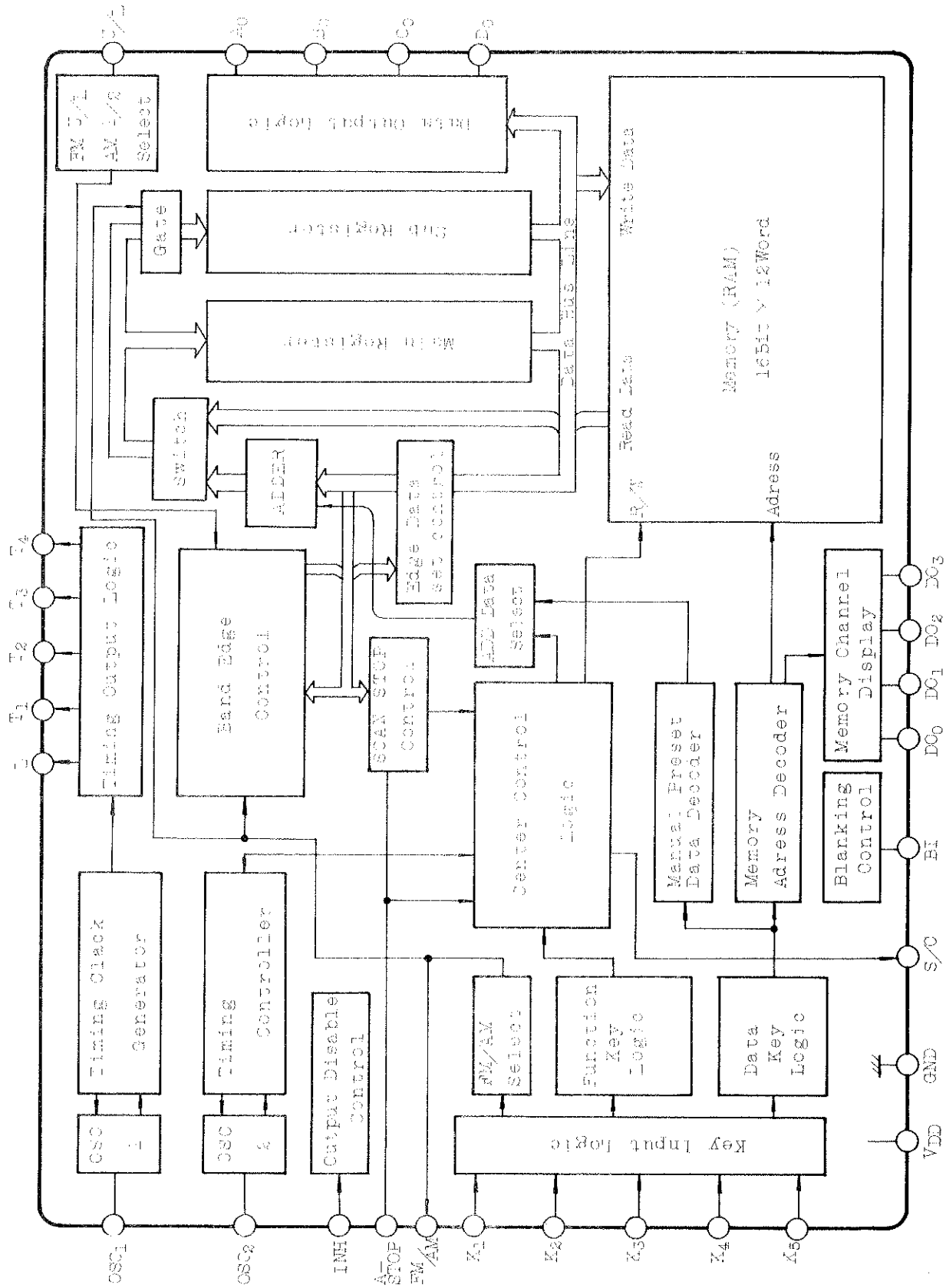
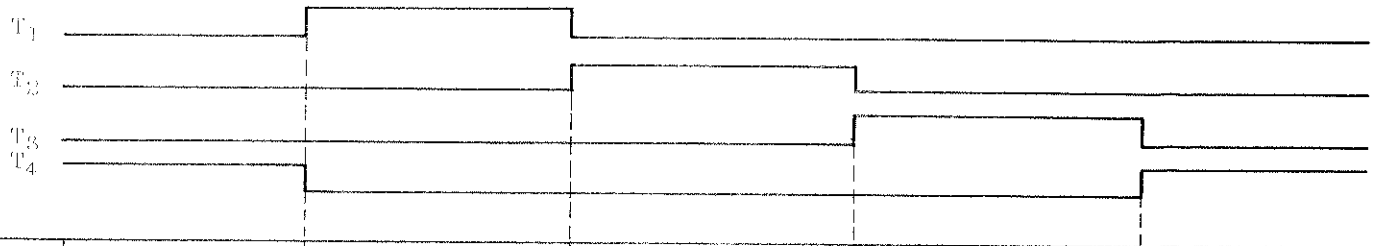


Table 1-1



SYMBOL	FUNCTION	T_1	T_2	T_3	T_4
A	Data output to TC9123BP and received frequency display device	Received frequency data × 1 digit 1	Received frequency data × 10 digit 10	Received frequency data × 100 digit 100	Received frequency data 1000
B		2	20	200	
C		4	40	400	Reception mode assigning output
D		8	80	800	
DO_0	Operation mode read-out display output	Direct tuning	Decimal point at FM	Auto-search tuning	Memory write
DO_1		Memory ①	Memory ②	Memory ③	Memory ④
DO_2		Memory ⑤	Memory ⑥	Memory ⑪	Memory ⑫
DO_3		Memory ⑦	Memory ⑧	Memory ⑨	Memory ⑩
K_1	Operation key signal input	FM mode designatin	Auto-search command	①	②
K_2		Direct tuning	Memory write command	③	④
K_3		Display dimmer	Clock change-over	⑤	⑥
K_4		Key lock		DOWN	UP
K_5		AM mode designation	FM mode designation	(n) + 6	(n) + 6
U/L	Band change input	Band change		FM_U designation	AM_2 designation

[A] Explanatory Supplement to Table 1

(i) A ∿ D Output Terminal

The four outputs (T_1 ∿ T_4) dynamically send out received frequency data and mode in synchronization with T_1 through T_4. These data are forwarded to frequency display section and connected, at the same time, to PLL LSI TC9123BP for various kinds of control.
A through D at the timing of T_1 through T_3 and A at T_4 are all BCD code frequency data, as listed in Table 1, but B, C and D at T_4 are operation mode assigning data of TC9123BP, as given below.

Table 1-2 (at timing T_4)

Mode	B	C	D
FM_U	H	H	H
FM_E	(L or H)	H	H
FM_L	H	L	H
AM_1	L	H	L
AM_2	L	L	L

- B in FM_E mode is "L" for frequency of integer times 100 kHz and "H" for frequency of +50 kHz.
- No special note shall be taken of these data; control will be effectuated simply by connecting A ∿ D lines to A ∿ D of TC9123BP.

(ii) Operation Key Input

K_1 through K_5 are inputs for keys for various operations, but they receive each of the timing signals T_1 through T_4 as a different instruction. When T_1 signal is given to K_2 terminal, for instance, it is an instruction for direct data preset with ten keys. If T_2 is given, it is an instruction for memory write. Similarly, T_3 is for read-out of memory 3 and T_4 for read of memory 4 .

In other words, five $K_1 \sim K_5$ lines and four $T_1 \sim T_4$ lines constitute a key matrix, permitting twenty kinds of instructions in total ($5 \times 4 = 20$).

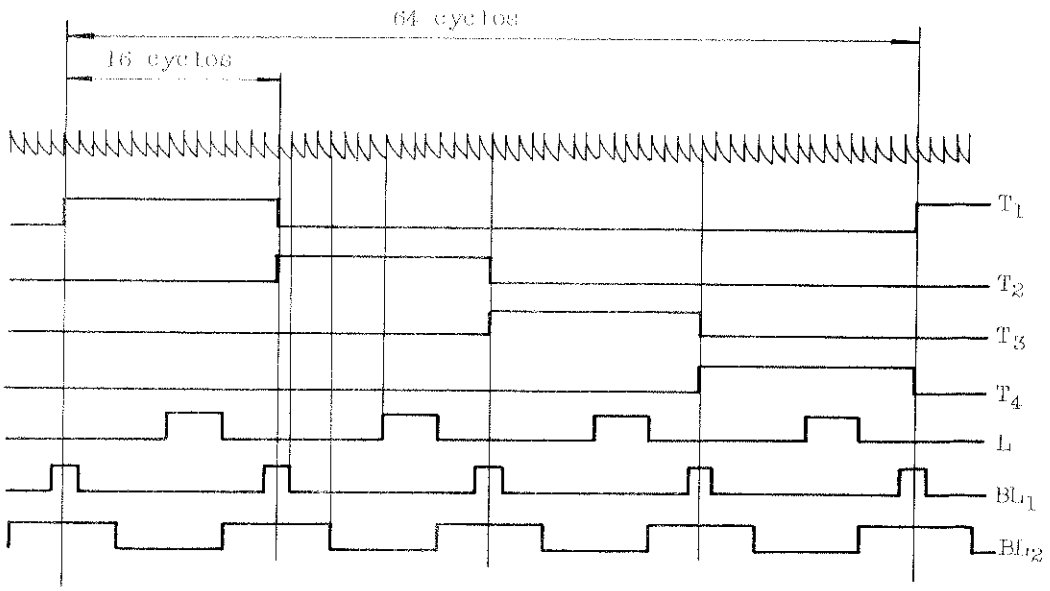
[B] Determination of Digit $T_1 \sim T_4$ Timing Frequency. (OSC_1)

$T_1 \sim T_4$ frequencies are determined by the constant of C, R externally connected to OSC-1 (⑨ pin). If f_1 stands for the oscillation frequency of OSC-1, each of the $T_1 \sim T_4$ frequencies will be $f_1/64$. Fig. 1-1 is the timing chart, showing the relation of f_1 frequency to other output terminals.

The frequency of T_1 through T_4 mainly determined by the optimum conditions for dynamic display, but usually for 4 digit dynamic, proper frequency will be in the order of 200 Hz to 1 kHz with a stationary radio set and 500 Hz to 1 kHz with a radio set which is subject to vibrations, as in vehicles. Therefore, the oscillation frequency of OSC-1 will normally be in the order of 30 to 60 kHz.

Oscillation of OSC-1 is stopped in inhibit state to reduce current consumption.

Fig. 1-1



[C] Determination of Frequency of OSC-2

(i) In addition to OSC-1 for timing clock generation for the system described above, TC9124AP has another oscillator OSC-2. This OSC-2 does not usually oscillate, except when required to control various timings. The following are controlled by the oscillation frequency f_2 (Hz) of OSC-2. (For more details, refer to the respective item of functional descriptions.).

1. Time T_1 before shifting is effected to continuous rapid feed by keep depressing [UP] or [DOWN] Key

$$T_1 = 20/f_2 \text{ (sec)}$$

2. Rapid feed tuning speed and scan speed in auto-search tuning

$$n \text{ step/sec}, \quad n = f_2 \text{ (step/sec)}$$

3. Writable time T_2 from the push of memory write [W] Key to automatic reset

$$T_2 = 64/f_2 \text{ (sec)}$$

(ii) The oscillation frequency f_2 of OSC-2 is determined by putting all these elements together, but since f_2 is affected by the oscillation frequency f_1 of OSC-1 as well as the constant of C, R which is connected to OSC-2 terminal, it is necessary to determine f_1 in advance. A proper value of f_2 will normally be 10 to 30 Hz.

2. METHOD OF SELECTING RECEPTION BAND

With TC9124AP, selectable bands are FM_U, FM_E, FM_L, AM_1 and AM_2, five in total, as described above. The following will describe how to select the bands in some details.

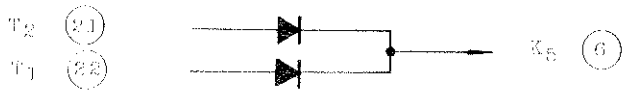
[A] FM/AM Select

For FM/AM select, connect KEY, as illustrated in Fig. 2-1, and apply T_1 signal to K_5 input for AM and T_2 signal to the input for FM.

The KEY used is normally a push type non-lock key. In this case, even when [FM] key is depressed into FM reception state, if AM channel stroke memory is once read out, it is changed over to AM state, as the memory content has priority.

Fig. 2-1

Fig. 2-2

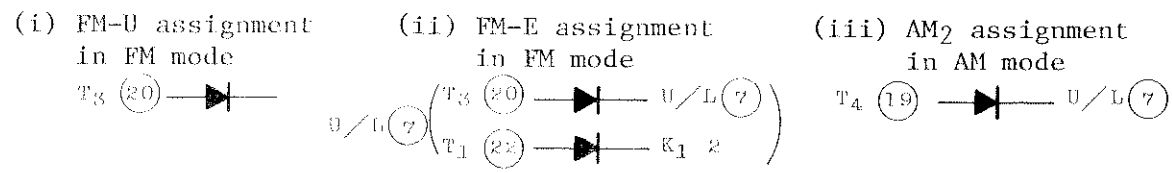


Without [FM] and [AM] keys, as shown in Fig. 2-2, when T_1 and T_2 are directly connected to K_5 through a diode, FM/AM select function will be such that FM mode is selected when T_3 or T_4 signal is applied to K_5 and AM when both signals are not applied to the terminal. (For more details, refer to the item of Memory).

[B] FM-U, -E and -L Select and AM-1 and -2 Select

When FM or AM mode is selected by the method described above, frequency band assignment in either mode can easily be made by connecting a diode as shown in Fig. 2-3.

Fig. 2-3



- o FM-L and AM_1 require no such connections as given above.
- o The diode K_1 to T_1 for FM_E can be changed over either to FM_U or FM_E by ON/OFF operation of the switch.

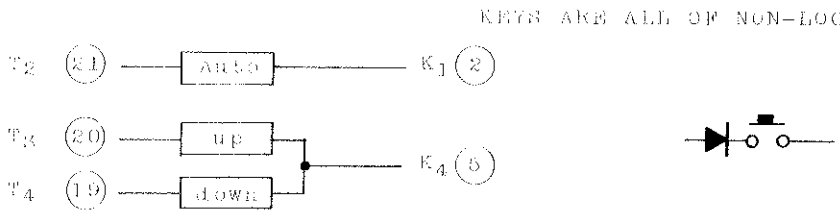
3. METHOD OF TUNING

As stated above, there are various methods of tuning for TC9124AP. The following will describe manual tuning with [UP] or [DOWN] Key and auto-search tuning with [AUTO] Key.

[A] Connection of [UP], [DOWN] and [AUTO] Key

The three keys used for tuning are connected as shown in Fig. 3-1.

Fig. 3-1



[B] 1 Step/1 Push Tuning

Single short-time push of [UP] or [DOWN] Key will shift up or down received frequency by 100 kHz for FM_U and FM_L, 50 kHz for FM_E and 1 kHz for AM_1 and AM_2.

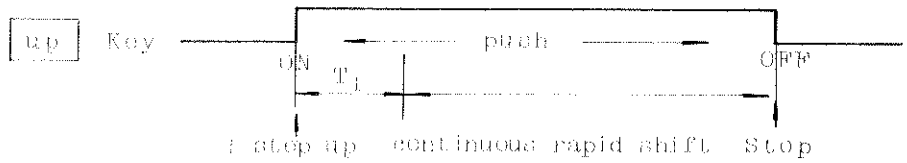
When the upper band edge specified is reached in continuous UP operation, no further key operation can shift the frequency. Similarly, in continuous DOWN Key operation, shift will stop at the lower band edge.

[C] Continuous Rapid Feed Tuning

Keep [UP] or [DOWN] Key depressed for a certain time T_1 for rapid up or down shift of received frequency. Release the key to stop the shift. The time T_1 and rapid shift speed are determiend by the oscillation frequency of OSC-2 ((10) pin). If this frequency is taken as f_2 (Hz), the parameters will be given by the formula:

$$T_1 = \frac{20}{f_2} \text{ (sec)}, \quad \text{Rapid shift speed} = f_2 \text{ (step/sec)}$$

Fig. 3-2



As in 1 step tuning above, scanning in continuous rapid tuning is stopped at either of the band edges.

[D] Auto-search Tuning

This auto-search tuning is one of the major advantages of synthesized tuner. In this system, tuner will automatically detect and receive broadcast frequency. TC9124AP is provided with many useful features utilizing this function.

Before we go into details of auto-search tuning, possible problem involving this tuning method.

o Problems in auto-search tuning

(i) Problem of scan speed:
User will prefer higher scan speed, especially in AM mode because of its wider reception band. However, as design of radio set is restricted by the lock up time of PLL system and the time constant of detection of received signal level, the scan speed can not be determined easily, where "cut-and try" methods are closely involved.

(ii) Problem of erroneous stop:
In AM broadcast, ideal step of receivable frequency is 1 kHz, but in auto-scanning, the operation can stop 1 to 2 kHz short of the station frequency by detecting any carrier, Unlike FM, AM mode has no means of detecting carrier frequency, so that it is very difficult to take a proper countermeasure against this problem.

(iii) Problem of detuning for auto-scan tuning:

Suppose certain broadcasting is being received, when auto-stop signal (reception detection signal) remains valid. In this case, separation from the current channel can be difficult for auto-scan. This is due to similar causes as those described in (ii). Sometimes, even in FM mode, the auto-stop signal can not be eliminated at 100 kHz step point immediately after auto-scan is started to cause the problem.

Thus, auto-search tuning method has various problems in designing radio sets, and it is the very part that frequently causes troubles. However, in TC9124AP, sufficient countermeasures against such problems have been taken to ensure reliable applications.

The following pages will have detailed explanation of auto-tuning functions of TC9124AP.

[E] Method of Auto-search Tuning

For auto-tuning with TC9124AP, depress [AUTO] Key first and the display lamp will go on. Then, select [UP] or [DOWN] Key for higher or lower frequency and depress it to start auto-scan operation.

Unlike manual tuning, once the key is depressed, auto-scan operation will continue if the key is released. When the band edge is reached in auto-tuning, the frequency data will not stop there but turn back to keep scanning. This is another difference from manual tuning.

Scan operation is stopped when "H" level signal is applied to A.STP terminal ((12) pin), and at the same time, the auto tuning display lamp will go off.

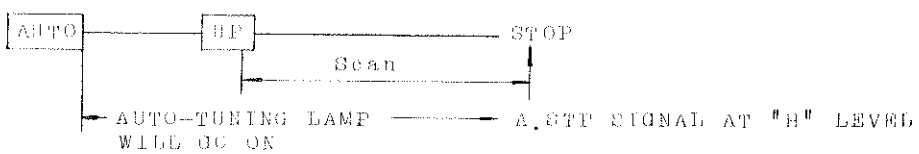
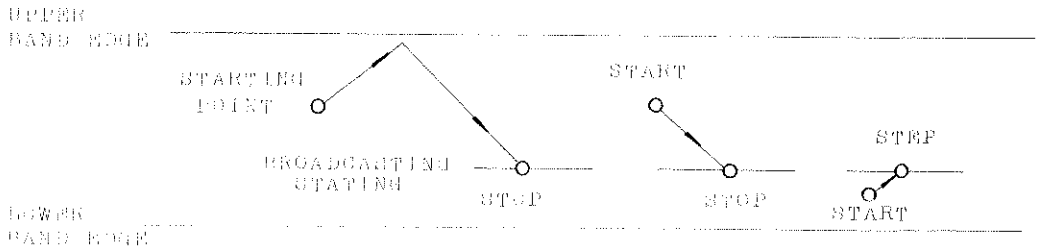


Fig. 3-3 Auto-tuning Procedure

Fig. 3-4 Auto-tuning Scan Method



[Note]

(1) When memory channel is read in auto-tuning operation, this operation is cancelled, and memory content is displayed in normal way.

(2) Auto-tuning will start with "H" level signal applied to A-STP terminal in reception.

(3) In upward auto-scan operation, depress DOWN Key, and it will be instantly changed to downward scanning.

(4) The signal to be applied to A-STP terminal is preferably IF (460 kHz) carrier rectifying signal for AM and resultant voltage of IF (10.7 MHz) rectifying voltage and S-curve center detecting signal for FM.

[F] Characteristics of Auto-search Tuning of TC9124AP

TC9124AP is characterized by the following auto-tuning functions.

(i) Adjustable auto-scan speed:
As in the case of continuous rapid shift tuning, auto-scan speed is determined by the oscillation frequency f_2 of OSC-2 (f_2 step/sec). Therefore, the adjustment of scan speed can be performed by altering the constant of C, R connected to OSC-2 to the properties of other parts of a radio set.

(ii) Auto-tuning stop point in AM:

To solve the erroneous stop problem mentioned above, TC9124AP is so designed that scan operation is not stopped when "H" level signal is applied to A.STP terminal unless the frequency data satisfy the following values.

MODE	FREQUENCY STEP	FREQUENCY AT WHICH SCAN STOPS
AM_1	10 kHz	Frequency of integer times 10 kHz
AM_2	9 kHz	Frequency of integer times 9 kHz

(iii) Separation from current channel in FM:

To ensure positive separation from current channel in FM mode, provision has been made so that stoppage will not occur at the step point immediately following the start of auto-scan operation - at frequency separated by 100 kHz - even when A-STP signal still persists. This permits allowance for the time constant of the circuit that generates auto-stop signal for receiver, with resultant ease of design.

4. MEMORY FUNCTIONS OF TC9124AP

One of the most useful features of synthesizer tuner is that optional frequency data can always be stored in memory for one-touch selection of desired channel. Memory functions of TC9124AP are substantially designed to give full play to the advantage.

[A] Characteristics of TC9124AP Memory Function

- o Built-in 12-station memory, independent of any external elements.
- o 12-station memory, capable of storing FM and AM data, thus permitting free use of FM and AM modes as well as assignment of six channels each for FM and AM.

- o Auto-memory function provided in addition to 12-station memory, permitting automatic data transfer between operation register and subregister in FM/AM change-over operation, without causing any inconvenience in the change-over operation.
- o Wide selection range of external key arrangement and memory application method, allowing comparative freedom in design of receiver functions, panel design and the like.
- o Capability of backup with minor current requirement, as TC9124AP is of C-MOS construction, causing all the operations to stop in INH (inhibit) state, while ensuring static memory retention.
- o Wide range of operating voltage in memory RAM, permitting ease of constant voltage backup with cell or condenser, as memory content can be held down to low voltage.

[B] How to Use 12-station Memory

(i) Method of memory-related key connection

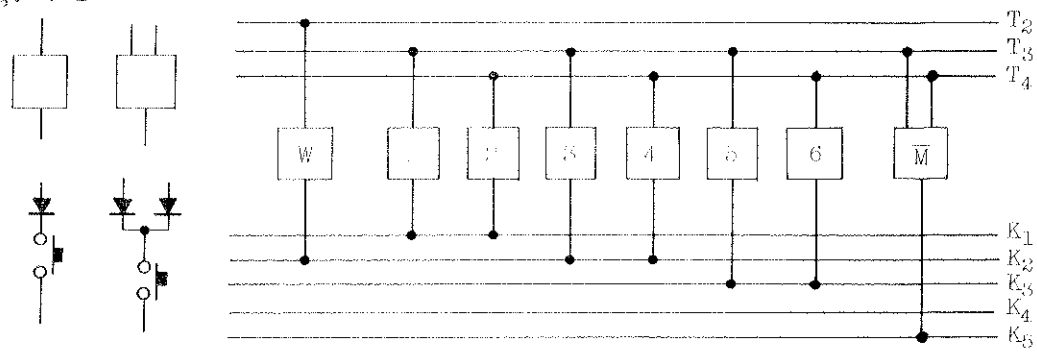
- o There are made available in TC9124AP various methods of use and connection of keys related to 12-station memory . The most fundamental composition is shown in Fig. 4-1.
- o In this method, twelve channels are assigned to the memory with six keys [1] through [6] and [M] Key; if only any of the keys is depressed, memory address corresponding to the key number is assigned, but when [M] key is operated simultaneously with any of the numbered keys, memory address corresponding to the key number plus 6 is designated.

(Example)

[3] key depressed	Memory address 3
[3] and [M] keys depressed	Memory address 3 + 6 = 9

o With reference to Fig. 4-1, the connection allows free write of FM and AM channels into any of the 12-station memory addresses. With FM dedicated units, it is possible to write either FM channels or AM channels into all the addresses.

Fig. 4-1



o [M] key function requires no special use of key, but six stations each can be selected for FM and AM by interlocking the FM/AM change-over key or add the other keys [7] through [12].
(For further details, refer to Item C to follow.)

(ii) How to write into memory

o Memory write is performed by two-time operation of keys. First, push [W] Key (write), and the memory write LED lamp will go on. Then, assign the desired memory address with the relevant key, when the received frequency data at that time will be stored in the memory.

o Depressing [W] Key will immediately put memory in writable state, but it is left to stand with no numbered keys depressed, the state will be cancelled after a certain time, and the LED lamp will also go off. The time depends upon the oscillation frequency f_2 of OSC-2 and can be expressed by the following formula.

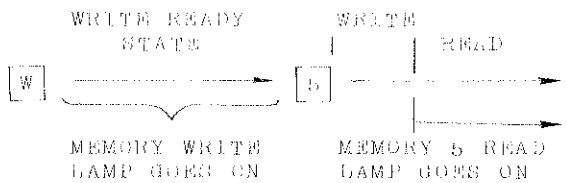
$$T = 64/f_2 \text{ (sec)}$$

If f_2 is 20 Hz, for instance, the time will be approximately 3.2 sec.

o The above automatic cancellation function is provided to prevent stored memory from being erased when [W] Key is operated by mistake.

o Suppose 80.0 MHz is selected by tuning and the frequency is set to memory 5. Depress [W] Key, and the memory write lamp will light. Then, push [5] Key. This operation will cause the lamp to go off, but instead, it will cause the read lamp of memory 5 to go on. This is because the write operation is completed after a complete cycle of the timing T_1 through T_4, and it is immediately followed by the read operation of memory 5 by a built-in change-over feature. This state is shown in Fig. 4-4.

Fig. 4-2



Note: For display part, such as memory write display, read display, etc., refer to descriptions of display functions in the following pages.

(iii) Memory read method

o Memory read can be executed simply by operating the key of desired memory number from any operation state. For example, when you want to select channel of memory 4, depress the key 4 , and the read display lamp of memory 4 will instantly go on. The frequency display will also change to the content of memory 4 to receive the channel frequency.

o At initial making of power supply, data stored in memory are not known. If memory read is executed in this state, there is a great possibility of frequency data beyond the reception band.

With TC9124AP, however, memory content is read for transfer to operation register, and at the same time, the band edge detection function will determine if the frequency is within the reception band; if not, the content in the operation register is corrected into the band edge data.

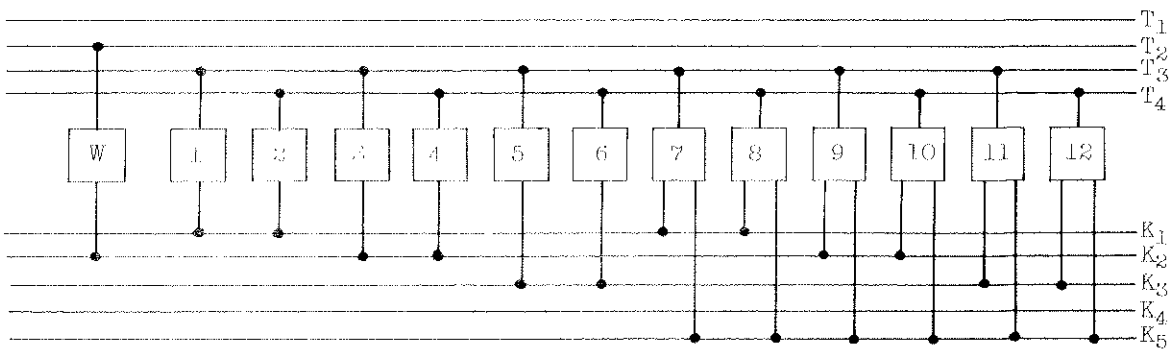
This operation is only for comparison between the content of the register and the band edge data stored in ROM in TC9124AP for ultimate correction, if necessary, but not for rewriting the memory content into the band edge data.

[C] Example of Use of TC9124AP Memory

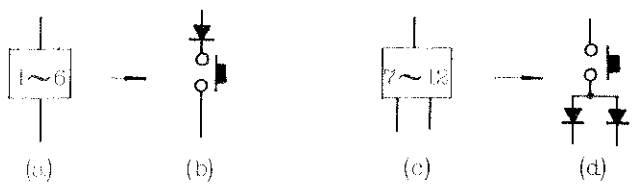
Various uses can be made of memory with TC9124AP by changing external key connections. A typical example will be explained below.

(i) 12 memory key, FM/AM free type

Fig. 4-3



(Note) Keys are all of non-lock push type.

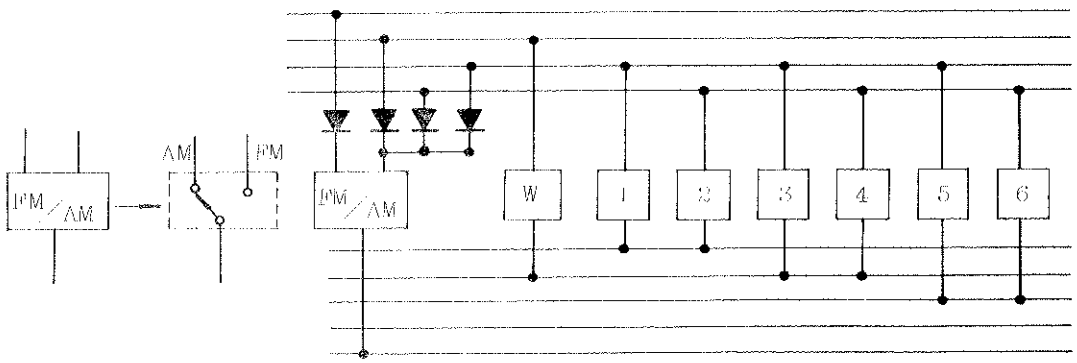


In this method, all the memories [1] through [12] can freely be used either in FM or AM channel. When FM is set to memory [1] and AM in memory [2], for instance, the system will be in FM mode if [1] is depressed, and it will be automatically changed to AM mode when [2] is operated. Therefore, it is necessary that [FM] and [AM] keys shall be of non lock push type.

(ii) 6 memory key, FM/AM each limited to 6 channels

12-station memory is divided into two parts, six channels each for FM and AM, and memory keys are six, [1] through [6]. Interlocking with FM/AM change-over, memory key addresses are changed to 1 through 6 and 7 through 12.

Fig. 4-4

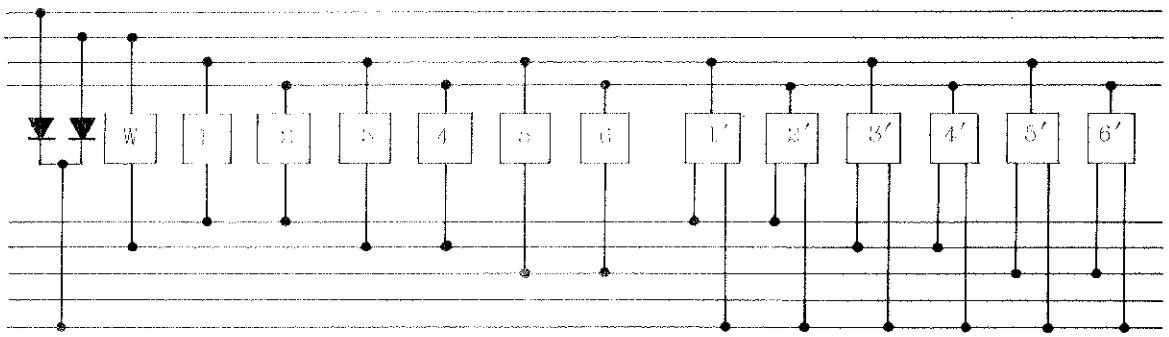


o In this case, FM/AM key is in common use, eliminating the M key as used in the method described in [B] (ii) above. Therefore, memory address [1] through [6] are assigned by operating through 6 in AM mode, but in FM mode, as [M] signal is already in, memory addresses 7 through 12 are assigned. Accordingly, lock type push key (not non lock type) or two-contact-per-circuit change-over switch is suitable as FM/AM key in this system.

(iii) 12 memory key, 6 channels each for FM and AM without FM/AM change-over key

This is an automatic change-over system without any keys or switches for FM/AM mode switching. Memories [1] thorugh [6] are depressed for AM mode and memories [7] through [12] for FM mode. As FM/AM change and main memory read-out are simultaneously executed in this system, auto-memory does not operate.

Fig. 4-5



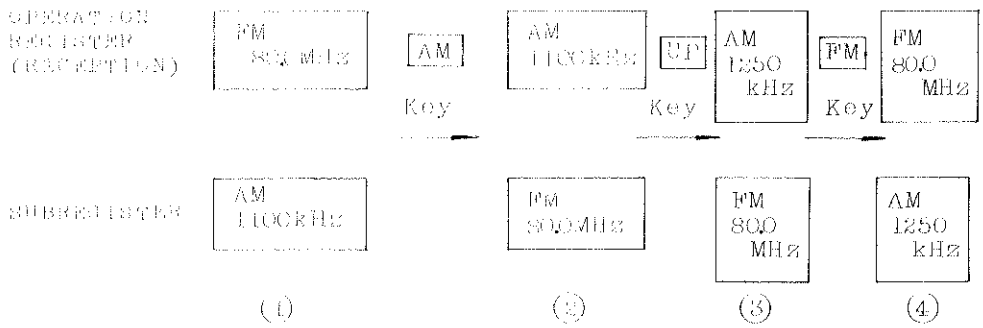
[D] Description of Auto-memory Functions

Suppose the mode is changed over to FM by depressing FM key while receiving 1100 kHz in AM. The 1100 kHz data signify 110.0 MHz for FM, but this frequency is outside the FM band and is thus drawn back to the band edge. To solve such inconveniences likely to occur in FM/AM change-over, auto-memory function is incorporated in TC9124AP.

- o Auto-memory is a data conversion function to automatically read the content of subregister into operation register and at the same time to write the frequency data being received till the time, that is the content of the operation register into the subregister, requiring no operation at the time of FM/AM change-over.
- o As shown in the diagram below, 1100 kHz data are currently entering the subregister and 80.0 MHz frequency is being received in FM mode.

If the set is changed to AM mode by pushing [AM] key, the operation register is instantly changed to 1100 kHz and the subregister is rewritten to 80.0 MHz data. Then, if [FM] key is depressed again after 1250 kHz frequency, as attained by operating [UP] key, etc. in AM mode, is received, the set will automatically be turned into 80.0 MHz receiving state in FM mode and 1250 kHz of AM mode is written in the subregister.

Fig. 4-6



o Exceptionally, however, if 82.5 MHz data of FM mode have been written in the address 3 of main memory in the condition ③ of the above diagram and its read-out is executed by operating [3] key, the set will be changed over to FM mode and the 1250 kHz data will enter the subregister, as illustrated in the above diagram, but the operation register will be changed to 82.5 MHz as main memory has priority.

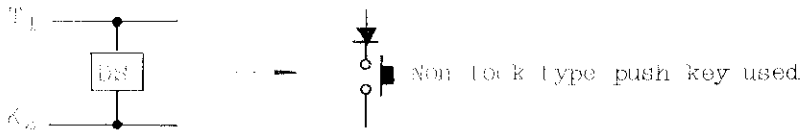
5. DIRECT DATA SET FUNCTION

As a characteristic tuning function of TC9124AP, the frequency data of desired channel can be directly set by using 10 keys (0 through 9). The following will describe this method in details.

o Direct data set key [DS]

To instruct TC9124AP to follow this tuning method, connect DS key between T_1 line and K_2 input, as illustrated in Fig. 5-1.

Fig. 5-1



o TEN Keys

This tuning method requires ten keys (0 ∿ 9), but as TC9124AP is provided with twelve keys (1 ∿ 12) as memory key, these are used in common. Namely, the circuits in LSI are switched by depressing DS key in such a way that all the memory keys operate as key for data input. The memory keys (1 ∿ 12) as data key will have the following correspondence.

Fig. 5-2

MEMORY KEY	1	2	3	4	5	6	7	8	9	10	11	12
SET DATA	1	2	3	4	5	6	7	8	9	0	1	2

o TC9124AP's operation with DS key depressed

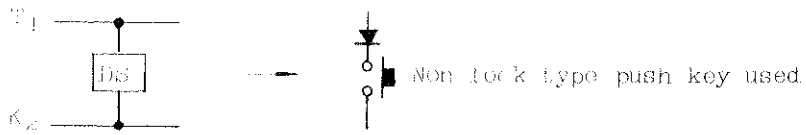
1. DS lamp will go on. (See description of T_1 timing display function for DO_1 output.)
2. Load signal of L output terminal ((14) pin) will stop, and data transfer to PLL LSI TC9123BP will no longer take place.
3. Memory keys are changed over to data keys (0 ∿ 9), as described above.
4. The function of band edge detection circuit will stop. (For details, refer to the explanation to follow.)

o Direct data set procedure

Key operation procedures for direct data set will be explained below by taking FM 82.5 MHz as example.

To instruct TC9124AP to follow this tuning method, connect DS key between T_1 line and K_2 input, as illustrated in Fig. 5-1.

Fig. 5-1



o TEN Keys

This tuning method requires ten keys (0 ∿ 9), but as TC9124AP is provided with twelve keys (1 ∿ 12) as memory key, these are used in common. Namely, the circuits in LSI are switched by depressing DS key in such a way that all the memory keys operate as key for data input. The memory keys (1 ∿ 12) as data key will have the following correspondence.

Fig. 5-2

MEMORY KEY	1	2	3	4	5	6	7	8	9	10	11	12
SET DATA	1	2	3	4	5	6	7	8	9	0	1	2

o TC9124AP's operation with DS key depressed

1. DS lamp will go on. (See description of T_1 timing display function for DO_1 output.)
2. Load signal of L output terminal ((14) pin) will stop, and data transfer to PLL LSI TC9123BP will no longer take place.
3. Memory keys are changed over to data keys (0 ∿ 9), as described above.
4. The function of band edge detection circuit will stop. (For details, refer to the explanation to follow.)

o Direct data set procedure

Key operation procedures for direct data set will be explained below by taking FM 82.5 MHz as example.

KEY	DESCRIPTION	DISPLAY
FM	FM channel data shall be set in FM mode. If it is in FM mode from the beginning, this key operation is not required. Any frequency data will do in this case. Suppose it is 80.0 MHz.	8 0 0
DS	The operation described above will follow. At the time, the receiver continues receiving 80.0 MHz.	0 0 0
8	8 is set in the low-order digit	0 0 8
2	8 is shifted one digit up, and 2 is set in the low-order digit.	0 8 2
5	8 and 2 are shifted one digit to the left, and the low-order digit will have 5 set.	8 2 5
W	If memory write key [W] is operated, all the functions of TC9124AP, as changed with [DS] key, are returned to normal. That is to say, 1. DS lamp will go off 2. Load pulse will appear at L output, 82.5 MHz data will be conveyed to PLL and receiption will start. 3. Data keys will return to memory keys. 4. Band edge detection circuit will operate.	8 2 5

Note: a. In case of wrong numeral data, depress [DS] key again to reset displayed data to 000.0.
b. When data beyond the frequency band specified by TC9124AP are set, operate [W] key in the last position to actuate the band edge detection circuit, which will correct the data to the band edge data. In the case of FM_L, the set data 18.0 MHz will be corrected to 90.0 MHz and 185.0 MHz to 76.0 MHz.

6. DISPLAY FUNCTIONS OF TC9124AP

A synthesizer tuner using TC9124AP requires the following displays.

1 Display of received frequency 4-digit numeric display

2 FM/AM display

3 Memory read display Total twelve (1 ∿ 12) or six

4 Auto-search display

5 Memory write display

6 Direct data preset display

7 Other displays

[A] Display of Received Frequency

o With TC9124AP, data are sent in BCD code from each of the output terminals (A, B, C and D), depending on the timing T_1 through T_4, as listed in Table 1 given in Item 1. Thus, received frequency can be displayed by connecting the output terminals A through D to BCD —— 7-segment decoder driver TC5002P, etc. and by driving it with digit signals T_1 through T_4.

o It should be noted here, however, that it is necessary to stop display, since B, C and D data at timing T_4 are operation mode assigning code to PLL LSI TC9123BP.

o As an example of A ∿ D output data, a timing chart at reception of 82.5 MHz in FM_L mode is given below.

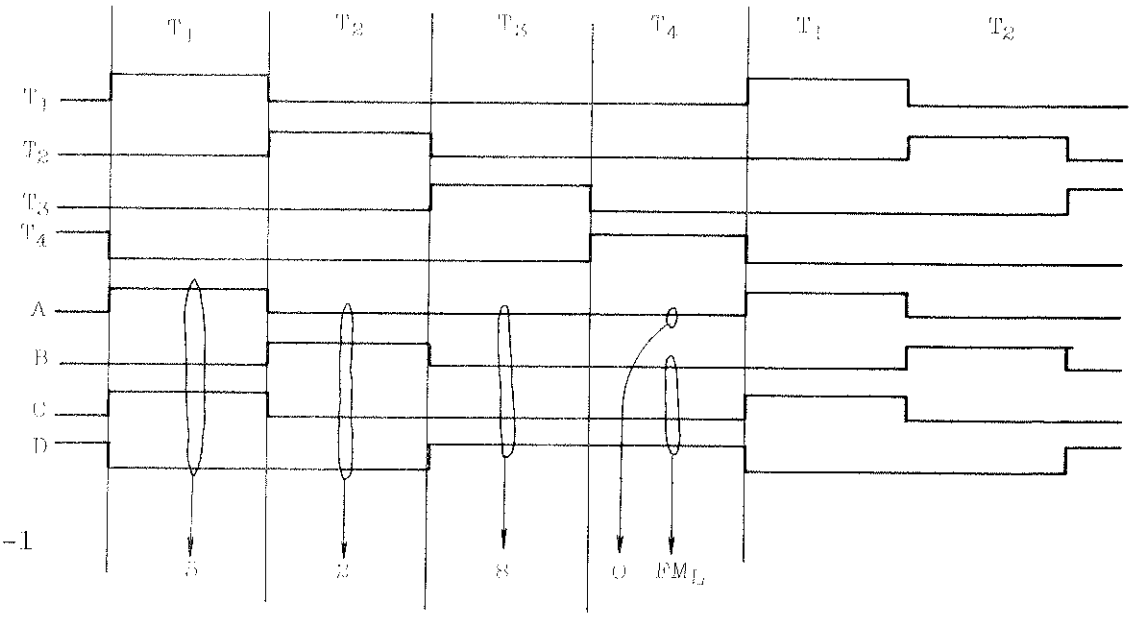


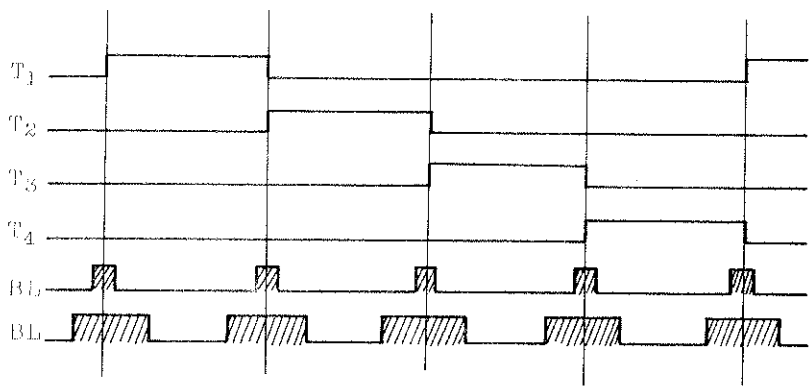
Fig. 6-1

o Function of BL (blanking) terminal

TC9124AP is provided with BL ((23) pin) as control terminal for prevention of blurred display and for regulation of brightness in two steps. The signal outputted from this terminal has such wave forms as shown in Fig. 6-2. It generates positive pulses when dynamic lighting of T_1 through T_4 is changed over. The pulse length will get larger when the key [L] (light), regulating brightness, is depressed.

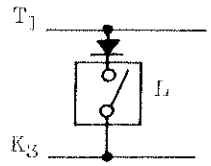
Thus, blur prevention and brightness adjustment can be attained by applying the BL signal to B_1 terminal of LED decoder driver IC TC5002P.

Fig. 6-2



Display is blanded along the broken lines

Fig. 6-3



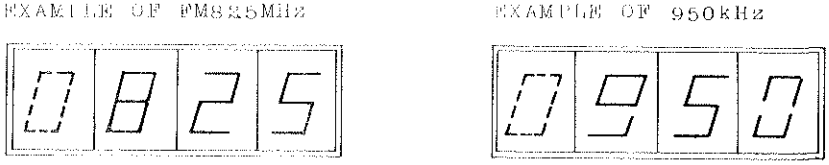
o Display brightness adjustment key [L]

Light key [L] is connected between T_1 and K_3 in the similar was as shown in Fig. 6-3. When this key is held down, display will get less bright, so lock key or ON/OFF switch is used.

o Method of zero suppression in the high-order digit

As received frequency is displayed in four digits, as illustrated in Fig. 6-4, with TC9124AP, the high-over digit will have zero display in the case of less than 100 MHz in FM and less than 1000 kHz in AM. To suppress this 0, apply T_4 to RBO (zero suppress terminal) of TC5002P. When input is 0, display is suppressed only at T_4.

Fig. 6-4



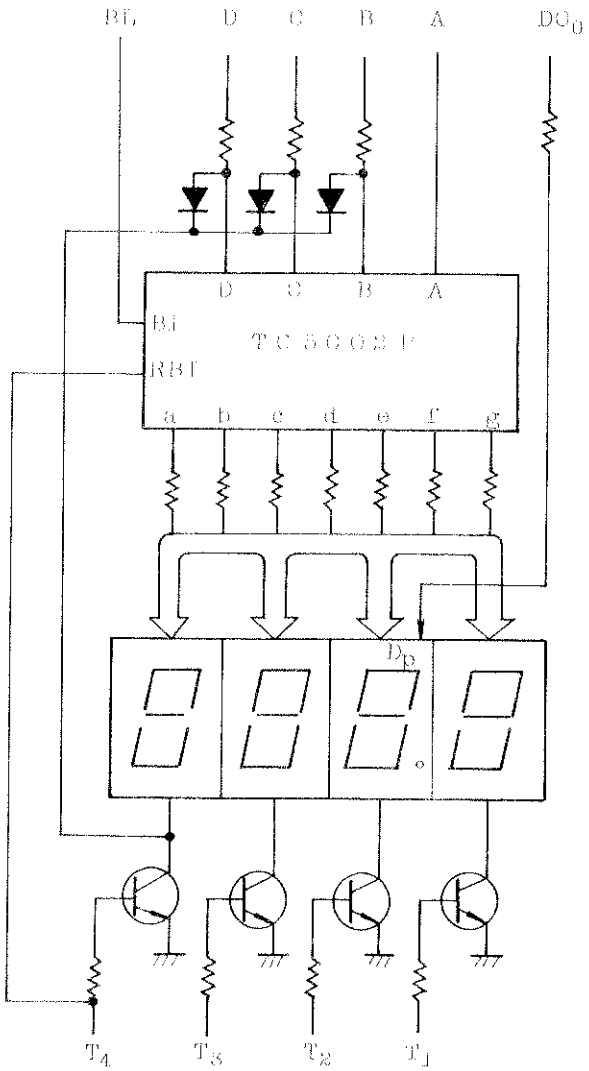
o Method of displaying decimal point in FM

Display in AM mode has oooo kHz, requiring no decimal point, but in FM, the display has a decimal point in the second digit from the lowest, as in ooo.o MHz. Accordingly, with TC9124AP, this decimal point drive current is supplied from DO_0 terminal ((21) pin) at the timing of T_2.

As the DO_0 terminal has a built-in bipolar driver transistor in LSI, the lamp can be lighted by connecting it to the Dp terminal of LED.

o The whole display circuit for received frequency of TC9124AP can be shown in blocks in Fig. 6-5. For more details of the circuit, refer to the example of applied circuit given below.

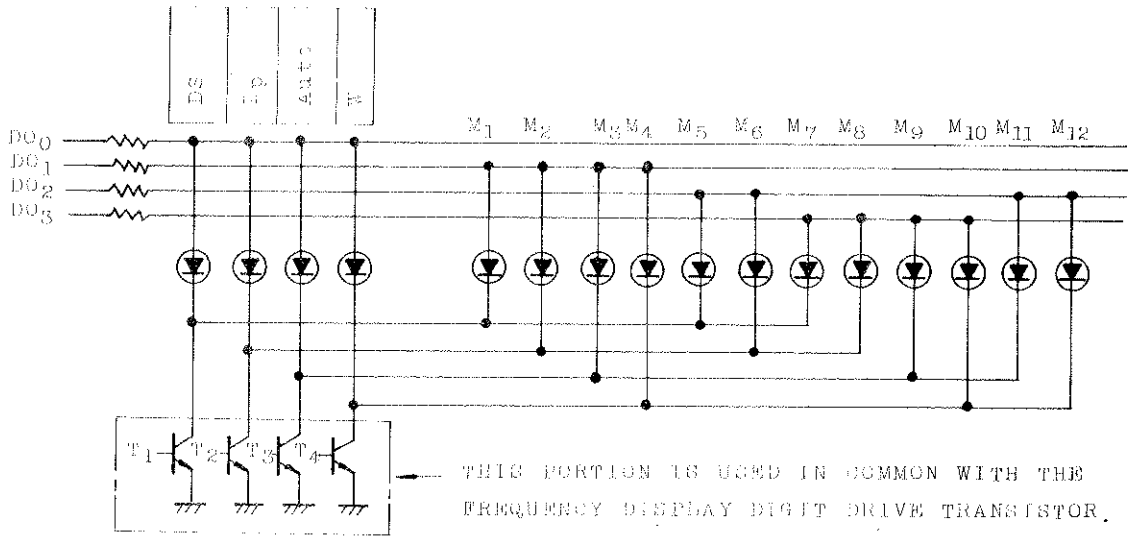
Fig. 6-5



[B] Display Functions by $DO_0 \sim DO_3$

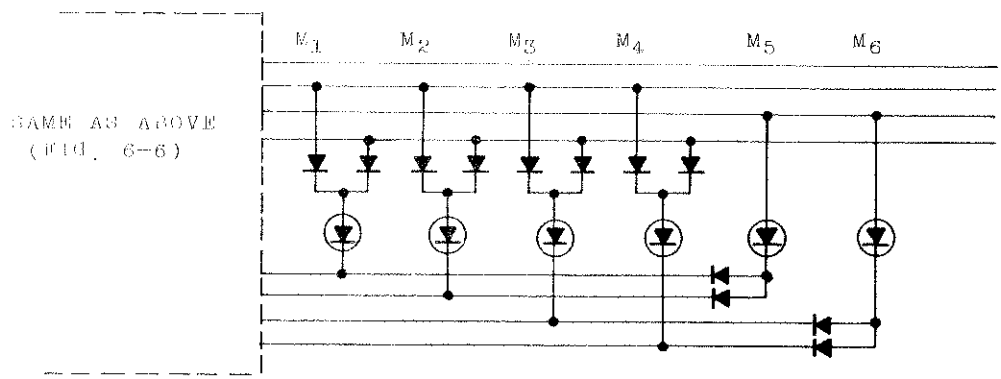
o TC9124AP has four terminals $DO_0 \sim DO_3$ as emitter follower output for the bipolar transistor so that LED lamp can be directly driven. They drive the lamp dynamically depending on $T_1 \sim T_4$, respectively. Therefore, sixteen (4 × 4) types of LED are provided. The contents are listed in Table 1 in Item 1. Their actual wiring will be as shown in Fig. 6-6.

Fig. 6-6



o When six channels each are used for FM and AM modes in a limited way by using 6 memory keys, as explained previously in relation to the use of memory, memory read display lamps are also six ($M_1 \sim M_6$), where the connection shall be as given in Fig. 6-7.

Fig. 6-7



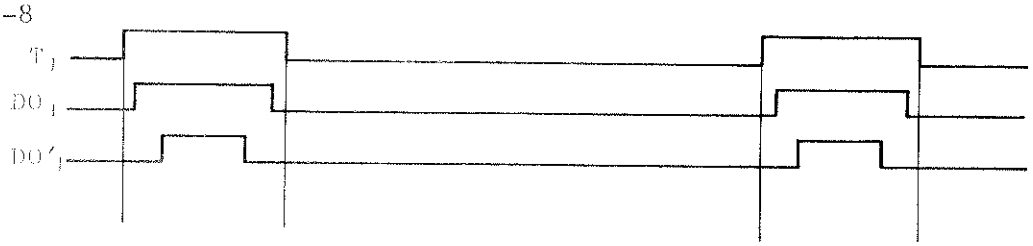
o Display brightness change-over at outputs $DO_0 \sim DO_3$

These display outputs require no blanking by BL signal, as LED is directly driven. They have function to change drive pulse lengths of $DO_0 \sim DO_3$ in LSI.

Brightness adjustment is performed by pushing [L] key in the same way as for frequency dispaly.

As an example, Fig. 6-8 shows a timing chart concerning LED of M_1 (DO_1 output at the timing of T_1).

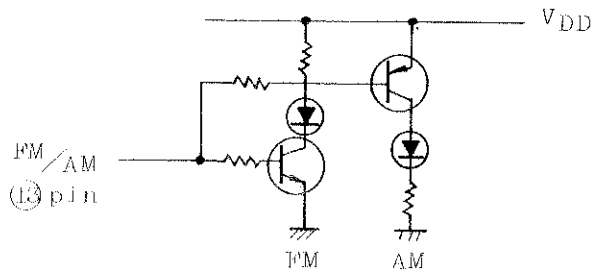
Fig. 6-8



o FM/AM mode display

For display of receiving mode of FM and AM, use is made of FM/AM output terminal (⑬ pin) of TC9124AP. This terminal becomes "H" level output in FM reception state and "L" level output in AM. As no drive is included inside, it is necessary to add external drive transistor. An example of the circuit is given in Fig. 6-9.

Fig. 6-9



7. OTHER FUNCTIONS OF TC9124AP

As the functions of TC9124AP, tuning, memory, display, etc. have been described thus far, and the following will be descriptive of other characteristic functions of this LSI.

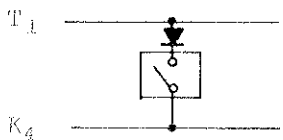
[A] Lock Function

TC9124AP have various operation keys, one of which controls the receiving state. Users may wish to continue receiving current broadcast by eliminating any possibility of erroneous operation of mischief by children. On such as assumption, TC9124AP is provided with a lock function to stop all read-in by operation key temporarily.

For this purpose, users can only connect T_1 line to K_4 line with a switch as shown in Fig. 7-1. When this switch is in "ON" position, all the other operation keys are made ineffective. The radio set will keep the receiption state as it was before the lock switch was operated. By putting the lock switch to "OFF" position, you can have normal functions of the keys.

This lock function is very useful in preventing erroneous operations, especially when the synthesizer tuner is remotely controlled.

Fig. 7-1



(ON/OFF switch or lock type push key)

[B] Inhibit Function

This function is closely connected with the memory backup function, the most characteristic of TC9124AP.

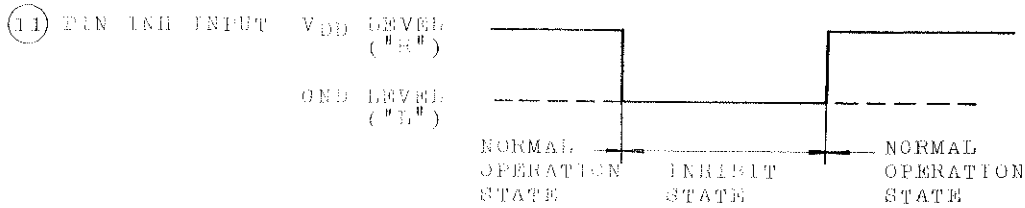
When memory backup is effected with a cell by supplying voltage only to TC9124AP with the power supply to the receiver in "OFF" position, there may occur various problems. For example, A ∿ D data outputs and T_1 ∿ T_4 timing signals can be supplied, although the power supply to PLL IC TC9123BP is in "OFF" position and while no current flows to DO_0 ∿ DO_3 LED lamp display and T_1 ∿ T_4 digit drive transistors.

And, there may be a problem of key operation in the backup state. Complete measures against these problems have been incorporated in TC9124AP as inhibit function.

(i) Controls of inhibit function

TC9124AP has an INH terminal ((11) pin), which is set to "L" level to actuate the inhibit function.

Fig. 7-2



(ii) Operation of TC9124AP in inhibit state

In inhibit state, TC9124AP operates differently from normal operation:

- o OSC-1 and -2 oscillation is compulsorily stopped inside; all the operational clocks in LSI are out of supply into complete still state.
- o All the key operation read is disenabled in the same way as in lock state, and any key operation can not cause the state prior to inhibition to change.
- o All the output terminals of TC9124AP are fixed as follows.
  - (1) $T_1 \sim T_4$, L and S/C outputs are fixed to "L" level.
  - (2) $A_0 \sim D_0$, BL and FM/AM outputs are at high impedance.
  - (3) $DO_0 \sim DO_3$ outputs stop their drive capability.
- o Under the output conditions, all displays are erased and data transfer to PLL LSI is stopped.

As mentioned above, all the internal operations of TC9124AP are stopped, and no current flows from the output terminals, so that the current consumption at the time is exceedingly small to memory backup with a cell.

o Concrete cell backup circuit using INH terminal

Fig. 7-3 shows a concrete circuit of memory backup with a cell.
Fig. 7-4 is an example of the backup with a condenser.

Fig. 7-3

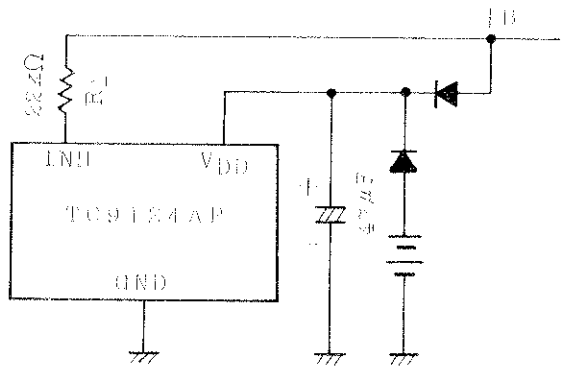
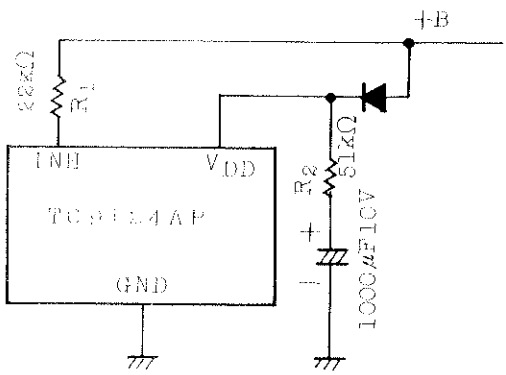


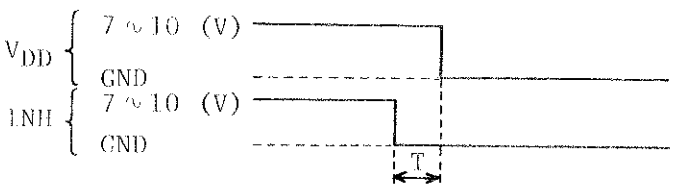
Fig. 7-4



o Resistance R_1 is provided as a means against latch up when V_{DD} or more voltage is applied to INH terminal.

o Resistance R_2 is provided to extend backup time in inhibit state by making the cell used in TC9124AP a constant-current type.

o INH Terminal Timing Chart



T: INH Operation
(V_{DD}="H" and INH="L")
T ≧ 10msec

CONTROL OF PLL SYNTHESIZER BY TC9124AP

The preceding pages have dealt mainly with the functions of TC9124AP. The ultimate object of TC9124AP is to ensure reception of desired frequency by controlling PLL synthesizer with instructions inputted by operating various keys.

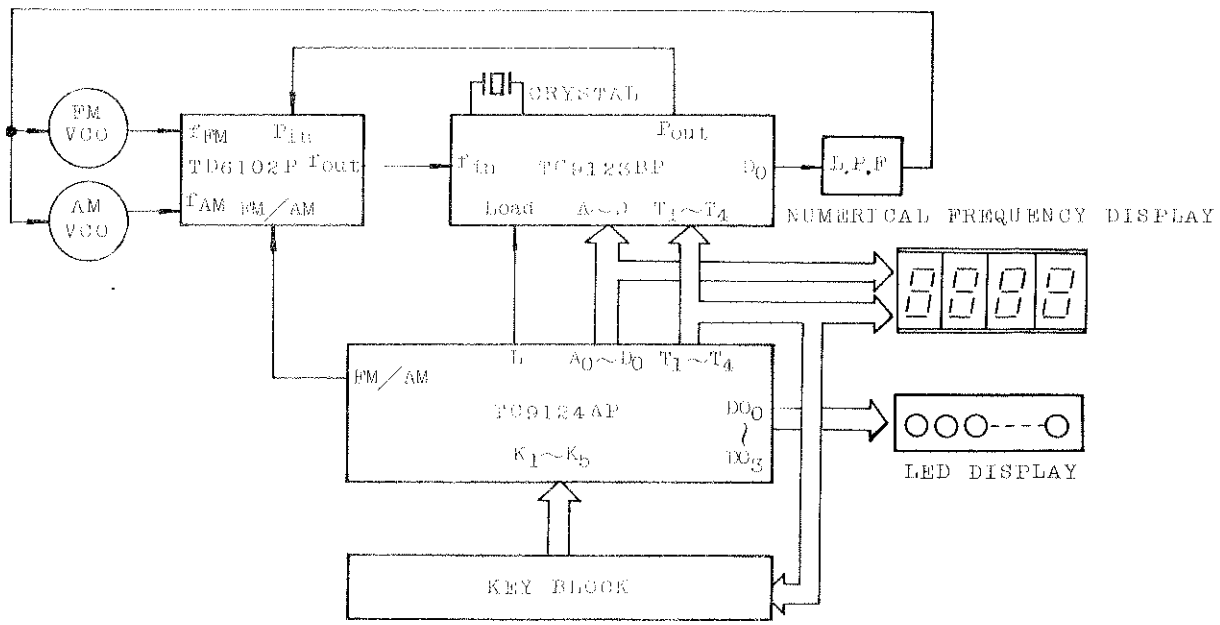
The following two types of ICs have been developed to constitute a FM/AM electronic tuner in combination with TC9124AP.

(1) LSI for PLL TC9123BP (C-MOS)

(2) Prescaller IC TD6102P (ECL)

Separate technical data are available on the two IC_S, and you can refer to them for any details. This technical data will describe the method of combining such IC_S with TC9124AP and the function of the whole system with major emphasis on TC9124AP.

o A synthesizer tuner composition is shown below in Block Diagram in particular reference to signal transfer between IC_S.



[A] Description of Control Signals

(i) Control signal to TC9123BP

Necessary control signals from TC9124AP to TC9123BP are A∿D, T_1 ∿ T_4 and L, 9 lines in total, as given in the diagram controlled by these signals are:

(1) Operation mode assignment to TC9123BP

Data for assigning the operation mode (FM_U, FM_L, AM_1 or AM_2) in which TC9123BP should operate. It depends on a combination of each of the outputs B, C and D at the timing of T_4. TC9123BP has its reference frequency for phase comparison and number of IF offsets of programmable counter controlled.

B_4	C_4	D_4	NAME OF MODE	REFERENCE FREQUENCY	IF OFFSET	REMARKS
H	H	H	FM_U	12.5 kHz	+10.7 MHz	100 kHz Sep
(L or H)	H	H	FM_E	"	"	50 kHz Sep
H	L	H	FM_L	"	-10.7 MHz	100 kHz Sep
L	H	L	AM_1	1.0 kHz	+460 kHz	In case of 10 kHz Setp
L	L	L	AM_2	"	+459 kHz	In case of 9 kHz Sep

(2) Assignment of number of frequency division N for programmable counter

TC9123BP has an IF offset function inside, and as the number of IF offsets is automatically switched by the mode assignment listed in the above table, receiption frequency data can be used as data from TC9124AP for setting the number of frequency division for programmable counter.

Accordingly, the number of frequency division is to be set for display of A ∿ D outputs as well as for transfer to TC9123BP.

Each of the control data in (1) and (2) above is transferred serially from TC9124AP in 4-digit BCD code in synchronization with timing (T_1 through T_4). A latch circuit to convert the serial to parallel data is provided inside TC9123BP.

(3) Load signal L

TC9123BP reads in A∿D data at each timing of T1 through T4. and the read timing is instructed by this load signal L, which prevents any possible malfunction in data reading when timing is changed over, and also controls stopping of signal read into TC9123BP when other data than frequency data are sent to A∿D line in direct data setting and clock display.

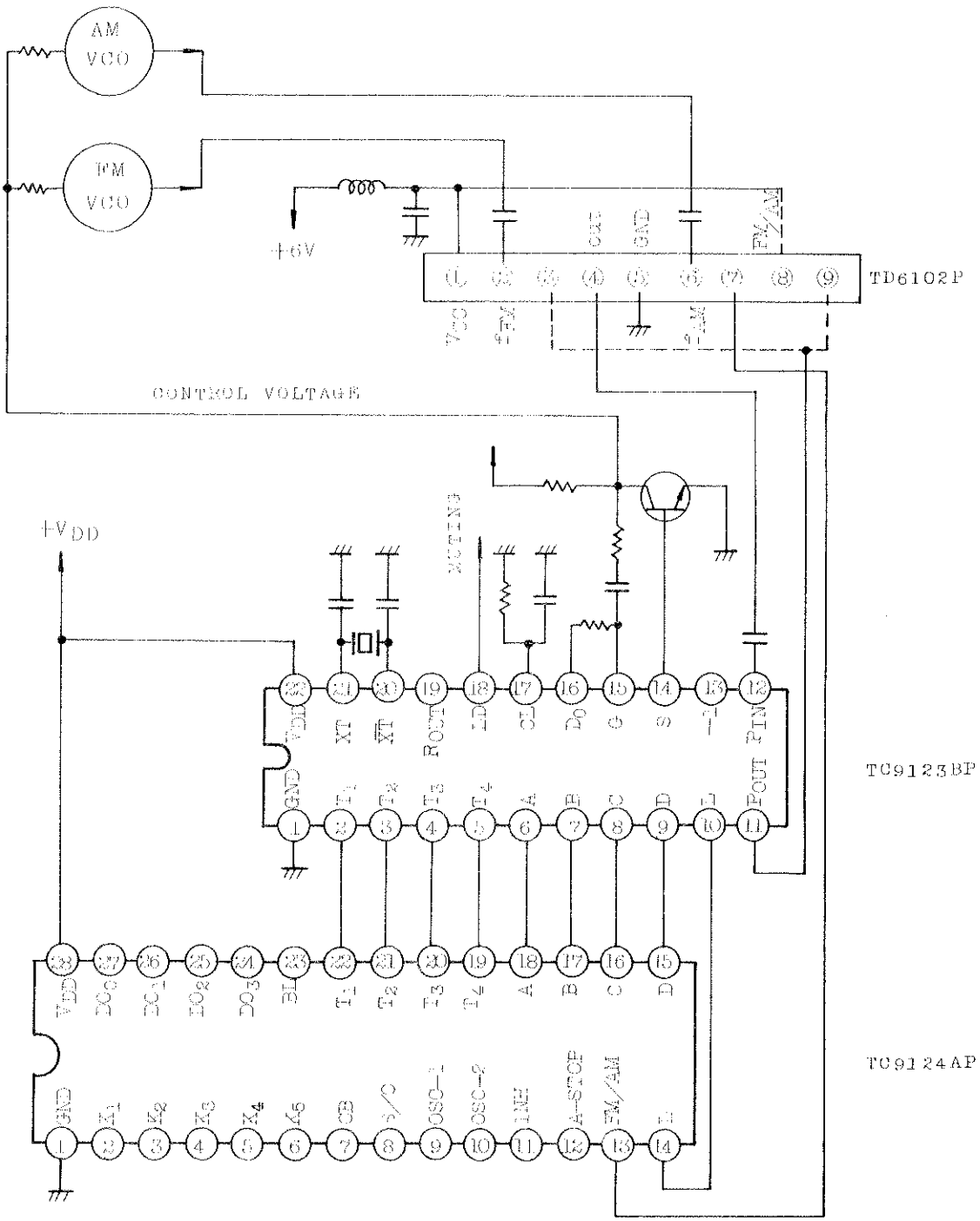
For timing chart for these signals, refer to Fig. 1-1 above.

(ii) Control signal to TD6102P

It is only FM/AM change-over signals that controls the prescaller TD6102P directly from TC9124AP. By this signal, TD6102P amplifies f_{AM} input in AM mode and directly output it to P_{IN} of TC9123BP, and in FM mode, it divides f_{FM} input into 1/8 frequency and outputs it. In FM_E mode, the prescaller requires +50 kHz shift operation command, which is transmitted from TC9124AP as operation mode assignment to TC9123BP, through which the instruction is conveyed to the prescaller from P_{OUT} terminal.

In this way, the control signals from TC9124AP to the synthesizer portion are $T_1 \sim T_4$, A ∿ D and L to TC9123BP and AM/FM to TD6102P. All the connections can be made directly without the necessary of changing levels. Careful consideration has been taken of pin arrangements of LSI and ICs so that writing of print patterns can be facilitated for mounting of radio receivers.

[B] Example of Circuits of TC9124AP and Synthesizer Section



EXAMPLE OF WIRING BETWEEN TC9124AP AND DISPLAY/KEYBOARD