SINGLE CHIP, 16-STATION TV DIGITAL TUNING SYSTEM

INTRODUCTION

The tuning system presented in this note is based on a single chip (the M490/M491), which integrates all the functions required by a complete digital-tuning system based on the voltage-synthesis principle.

The information necessary to recall up to 16 TV stations can be stored in a non-volatile memory which is integrated in the M490/M491 together with the control circuitry and the logic which performs the digital-tuning system functions.

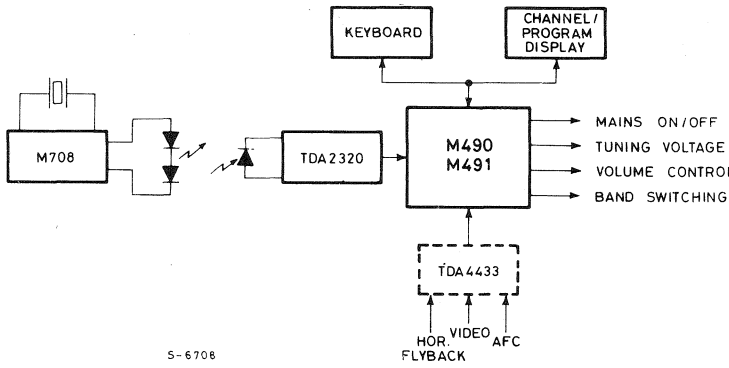
Automatic and manual modes of tuning operation are provided.

The system can be both on-panel or remote controlled. The M490/M491 includes keyboard scanning and a PCM infrared remote-control receiver.

Integrated circuitry allows direct station-memory display. Two different options of the single chip are available. The M490 provides single-dot LED memory display, while the M491 provides seven-segment LED memory display.

Due to the high level of integration and resulting low cost and improved reliability, the described system is able to replace the conventional potentiometers and band-switch arrays in TV sets, especially in low-cost models.

Fig. 1 - Block diagram of the complete tuning system



SYSTEM COMPONENTS

A block diagram of the complete tuning system is shown in fig. 1.

In the simplest system configuration (without remote control and automatic station search), only the M490/M491 is required. To implement higher-class tuning systems, a few integrated circuits are needed in conjunction with the M490/M491.

The main features of these IC's are the following.

M490/M491 - Digital tuning, remote-control receiver and memory display single chip

- Non-volatile memory for 16 programs (16 words of 19 bits)
- Four band-switch outputs
- Voltage synthesizer: 13 bits (BRM/PWM conversion)
- Fine detuning: 4 bits (PWM conversion)
- Keyboard scanning for on-panel control
- PCM IR remote-control receiver
- Volume control output (6 bits), with integrated mute function
- Direct memory display:
  single-dot LED display (M490)
  seven-segment LED display (M491)
- Memory addressing and copy capability
- Digital and linear AFT can be used
- Automatic and manual modes of operation, including station search
- Automatic station preset
- Search display output
- Memory and band skip function
- Integrated digital power-on reset
- Clock oscillator: 445 to 510 kHz cheap resonator

M708/M708L - PCM remote-control transmitter

- 30 commands, 4 addresses
- Single-contact matrix keyboard scanning (5 x 6), with integrated interlock and antibounce
- 2-bit binary address inputs
- End-of-transmission code
- Very low power transmission duty-cycle (0.15% with flash mode)
- Wide operating supply range
- M708L: low-voltage supply

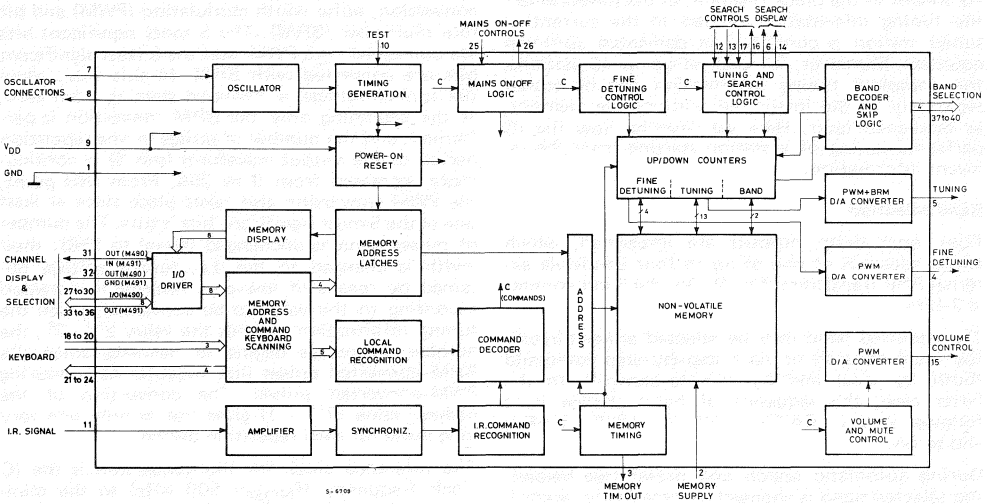
TDA 2320 - Remote-control signal pre-amplifier

- Low noise
- High gain and sensitivity

TDA 4433 - TV signal identification circuit and interface for digital AFC

- Conversion of the AFC S-curve into digital output signals
- Adjustable, high sensitivity
- Station identification output

Fig. 2 - Block diagram of the M490/M491



FUNCTIONAL DESCRIPTION OF THE M490/M491

The M490/M491 is the heart of the whole system presented here.

In this note, therefore, we shall carry out the detailed functional description of this device, while the other system components will be described more concisely in the next section.

For more details about these devices, the reader should refer to the relevant data sheets.

General information

Technology

The M490/M491 is manufactured using a well-estabilished, highly reliable double-polysilicon NMOS technology which allows the integration of all the functions required for a complete TV digital-tuning system, including non-volatile station memory.

Supply voltages

The M490/M491 needs a single supply voltage for all the logic: $V_{DD} = 5V \pm 5\%$

A single-polarity higher-voltage supply is also required for memory operations: 25V ± 1V.

Block diagram

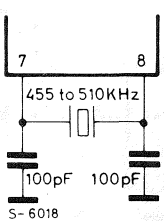
The main functions performed by the device are shown in the block diagram of fig. 2.

Timing

An oscillator is integrated, which operates with a ceramic resonator or with a simple LC network. The resonating frequency has to be within the range 445 to 510 kHz (nominal frequency of the ceramic resonator: 455 to 500 kHz), to allow a resonator with a frequency varying in the same range to be used in the remote-control transmitter. For oscillator connections, see fig. 3.

All the timing of the device is derived internally from this oscillator.

Fig. 3 - M490/M491 oscillator connections



Voltage-synthesis digital tuning

As shown in the block diagram, in the M490/M491 the tuning information related to the currently-tuned station is contained in dedicated up/down counters. Moreover, for each of up to 16 stations, the complete tuning information can be stored separately in the integrated non-volatile memory, as explained later. Here we describe how the IC performs tuning of a station starting from the relevant information.

Band selection

Four open-drain outputs are integrated, which allow selection of one of up to four bands via external PNP transistors (fig. 4). So, the band counter is 2-bits.

The required band may be selected either directly (by local control) or via a step-by-step command (both by local and by remote-control). In the latter case, the sequence of band change is as follows: VHF I - CATV - VHF III - UHF - VHF I, and so on.

During automatic search and preset (see below), the selected band is changed automatically, according to the same sequence.

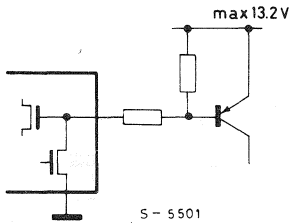
If one or more bands do not correspond to any possible broadcasting station, they may be disabled by short-circuiting the corresponding outputs to ground. In this way, the device will automatically skip disabled bands during automatic search and preset and band selection.

Tuning voltage

The information concerning the tuning voltage is contained in the integrated tuning-data up/down counter, as a 13-bit binary word. The device synthesizes the tuning voltage starting from this information, by means of a time-weighted D/A conversion.

This kind of conversion provides a repetitive output square waveform, with a duty-cycle depending on the binary value to be converted. By means of low-pass filtering, this waveform gives a d.c. voltage which is applied to the tuner's varicap to tune the TV set to the desired station. Since 2^{13} (8192) steps are available in the synthesized voltage, a resolution of 3.9 mV is provided if the tuning-voltage range is 0 to 32V, as in commonly available tuners. This corresponds to a resolution of about 75 kHz in the UHF band.

Fig. 4 - Band selection outputs



The D/A conversion is performed combining the two well-known basic principles of a time-weighted conversion, pulse width modulation (PWM) and bit rate multiplier (BRM). The 5 most significant bits are converted with PWM, and the 8 least significant bits are converted with BRM. In this way, when the tuning voltage is increased starting from zero, at the beginning only the BRM conversion is performed, and the number of pulses in one repetition period of the output waveform (pin 5) is continuously increased from 0 to 256. From this point, the PWM conversion also takes place since at least one of the 5 most significant bits is true. The number of pulses remains unchanged (equal to 256): their width is changed so the d.c. tuning voltage obtained by means of low-pass filtering is increased according to the value to be converted. When the tuning information reaches the value $2^{13} - 2^8$, the number of pulses begins to decrease since the BRM-converted pulses link together neighbouring PWM-converted pulses. The conversion of the highest value ($2^{13} - 1$) gives rise to only one very long pulse for each repetition period.

The reference clock for the conversion is the IC clock frequency (f_{NOM}= 500 kHz) so the minimum pulse width is 2 μs. This gives a repetition period of the output waveform of about 16 ms, which simplifies external filtering and allows good time response of the tuning system.

The chosen combination of the two conversion principles has been optimized to get the following advantages:

- minimum ripple on the filtered tuning voltage. The number of pulses per second in the output waveform is high enough to provide low ripple of the filtered voltage also at the extreme limits of actual working tuning voltages, so visible noise on the TV screen is avoided.
- minimum temperature dependence of the synthesized voltage. This is due to the temperature variation of the switching times of the output pulses, which are always kept within a very low number (256) even for the worst case.
- monotonic relationship synthesized tuning voltage vs binary tuning information. The chosen combination, in fact, ensures that the difference between the number of pulses in the output waveforms which convert two adjacent values is never greater than one.

Fine detuning

This function is provided to allow the TV user to perform a slight detuning of the system with respect to the central position of the Automatic Frequency Control (AFC), for the best TV-signal reception. Fine detuning is performed applying a d.c. voltage to a varicap diode connected in parallel with the AFC discriminator, while maintaining the AFC action.

The digital fine-detuning information contained in the dedicated counter (4 bits), is converted into a variable duty-cycle square waveform by means of a PWM D/A converter, which is suited to this purpose since in this case ripple problems on the filtered d.c. voltage are not so heavy. The output

waveform (repetition frequency ≃ 15.6 kHz) is externally low-pass filtered to get the fine-detuning voltage.

Fine-detuning position is set at the mid range when a search (manual or automatic) starts. When a station is tuned, fine detuning can be changed with step-by-step commands, both locally and by remote control (overflow and underflow protections are integrated).

Commands

The system can be both on-panel and remote controlled. Most commands are available by means of both controls, while some of them can be issued only in one way.

Local control

The device performs complete scanning of a single-contact matrix keyboard, by means of which up to 20 different commands may be given (fig. 5). In the M490, also direct memory-location selection is provided locally, by means of a second single-contact matrix keyboard (fig. 6). In the M491, direct memory-location selection is available only by remote control.

In the keyboard-scanning section(s), antibounce and interlock are fully integrated.

To perform keyboard scanning, the IC generates sequential pulses on lines X1 to X4, pins 24 to 21 (fig. 7) and detects contact closure on lines V1 to V3, pins 20 to 18 (local commands) or on lines Y1 to Y8, pins 27 to 30 and 33 to 36 (only M490, direct memory-location selection).

The actual keyboard scanning is performed when the low pulses are present on the X lines. Initialization and decision times are internally provided for correct operation of this section. Most part of the total scanning-period is dedicated to the memory display LED-driving function (see below).

A command is accepted and executed if the related key has been closed for at least four successive scanning periods, i.e. for a minimum time of about 30 ms.

Fig. 5 - Local-control keyboard

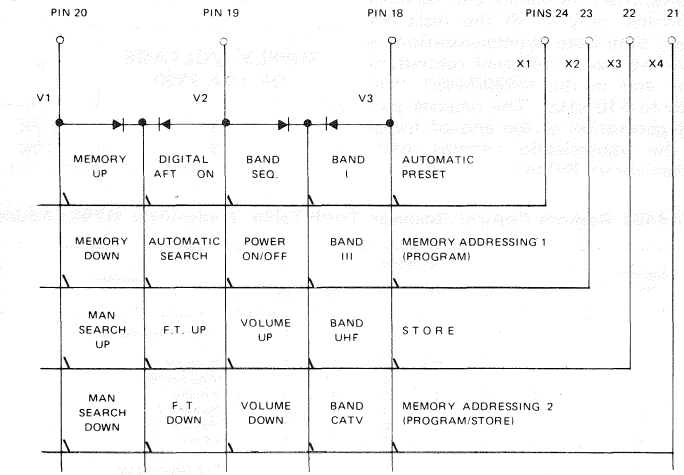


Fig. 6 - Direct memory-location selection keyboard (only M490). Memory-display array is also shown.

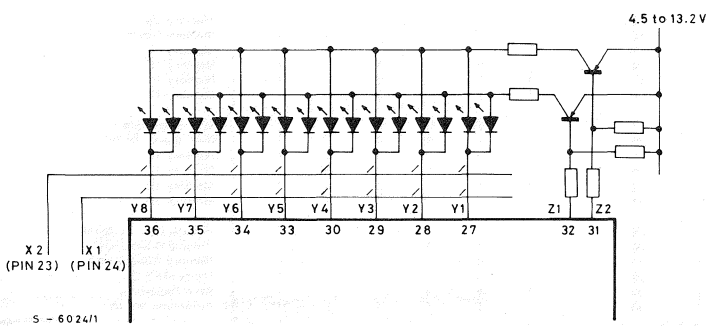
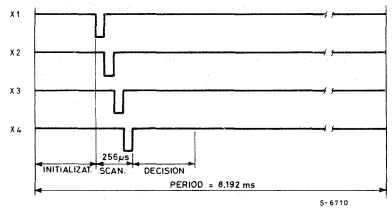


Fig. 7 - Timing of keyboard scanning



Remote control

The M490/M491 also includes a PCM infrared (IR) remote-control receiver, which decodes and executes directly up to 30 different commands. The remote-control system is based on a Pulse Position Modulation (PPM) code, which ensures error-free signal detection even in the presence of high noise. The basic features of the IR transmitter (M708) and of the remote-control system are outlined in the next section.

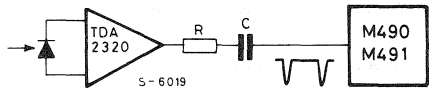
To achieve good noise immunity, the M490/M491 performs a series of tests on the incoming pulses which code the transmitted command, and decodes the received command only if all the tests are fulfilled. Moreover, time-base synchronization is provided, to allow the use of different resonators in the transmitter and in the M490/M491 (frequency range: 445 to 510 kHz). The receiver section also provides generation of the end-of-transmission code if the transmission remains interrupted for more than about 550 ms.

The remote-control truth table is shown in table I. Received commands are accepted and executed by the M490/M491 only if transmitted with address 9.

An integrated a.c.-coupled amplifier ensures very high sensitivity to the remote-control input of the device, pin 11 ($V_{PP\ min}$= 0.5V in the worst case). Thanks to internal circuitry which prevents electron injection into the substrate when large negative transients occur on the input node, very high V_{PP} signals (up to 15V) can be applied to the external a.c.-coupling network (see fig. 8 for the suggested configuration).

Local and remote-control commands have the same priority, i.e. one local command is not accepted and executed until a previously accepted remote-command has been completely executed and the end-of-transmission code has been generated, and viceversa.

Fig. 8 - Coupling network for the remote-control signal input



SUPPLY VOLTAGE OF TDA 2320	R	C
5	2.2K	4.7 nF
12	10K	4.7 nF

TABLE I - M490/M491 Remote Control Receiver Truth Table. Transmitter M708; Address Code No. 9

Command No.	IR CODE C1	C2	C3	C4	C5	C6	Function
0	0	0	0	0	0	0	End of Transmission
1	1	0	0	0	0	0	Power On/Off
2	1	1	0	0	0	0	Mute On/Off
3	0	0	1	0	0	0	Memory 1
4	1	0	1	0	0	0	Memory 2
5	0	1	1	0	0	0	Memory 3
6	1	1	1	0	0	0	Memory 4
7	1	0	0	0	1	0	Fine Detuning Up
8	1	1	0	0	1	0	Fine Detuning Down
9	0	0	1	0	1	0	Memory 5
10	1	0	1	0	1	0	Memory 6
11	0	1	1	0	1	0	Memory 7
12	1	1	1	0	1	0	Memory 8
13	1	0	0	0	0	1	Memory Up
14	1	1	0	0	0	1	Memory Down
15	0	0	1	0	0	1	Memory 9
16	1	0	1	0	0	1	Memory 10
17	0	1	1	0	0	1	Memory 11
18	1	1	1	0	0	1	Memory 12
19	1	0	0	0	1	1	Man. Search Up
20	1	1	0	0	1	1	Man. Search Down
21	0	0	1	0	1	1	Memory 13
22	1	0	1	0	1	1	Memory 14
23	0	1	1	0	1	1	Memory 15
24	1	1	1	0	1	1	Memory 16
25	1	0	0	1	1	1	Volume Up } Mute
26	1	1	0	1	1	1	Volume Down } Off
27	0	0	1	1	1	1	Memory Addressing 1
28	1	0	1	1	1	1	Digital AFT On
29	0	1	1	1	1	1	Band Sequential
30	1	1	1	1	1	1	Automatic Search

Station tuning and recall

To tune the TV set to a station, the user may either perform a search (manual or automatic) or recall a program from the non-volatile memory. Automatic station preset is also available to simplify the presetting of the TV set.

The system can work either with linear or with digital Automatic Fine Tuning (AFT).

In the first case, the AFC loop is all external to the M490/M491. Only manual station search is available.

When the digital-AFT system is used, the AFC loop is closed through the TDA 4433 and the M490/M491. With this configuration, both automatic search and manual search are available.

No external component nor manual adjustment are needed to determine the "search speed", i.e. the rate of variation of the tuning voltage during station search. This speed, in fact, is derived from the IC master-clock frequency and is internally optimized taking into account the search mode (automatic or manual) and the band where the search is performed.

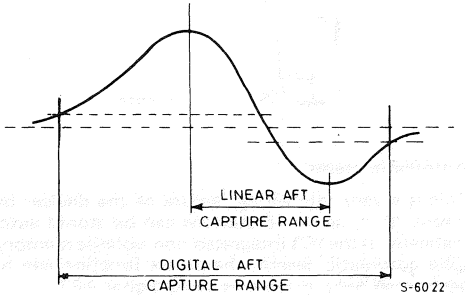
Normal operation

When the TV set is tuned to a station and the user gives no command to change tuning, the tuning voltage synthesized by the M490/M491 can be adjusted automatically by the system only when digital AFT is used.

In case of linear-AFT systems, in fact, the AFC loop does not interfere with the M490/M491 operation: the voltage output from the AFC discriminator is added to the tuning voltage synthesized by the M490/M491 (which remains unchanged), thus correcting the actual voltage fed to the tuner's varicap.

In digital-AFT systems, on the contrary, the AFC discriminator output is converted into two digital signals by the TDA 4433, according to table II, where f_0 is the very narrow frequency range (38.8 to 39.0 MHz when fine detuning is in the middle position) in which the system is perfectly tuned, and the range $f_0 - \Delta f_1$ to $f_0 + \Delta f_2$ is the digital-AFT capture range, i.e. the range within which the system can control the tuning of the TV set.

Fig. 9 - Linear and digital AFT capture range



The two digital signals are applied to the M490/M491 pins 12 and 13, and act as up/down commands for the synthesized tuning voltage which, therefore, is kept at the optimal value. As shown in fig. 9, the digital-AFT capture range is greatly increased.

Digital-AFT operation of the TV system can be enabled only when pin 17 of the M490/M491 is kept at a high level (i.e., left open or connected to V_{DD}). In this case, digital AFT is enabled automatically at power-on. It is disabled when a manual-tuning command is issued and is re-enabled by an automatic search or preset command or by the dedicated "digital AFT on" command.

The digital-AFT status of the system can be easily displayed by means of a single-dot LED, as shown in fig. 10. When digital AFT is enabled, the output pin 6 is driven low, so the LED is switched on.

When digital AFT is enabled, if the station is perfectly tuned, the M490/M491 does not change the level of the synthesized tuning voltage. When a detuning occurs, the M490/M491 receives the AFT up/down commands on its input pins 12 and 13, and changes the tuning voltage so as to restore the system's tuning frequency within the range f_0. Retuning is performed at an internally generated speed (61 Hz when a detuning in the lower direction has occurred, 7.6 Hz in the opposite case).

Fig. 10 - Digital-AFT status display

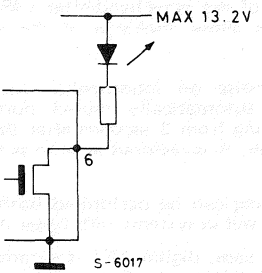


TABLE II - Truth table of TDA 4433 output pins 2 and 6

TDA 4433 pin 2 M490/M491 pin 12	TDA 4433 pin 6 M490/M491 pin 13	Tuning position
H	L	Low ($f_0 - \Delta f_1 < f < f_0$)
L	H	High ($f_0 < f < f_0 + \Delta f_2$)
L	L	Centered (or out of tuning)
H	H	– – –

Manual tuning

Manual-search commands are provided to allow both actual manual station search and tuning adjustments.

Manual tuning can be performed both up and down, by means of manual-search up and down commands, which can be issued both locally and by remote control. In case of local command, tuning voltage is increased (or decreased) as long as the command is issued. The speed at which the tuning voltage is changed is progressively increasing with time, and reaches its maximum value after 3 seconds, as shown below:

Time	Seach speed
Command accepted	max/8
After 1 s	max/4
After 2 s	max/2
After 3 s	max

Maximum speed is equal to 512 tuning steps per second in VHF bands and 128 in UHF and CATV bands, which gives a total sweep time per band of 16 and 64 seconds respectively.

In case of remote-controlled command, tuning voltage is changed every two received commands, i.e. every about 200 ms when a command is issued continuously.

When, during the search, the upper or lower limit of a band is reached, the search restarts from the other limit of the same band after a 480-ms delay, provided to allow discharge of the external circuitry.

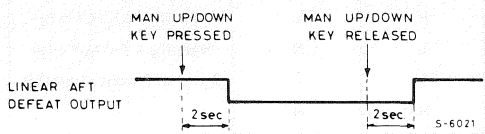
To avoid noise on loudspeaker during search, volume is automatically muted during all the search starting from 3 seconds after the beginning of the search. It is restored as soon as the search is stopped.

Manual tuning can be performed both in systems with digital and in systems with linear AFT.

In the first case, digital AFT is automatically disabled at the beginning of the search and remains disabled until the TV user reenables it.

When the system uses linear AFT, during manual search the AFT loop has to be disabled to perform problem free searches. The M490/M491 outputs a signal (pin 16, linear-AFT defeat output) which is low during the whole search: it goes low 2 seconds after search start, to allow small-detuning operations, and returns high 2 seconds after search end (fig. 11).

Fig. 11 - Linear-AFT defeat



Automatic search

Automatic search can be performed only in systems which use digital AFT. To stop the search when a station is encountered, in fact, the M490/M491 needs the digital-AFC signals output by the TDA 4433 (connections between the two IC's are shown in table II).

When activated, the automatic search starts from the actual band and tuning position (fine detuning is set at mid range), and is always performed from lower to higher tuning-voltage levels. The search routine is controlled by the two signals coming from the TDA 4433, which act as search control commands and cause the system to stop when a broadcasting station it encountered (for details please refer to the M490/M491 data sheet). The sensitivity to the station signals can be easily controlled by adjusting the external control network of the TDA 4433 (see application notes).

When the upper limit of a band is reached, the search restarts from the beginning of the successive band after a 480-ms delay. The band-change sequence is equal to the sequence followed in band step-by-step selection, and disabled bands are skipped automatically.

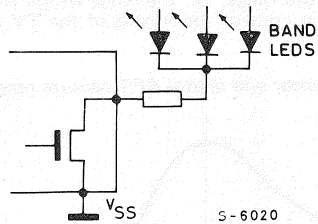
A search routine can be stopped by the TV user recalling a station from the memory.

The automatic-search sweep speed is internally generated. Unless the presence of a station is recognized (in which case the speed is changed, according to the commands coming from the TDA 4433), the speed is equal to 1024 tuning steps per second in VHF bands, and 256 in UHF and CATV bands, which corresponds to a sweep time per band of 8 s and 32 s respectively.

Volume is muted during the whole search routine.

The device has also an output (pin 14) which is normally low, and delivers a square waveform (period ~ 160 ms) during automatic search and preset to provide flashing of the selected-band display LED, if connected as shown in fig. 12.

Fig. 12 - Automatic-search display



Automatic preset

This is a very interesting feature of the device: by means of it, up to 16 stations can be stored automatically in the IC's integrated non-volatile memory. Like automatic search, the preset function can be performed only in systems using digital AFT.

When the automatic-preset command is accepted, an automatic station search starts from the lowest tuning-voltage level and band VHF I (the lowest program-memory address is selected automatically).

When a broadcasting station is recognized and tuned, the search is momentarily stopped and the relevant tuning information is stored in the addressed memory word. Then, memory address is incremented and the system starts to search for the next station. This routine is repeated until different stations have been stored in all the available memory locations or until all the enabled bands have been swept.

When the preset routine has been completed, the system tunes the TV set to the station stored in the lowest-address memory location.

During all the routine, volume is muted.

Station recall

When a memory-location selection command is issued (both direct or step-by-step), a memory reading routine is started and the TV set is tuned to the recalled station. All the timing to perform memory reading is generated internally.

During station recall routine, volume is muted automatically to avoid noise on the loudspeaker.

When digital AFT is enabled, the tuning voltage is read from memory with a subtraction of a fixed value of 8 steps (~ 31.2 mV). This causes a slight detuning into the part of the IF response curve which corresponds to the fully transmitted sideband. This feature increases the AFT capture range, compensating for the asymmetry of the AFC S-curve. Digital-AFT commands are momentarily disabled internally during reading routine and are reenabled automatically at the end of the routine.

When digital AFT is disabled (digital - AFT status off), of course, tuning-voltage information is read without any change.

Non-volatile memory

The M490/M491 integrates an Electrically Erasable Programmable Read-Only Memory (EEPROM), where the tuning information related to 16 different stations may be stored. Each memory word corresponds to a station, and stores 13 bits for tuning-voltage information, 4 bits for fine detuning and 2 for band. So, the memory, which is word-modifiable, is organized in 16 words of 19 bits.

The memory is based on a "two stacked polysilicon gate" cell. This cell is highly reliable and ensures very long retention of the stored information (in excess of 10 years).

The timing and the circuitry needed to address and drive the memory and to perform correctly the memory operations are fully integrated. Only an external transistor is needed to control the switching of the memory supply (see application notes).

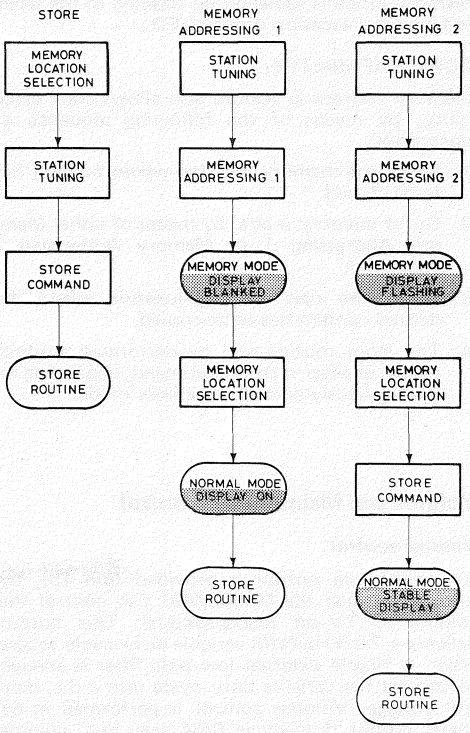
Owing to physical limitations in the modify characteristics of the EEPROM cells, the time necessary to store a content in a memory word increases during the memory life, ranging from some tens to hundreds of ms. A maximum time of 1 s is fixed internally for a complete store operation. The internal routine to modify a memory word has been optimized to provide the longest endurance to each word. Experimental measurements have shown typical endurance in excess of 10^4 complete store cycles per word.

Store commands

Three different modes of store operation are available, to give the system maximum flexibility (fig. 13). In all of them, the store function is inhibited internally after any store operation to protect the memory and optimize its life. It is re-enabled after a tuning operation or a memory-program change. Moreover, while a store operation is being executed, most commands to the M490/M491 are disabled internally to prevent any change in the content to be stored and in the selected memory word address during the operation.

Copy capability is also provided.

Fig. 13 - Memorization routines



STORE

In this routine, memorization is started by issuing the store command: thus, the memory location where the tuning information is to be stored has to be selected before tuning the system to the desired station.

MEMORY ADDRESSING 1

This routine allows a memory location to be selected after tuning the station to be stored. When the "Memory Addressing 1" command is accepted, in fact, the system is switched to the "memory mode", which allows memory address to be changed without performing reading of the new selected memory word. The store routine is started automatically when the new memory location has been selected.

During memory-mode operation, memory display LED's are blanked. The start of store routine resets the system to the normal mode.

MEMORY ADDRESSING 2

This routine too allows selection of the memory location after station tuning. In this case, however, memory store is not started when the new memory location has been selected, but when the store command is issued. So, this routine is particularly useful to provide memory-mode operation when sequential memory selection is used.

Memory mode is signalled by flashing of the selected memory-location display LED.

COPY CAPABILITY

Memory addressing feature also allows copy capability, by means of the following sequence of operations:

1. Select the memory location whose content has to be copied.
2. Go to memory mode, by means of either Memory Addressing 1 or Memory Addressing 2 command.
3. Select the new memory-location where the desired content has to be copied.
4. The store routine will be performed automatically or after a store command, depending on the previously activated memory mode.

Volume and Mains on/off control

Volume control

An open-drain output is provided (pin 15), by means of which the M490/M491 can control the volume of TV-set loudspeaker(s). This output delivers a 7.8-kHz PWM variable duty-cycle square wave. A simple external low-pass filter is enough to convert the variable duty-cycle into a d.c. control voltage. Volume control is performed in 63 steps: output duty-cycle 0/64 gives zero volume while duty cycle 63/64 gives the maximum volume.

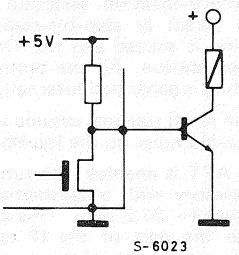
At power-on reset, output duty-cycle is set at 21/64. When the TV set is switched on, volume can be controlled both locally and from remote control (overflow and underflow protection are integrated).

Mute function is also provided: it switches the IC volume output to ground, so the TV-set loudspeaker volume is set to zero. Multe function can be activated automatically in some cases when required by the system (during program change for 440 ms, during mains on/of for 1 s, during station search, during power-on reset time for 0.5 s).

Mains on/off

The Mains on/off output (pin 26) delivers an internally latched signal which can be used to control the on/off switching of the TV set via a transistor and a relay (fig. 14): when the M490/M491 output is off, the TV set is switched on.

Fig. 14 - Mains on/off switching control



Memory display and selection

To improve system flexibility and fulfill different TV manufacturers' requirements, two IC's have been designed, which provide different memory-display modes: the M490 (single-dot LED memory display) and the M491 (seven-segment LED memory display). Both IC's drive the LED's directly and provide memory-skip function to allow easy design of TV models where less than 16 programs are used.

When IC power-supply is switched on, the lowest-address memory location is selected automatically. Direct and step-by-step selection of a memory location is available from remote control in both devices, as well as local step-by-step selection. Direct memory selection from TV front-panel is available only with the M490.

M490

This IC is designed to drive single-dot LED display. One LED is used for each enabled memory position, so memory display is made of an array of up to 16 single-dot LED's (fig. 6).

By using a set of transparent numbers placed in front of the LED's, the number of the channel stored in the selected memory location may be displayed very easily: each time the TV-user stores a new station in a memory word, he has only to set the right number in front of the related LED.

As shown in fig. 6, only eight LED drivers are integrated in the IC (outputs Y1 to Y8). The display of all the 16 stored channels is achieved multiplexing the LED's by means of the two control outputs Z1 and Z8, which provide selection between odd and even memory location related LED's.

On-panel direct memory-location selection is achieved by means of a single-contact matrix keyboard. As shown above, in fact, the LED-driving output pins operate also as sensing inputs for the memory-selection keyboard-scanning section of the device.

Memory locations 11-12, 13-14 and 15-16 may be disabled by connecting pins 34, 35 and 36, respectively, to ground. In this way, when a disabled location is selected, integrated circuitry senses this connection and causes automatic skip to the next permitted location.

M491

This IC can drive directly a 1 and 1/2 seven-segment display. The binary to seven-segment decoder is also integrated. Thus, display of the selected memory location (1 to 16) is easily provided: only current-limiting resistors are needed externally.

Pin 31 provides selection between two different options of program operation. If its level is high (pin open or connected to V_{DD}), all 16 programs are enabled. If it is connected to ground, only 8 programs (1 to 8) are enabled, and programs 9 to 16 are skipped automatically in case of step-by-step memory-location selection commands.

DESCRIPTION OF THE OTHER SYSTEM COMPONENTS

M708 - PCM remote-control transmitter

Technology: Si-gate CMOS.

Supply voltage: 4.5 to 10.5V

This device belongs to the family of IC's which implement the SGS PCM remote-control system for consumer and industrial applications. Its main functional difference with respect to the other transmitters of the family (M709, M710) is the number of channels that may be transmitted: 30 commands x 4 addresses (1, 2, 9 and 10). This makes the device particularly suited for use in conjunction with the M490/M491.

For details about the system, see SGS Technical Note TN 155. Its main features are outlined here.

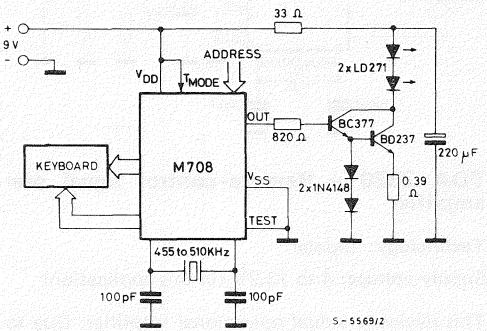
The commands are transmitted by means of infrared-light pulses which are coded using a Pulse Position Modulation (PPM) technique. Each transmitted word consists of 14 bits. The binary information associated to each bit is determined by the time interval between two successive pulses. The chosen code ensures high reliability and noise immunity to command transmission and detection. Four transmission bits are reserved to address code, so the transmitter can address up to 16 different receivers causing no interference between one another since only the receiver with the address equal to the transmitted one accepts and executes the received command (the M708, anyway, has only 4 available addresses). Six bits are dedicated to command code: so, in the complete system up to 64 different commands may be transmitted (the M708 can transmit only up to 30 commands). The remaining 4 transmission bits are the parity bit and three formating bits.

The system provides self-synchronization between transmitter and receiver, to allow the use of different resonators in transmitter and receiver sections (in both ends a resonating frequency of 445 to 510 kHz has to be used), so expensive adjustments are avoided.

All the transmitters of the family can generate a transmission with carrier ("carrier mode") or without it ("flash mode"). When used in conjunction with the M490/M491, the M708 has to be used in flash mode. In this case, transmission duty cycle is equal to about 0.15%, which guarantees very low power consumption even using high peak current for transmission LED driving.

A typical application of the M708 (flash-mode transmission) is shown in fig. 15.

Fig. 15 - Typical application of M708 (flash mode)



INFRARED DIODE PEAK CURRENT = 1.8A
TOTAL AVERAGE CONSUMPTION = 6.5mA

M708L - Low-voltage PCM remote-control transmitter

Technology: Si-gate CMOS

Supply voltage: 2 to 5 V

This device performs the same functions performed by M708.
It requires low-voltage power supply (typ. 3V), thus allowing use of flat low-voltage batteries. Two typical applications of the M708L (flash mode) are shown in figs. 15a and 15b.

Fig. 15a - Typical application of M708L (flash mode)

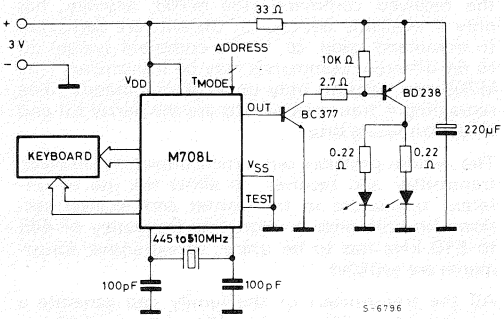
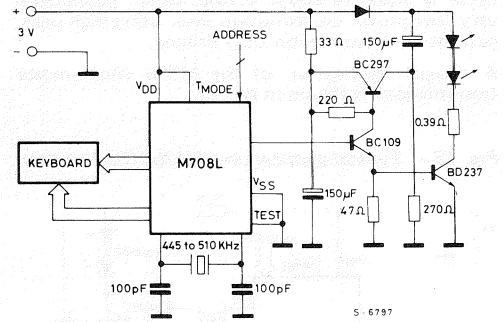


Fig. 15b - Application of M708L (flash mode) with voltage duplicator



TDA 2320 - Remote-control signal pre-amplifier

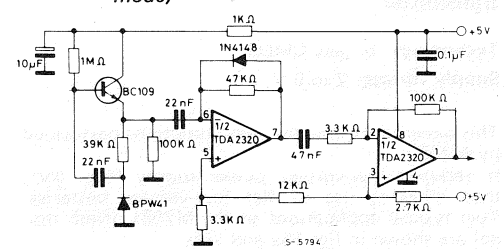
Technology: bipolar

Supply voltage: 4 to 13.2V (in this application)

This device is a dual operational amplifier. Due to its high sensitivity and noise immunity, it is particularly suited for the design of the IR remote-control signal preamplifier.

Fig. 16 shows a suggested configuration for the wide-band preamplifier which can be used to drive the remote-control digital input of the M490/M491 (flash-mode transmission).

Fig. 16 - Remote-control signal preamplifier (flash mode)



TDA 4433 - TV signal identification circuit and interface for digital AFC

Technology: bipolar

Supply voltage: 10.8 to 14.5V

This device performs the identification of the TV signal, delivering relevant information to the output pin 10, and the conversion of the analog-AFC S-curve into two digital signals which can be fed to the M490/M491 for tuning-control purpose in the digital-AFT system configuration.

The device also integrates a voltage regulator, required by the internal circuit, which provides its regulated output voltage also externally (pin 4).

The conversion of the AFC S-curve takes place only when a TV signal has been identified: in this case, the state of the two output pins 2 and 6 of the IC shows the tuning position with respect to the perfect station tuning as previously shown (table II). By connecting these two pins to the input pins 12 and 13, respectively, of the M490/M491, digital AFT is provided to the system.

APPLICATION NOTES

The functions performed by the tuning system presented here, as well as the external connections and the commands needed to activate each function, have been explained in the M490/M491-features description section.

In this section, we shall focus attention on some of the application aspects particularly important to getting the best performance out of the tuning system.

Finally, complete electrical diagrams of some typical applications will be shown.

M490/M491 power supplies

V_{DD} (+ 5V)

The voltage level of this supply must be between 4.75 and 5.25V.

To provide correct initialization to the circuit and to protect the integrated non-volatile memory against spurious commands during V_{DD} power-supply transients, power-on reset circuitry is fully integrated in the M490/M491. This circuitry needs no external components, and is triggered when V_{DD} power supply is applied to the IC, and when its level falls below an internally-determined threshold level (about 3V). Reset ends about 500 ms after the normal supply condition is restored.

V_{PP} (+ 25V)

The voltage level of this supply, needed for memory operations, must be between 24 and 26V. To ensure good reliability of the device and to avoid incorrect read and store operations, V_{PP} line has to be stabilized accurately within the specified range.

V_{PP} must always be present during writing, erasing and reading the memory.

Memory reading routine is performed with memory supply pulses with a duty cycle equal to ~ 35%. Maximum memory supply peak current is equal to 8 mA.

Memorization is accomplished by means of erasing and writing operations (internally-generated sequence is write, erase, write for each store routine). Writing is performed with 25%-duty-cycle pulses and 42-mA maximum peak current. Erasing is performed with 50%-duty-cycle pulses and 9-mA maximum peak current. After each modify pulse, a reading operation is performed to accomplish "intelligent" memory modify.

Two application circuits to provide correct memory supply are shown in fig. 17.

A simple external buffer (fig. 18) is required to control memory supply switching needed to perform memory operations. Internally-generated timing is delivered to pin 3 to drive the buffer which, in turn, feeds internal memory supply line (pin 2).

Fig. 17 - Memory supply voltage (Vpp) generation

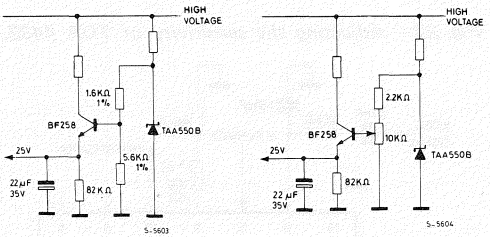
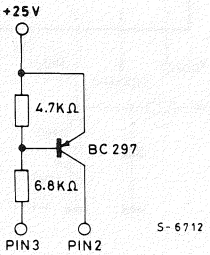


Fig. 18 - Memory supply switching buffer



Mains on/off

When V_{DD} power supply is applied to the M490/M491, the TV set is turned on automatically (the lowest-address memory location is selected) if pin 25 is connected to ground ("automatic mains-on option" selected). Otherwise, the system is put in stand-by condition, and the TV-set can be switched on by a mains-on command issued for more than 0.3 s.

Mains-on command is a toggle command. If issued when the TV-set is on, it acts as mains-off command and puts the system in stand-by condition.

In this condition, the only command which is accepted by the system is the mains-on command. During stand-by, the last address and volume level information is preserved as long as V_{DD} supply is present, and is recalled automatically when the TV set is switched on.

At each mains-on switching, a memory reading routine is performed automatically to tune the system to the station stored in the addressed memory location. As V_{PP} is needed for this operation, a 1-s delay is provided internally before performing reading. For correct operation, V_{PP} must reach its full value (more than 24V) within 1 s after a mains-on command has been accepted. In case of automatic-mains-on option selection, when V_{DD} is applied both power-on reset and mains-on delay are provided. So, in this case, at power-on the total internal delay is about 1.5 s.

Interfacing TDA 4433 with AFC circuits

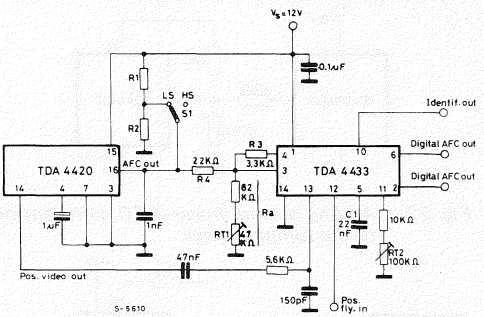
Fig. 19 shows the typical application when the TDA 4420/1 is used as an AFC circuit.

The passive components should be chosen as follows:

R1 and R2 : they define the AFC response slope in case of low-slope selection. For R1 = R2 = 5.1 KΩ, the typical slope is 750/11 kHz/V (with AFC output unloaded).

S1 : it switches between low slope (LS) and high slope (HS) of the AFC response. The high slope is typically 88/11 kHz/V.

Fig. 19 - Interface circuit between TDA 4433 and TDA 4420/1.



R3 and R4 : the ratio (R3 + R4)/R3 defines the digital-AFC width (δ f) obtained from the linear-AFC width (2 Δ f) - see fig. 20. δ f is the very narrow frequency range where the system is perfectly tuned when digital AFT is used (this is the range f_0 described on pag. 7).
With TDA 4433 supply voltage V_S= 12V, the relationship is:

$$\delta f = 0.036\ (2\,\Delta f)\ \frac{R3 + R4}{R3}$$

RT1 : by means of this trimmer it is possible to align the linear tuning with the digital one, at the same frequency. The typical relationship is:

$$R_a = 33\ R3$$

With R3 = 3.3 kΩ, R_a can be implemented with a fixed resistor of 110 kΩ, or with a 150-kΩ trimmer.

RT2 : by means of this trimmer it is possible to choose the best sensitivity. It is possible to put a fixed resistor at pin 11 in the range of 68 kΩ to 100 kΩ.

When the TDA 2540/1 is used, a good solution is shown in fig. 21.

When desired, a fast AFC correction loop can be superimposed to the digital-AFC loop, by adding a small linear-AFC contribution to the tuning voltage as shown in fig. 22.

Fig. 20 - Linear and digital AFC

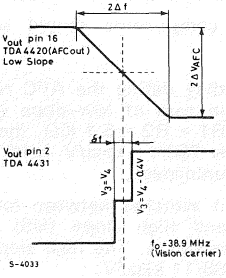


Fig. 21 - Interface circuit between TDA 4433 and TDA 2540/1

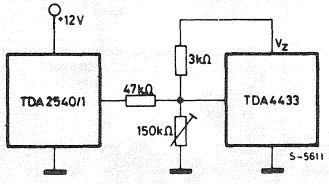
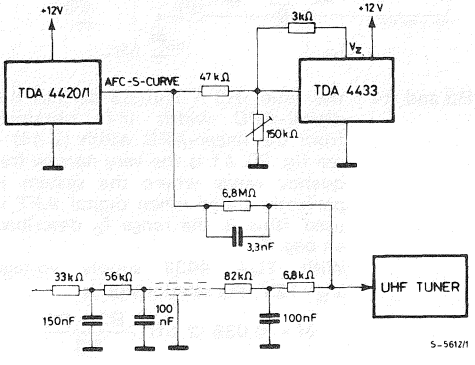


Fig. 22 - Adding a small linear-AFC contribution to the tuning voltage



Adjusting the sensitivity of TDA 4433

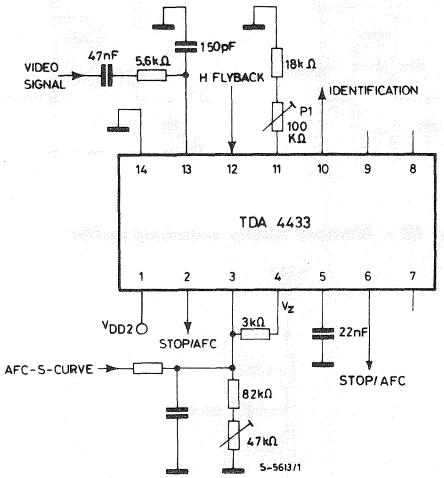
The capacitor connected between pin 5 of TDA 4433 and ground controls the time constant of the coincidence detector of the TV signal identification circuit. By reducing the size of this capacitor, the integration time constant is reduced and faster system reaction is achieved. In presence of weak TV signals, the circuit can easily make detection errors and, as a consequence, it can cause wrong operation of the system during automatic station search.

A control of the sensitivity is possible by controlling the discharge current of the integration capacitor.

A relatively high value capacitor can be chosen in conjunction with a relatively small discharge current, so achieving a high sensitivity and fail proof detection circuit.

By applying a signal having the minimum value the circuit has to recognize to the video input of TDA 4433, it is possible to set the sensitivity of system. This is done by tuning the trimmer P1 and controlling detection/not detection on pin 10 (see fig. 23).

Fig. 23 - Adjusting the sensitivity of TDA 4433.



Typical applications

Figs. 24 to 26 show circuit diagrams for various system configurations.

Automatic and/or manual search applications are available using either digital or linear AFT.

The configurations shown include the remote-control feature. Also system configurations without remote-control can be implemented for low-cost applications.

Fig. 24 - M490 application circuit - Manual search with linear AFT

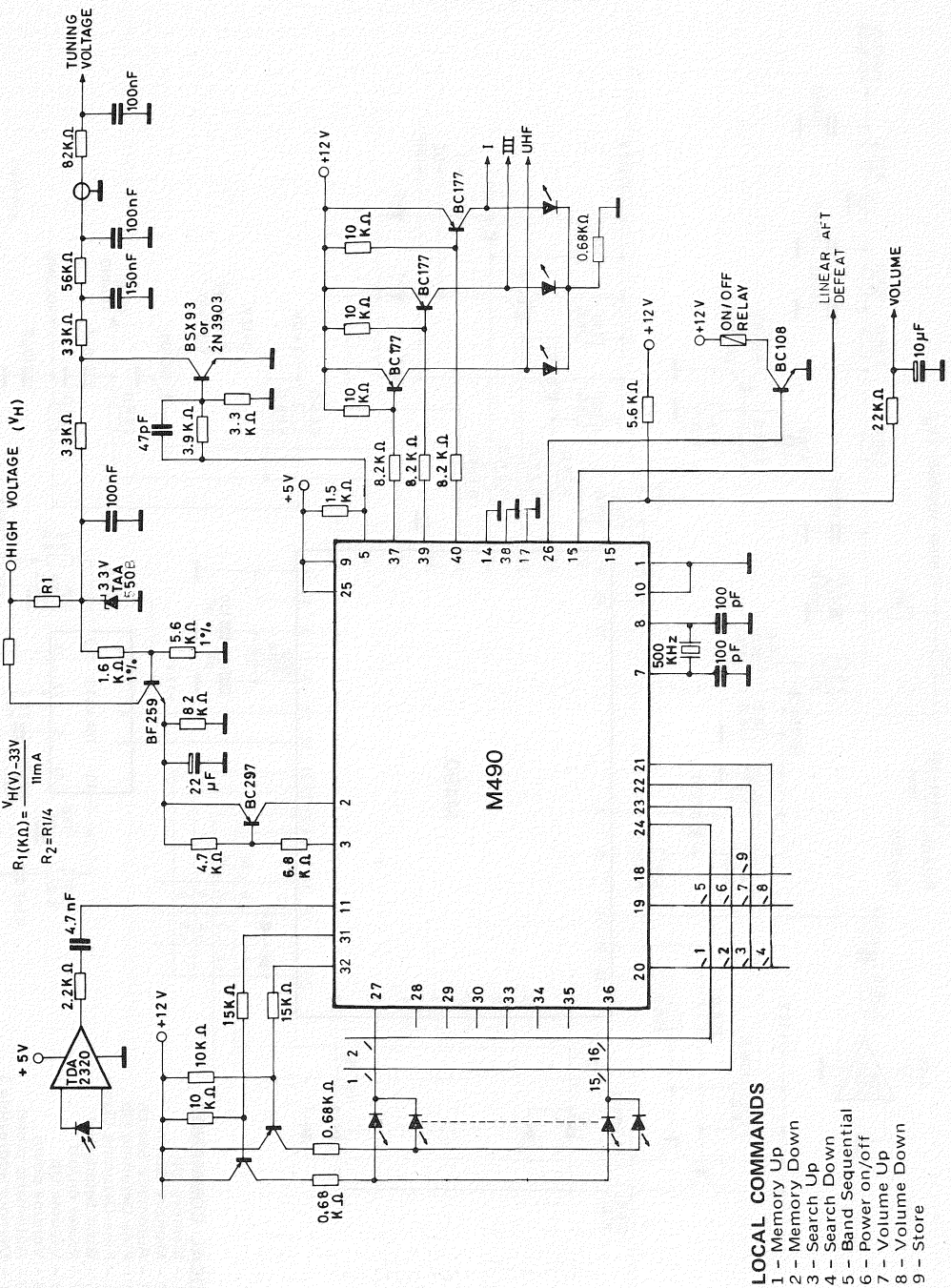
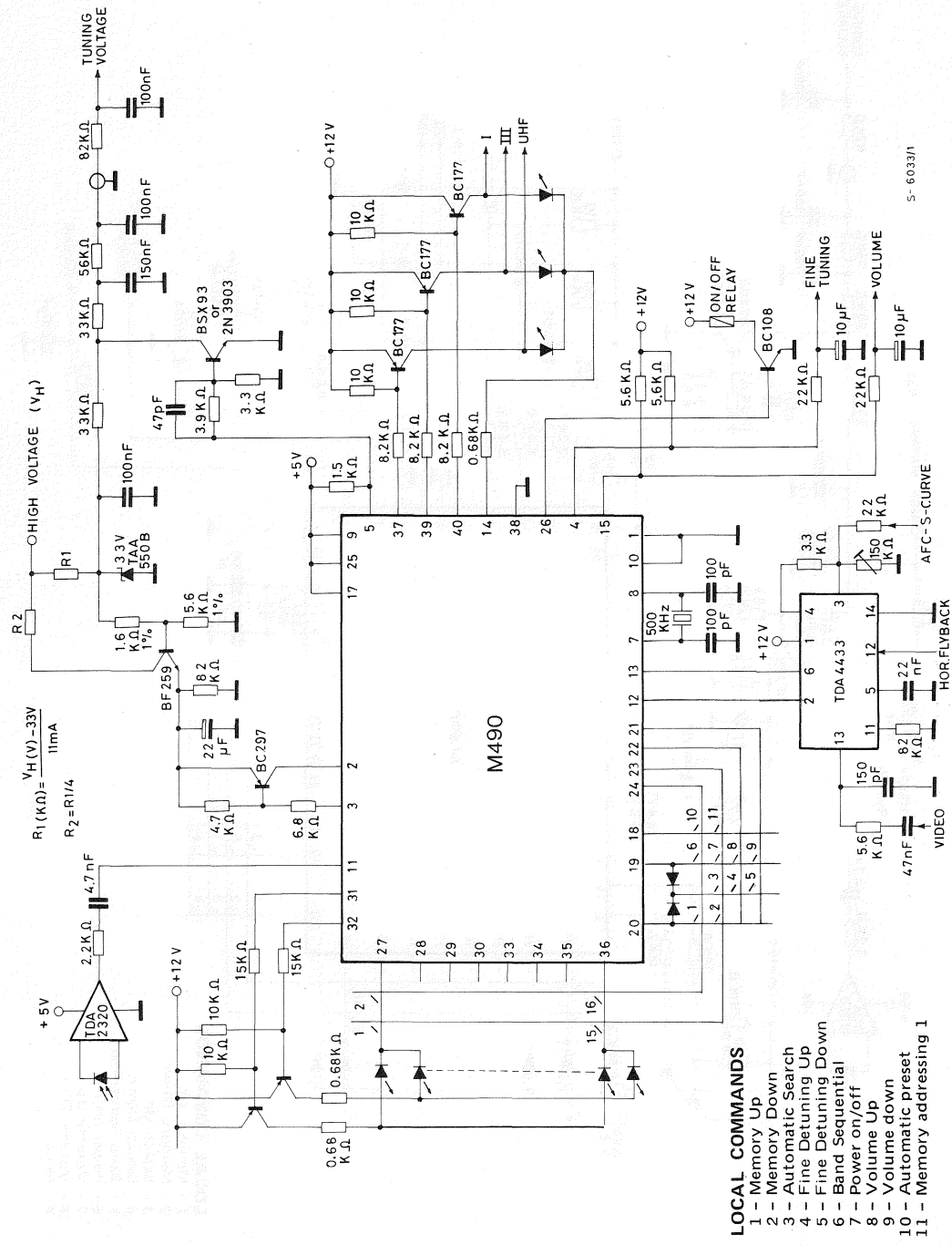


Fig. 25 - M490 application circuit. Automatic search
Automatic preset
Fine tuning with D/A } *Digital AFT*



LOCAL COMMANDS
1 – Memory Up
2 – Memory Down
3 – Automatic Search
4 – Fine Detuning Up
5 – Fine Detuning Down
6 – Band Sequential
7 – Power on/off
8 – Volume Up
9 – Volume down
10 – Automatic preset
11 – Memory addressing 1

Fig. 26 - M490 application circuit. Automatic search / Automatic preset / Manual Up/Down } *Digital AFT*

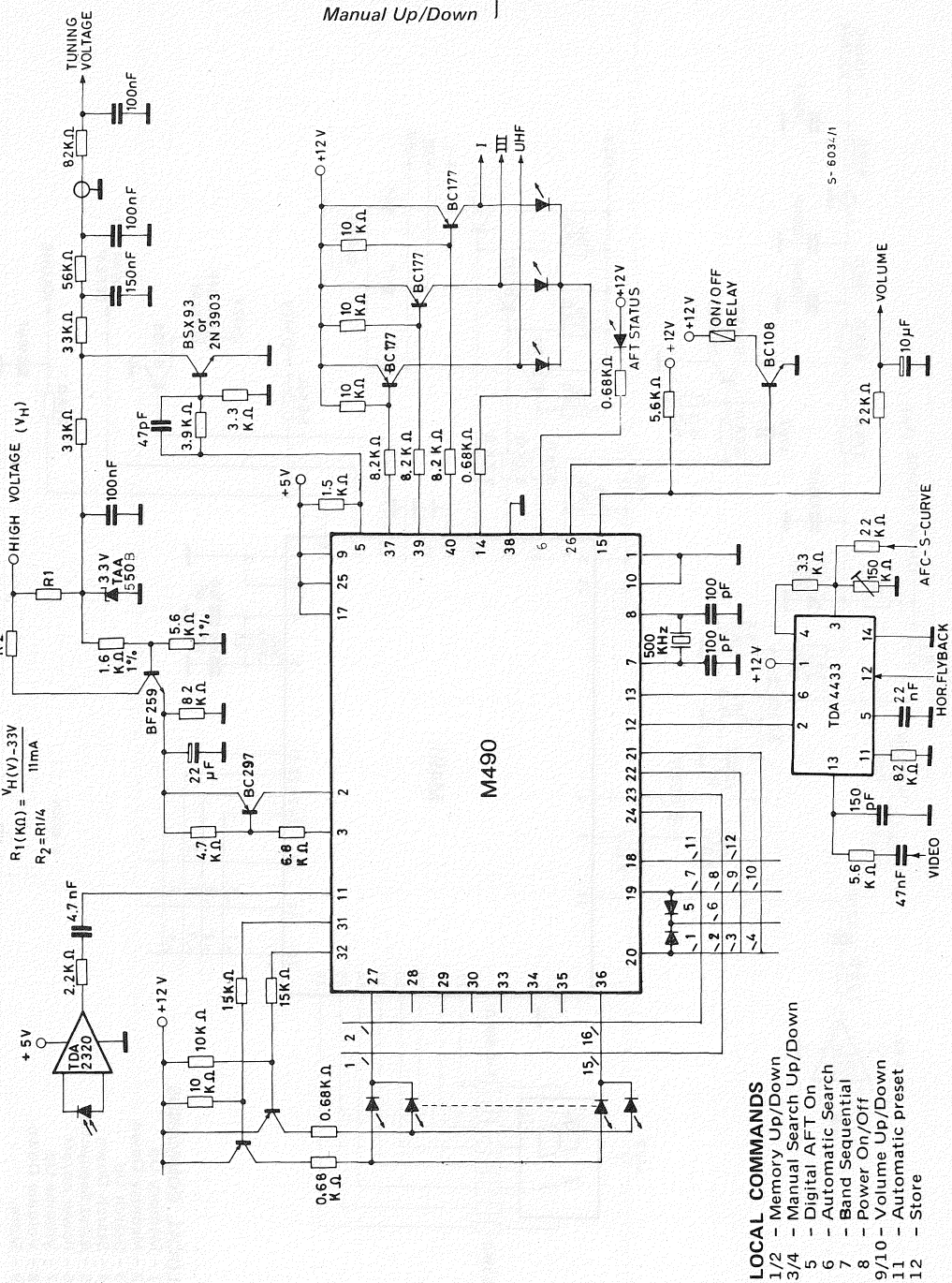


Fig. 27 - M491 application circuit - Manual search with Linear AFT (16 memory Option)