

# (BCM) 87C751 Specification for a bus-controlled monitor

AN442

## SUMMARY

BCM87C751 is a powerful, flexible and low cost Digital Controlled Monitor System, based on the 87C751 microcontroller. It employs I<sup>2</sup>C bus control with various I<sup>2</sup>C bus controlled peripherals (PCF8582EP-EEPROM and TDA8444 D/A converter). The control function is implemented via 8 6-bit DC voltage output from TDA8444.

Some features of the system:

- Flexible approach, especially for multisync or auto sync operation
- Mode detection and frequency measurements by microprocessor
- Mode switching under software control
- Elimination of potentiometers
- Quick factory alignment (DACs can be preset)
- Automatic factory alignment possible

This document describes the operation and the use of the system. it provides necessary information concerning operation, required hardware, flow charts and their effect on the performance.

## INTRODUCTION

Figure 1 shows the block diagram of a high-performance color monitor with microcontroller and several parts that communicate via the two-wire I<sup>2</sup>C-bus.

The system can perform the following:

- Determine the mode and standard of incoming signals with the stored values in memory (e.g., multisync modes).
- Enter parameters of user defined modes into memory via a keyboard.
- Control analog parameters such as contrast and brightness via the bus from keyboard inputs.
- Control mode and standard parameters (such as picture geometry parameters and the free-running oscillator frequency).

## Features

- Multisync or Autosync operation
  - FH = 31kHz-95kHz
  - FV = 50Hz-114Hz
- Selectable four or five function control configurations
- Selectable one digit, or one and one-half digit, or null seven segment mode display.
- Selectable Horizontal direct ratio or indirect ratio F to V converter DAC output configurations
- Selectable ten user modes plus ten factory modes, or, one user mode plus 19 factory modes configurations
- Selectable multiple up/down keys or minimum keyboard configuration
- Change function without save key, all keys but the reload key have a repeat function
- Both Horizontal and Vertical outputs have F-to-V converter DAC outputs

- Four outputs of Horizontal PLL capacitor selection signal. This can be easily adapted for further extension.

## IC DESCRIPTIONS

### 87C751

A derivative of the 8051 family of microcontrollers, the 87C751 has an 8-bit CPU, 2k bytes EPROM, 64 bytes RAM, 19 I/O lines, a bi-directional inter-integrated circuit (I<sup>2</sup>C) serial bus interface, and an on-chip oscillator.

### PCF8581/2

A 1k- or 2k-bit, 5V electrically erasable programmable read only memory (EEPROM) organized as 128 or 256 × 8 bits. The stored information is electrically alterable on a word-by-word basis, I<sup>2</sup>C-bus controlled.

### TDA8444

Comprises eight DACs, each controlled via the I<sup>2</sup>C-bus. The DACs are individually programmed using a 6-bit word to select an output from one of 64 voltage steps. the maximum output voltage of all DACs is set by the input VMAX and the resolution is approximately VMAX/64.

For detailed information on these devices, please refer to their respective data sheets.

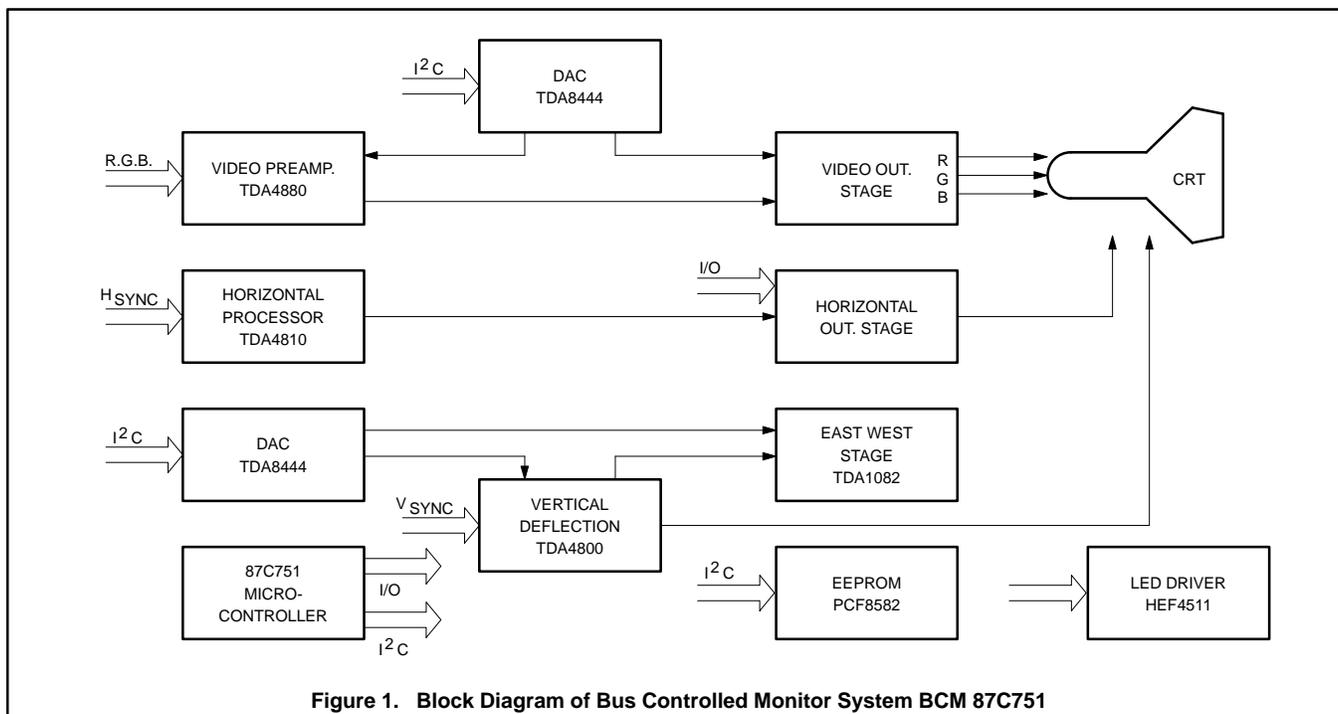


Figure 1. Block Diagram of Bus Controlled Monitor System BCM 87C751

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## OPERATION INSTRUCTION

### Function Selection and Change

When the monitor is powered on it will automatically enter the corresponding mode depending on the input signal. Different configurations and functions can be defined by users with the use of different features. The following configuration's functions are examples for user's reference. See Figure 2 for Configurations 1 through 4.

To adjust functions such as V-size, V-shift, H-center, H-shift, and PCC (Pincushion Correction Circuitry):

1. The "Function" key should be pressed until the required function LED is lit.
2. If the V-shift LED is on, the user can then adjust V-shift by pressing Up or Down key. If the Up key is pressed, the V-shift DAC output will increase one step. While the Down key is pressed, the V-shift DAC output will decrease one step. The user can repeat the Up or Down key simply by pressing it longer than 0.5 second. It will then automatically repeat approximately 2 times per second until the key is released.

### Mode Selection and Change

(See Figure 4)

In Figures 3 and 4, the mode number is displayed on the two seven-segment LEDs.

Each number denotes one mode. Modes 10 through 19 are user modes, which can be defined by the user. When there is a new mode entering the monitor that does not belong to any mode stored in the EEPROM, the mode display will show "19". If the user presses the Reload key while the mode display is "19", the display will flash. When the mode display is flashing, the user can select the destination mode by pressing the Up/Down keys. The destination mode is between 10 and 19.

Every press of the Up key causes the flashing display to add one, unless it already reached 19. Every press of the Down key causes the flashing display to subtract one, unless it has reached 10. When the user lets the destination mode flash on the display, the user can press the Reload key to store the new mode to destination mode. When the mode display stops flashing, the new mode is stored. The newly stored destination mode is permanent, unless the user repeats the entire procedure.

To change an old user mode, already stored in EEPROM, to a different user mode, press the Reload key for longer than 8 seconds while the monitor is working in the old mode. The mode display will flash the old mode, then the user can use the Up/Down key to select the new mode. Press the Reload key again to copy the old to new destination user

mode. If the user forgets to press the Reload key again, the flashing of the mode display will last for 2 minutes, then the program will cancel the copy old mode to new user mode command.

During the flash period, the program still monitors the Horizontal and Vertical sync signal to adapt the DAC to the proper mode. For example, while the user tries to copy new mode 13 to mode 15, and the mode display 13 (15) is flashing, if the PC sends out a signal for mode 3, the program will change the DAC output to adjust the monitor to work in mode 3, but the mode display is still flashing on user mode 13 (15) and the store procedure is still going on until the user presses the Reload key again, or terminates the copy procedure after the 2 minutes time out. The mode display then shows 3.

NOTE: Upon request, we can also program in advance those 10 user-defined modes that can still be changed by the user if necessary for further extension.

For Configuration 5 to Configuration 8, see Figure 3.

To adjust functions, the user can simply press the corresponding push button. The upper push button will increase the DAC output. The lower push button will decrease the DAC output. (A total of 64 steps can be programmed in advance.)

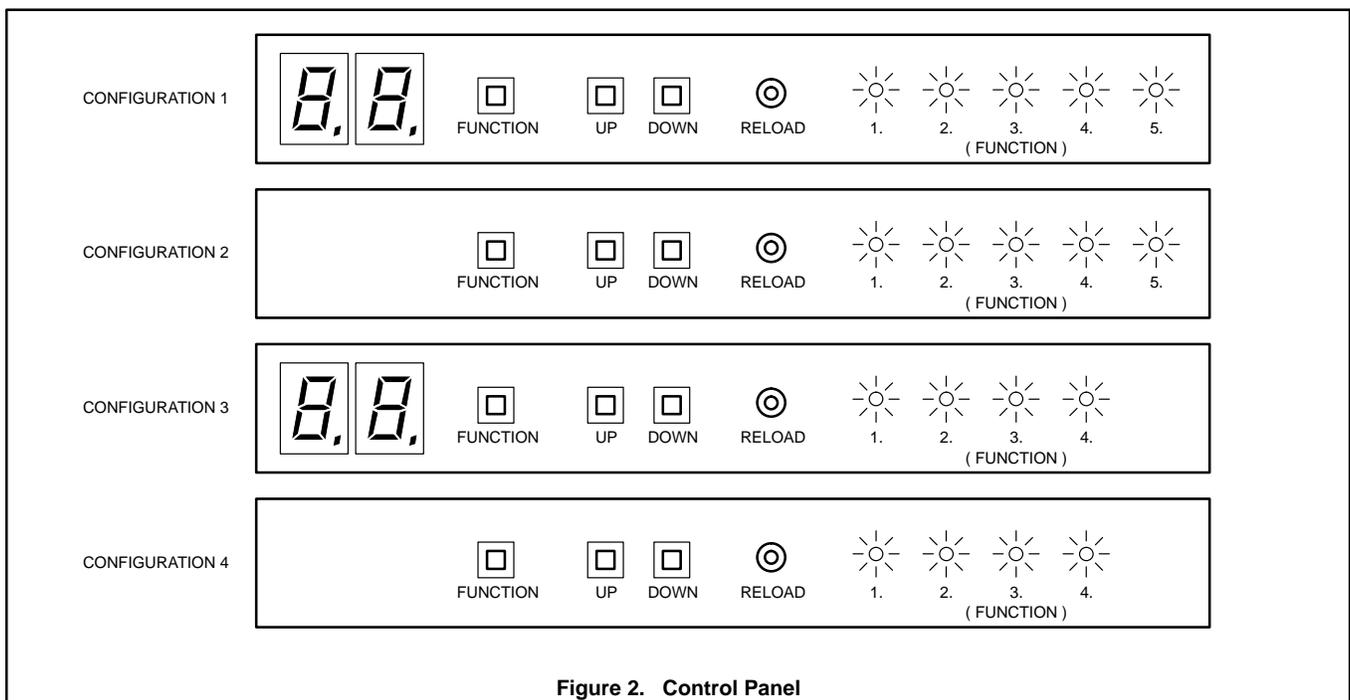
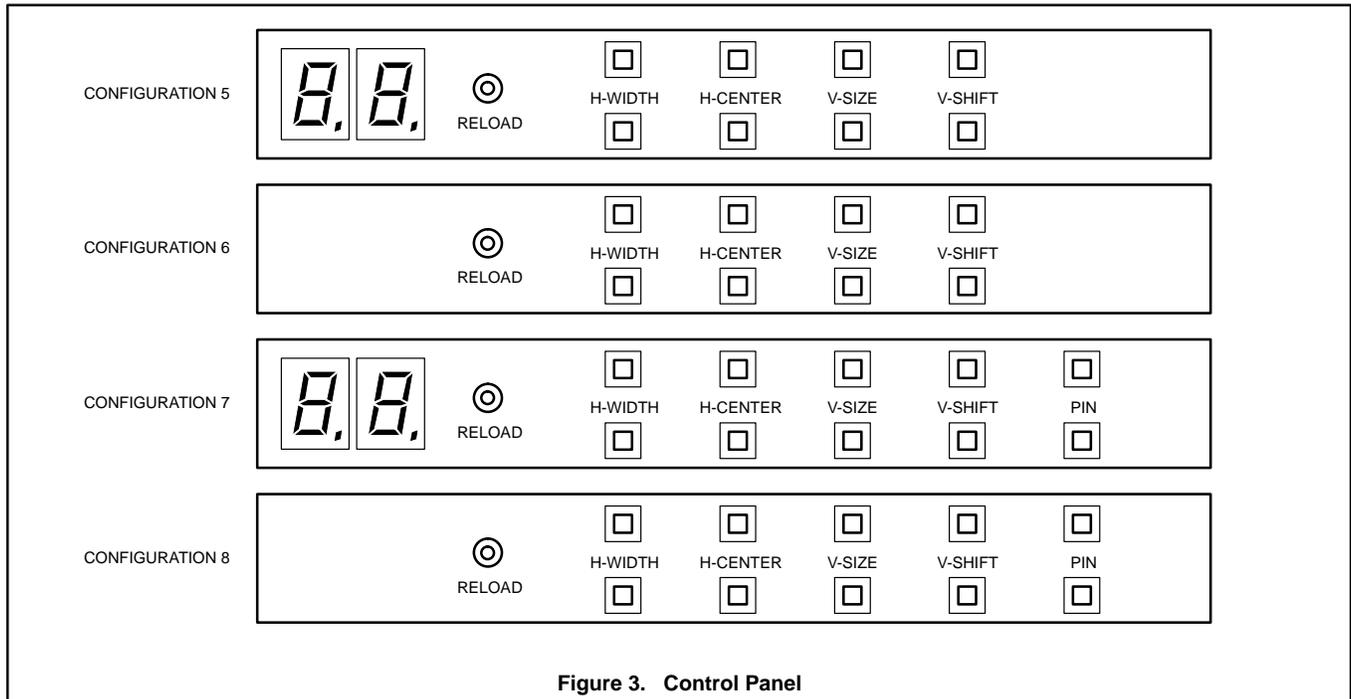


Figure 2. Control Panel

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MODE	NAME	H.F.	V.F.	H.P.	V.P.
0	VGA-1	31k	70	+	-
1	VGA-2	31k	70	-	+
2	VGA-3	31k	60	-	-
3	8514A	35k	87	+	+
4	SVGA-1	35k	56	+	+
5	UVGA-1	48k	60	+	+
6	VESA	56k	70	-	-
7	V64-1	64k	60	+	+
8	SVGA-2	37k	60	+	+
9	V78	78k	60	+	+
10	USER DEFINE	.	.	.	.
.	.	.	.	.	.
18	.	.	.	.	.
19	.	.	.	.	.

Figure 4. Mode Selection

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## SOFTWARE FLOW CHART DESCRIPTION

(See Figures 5 through 7)

When power is on, software initializes the hardware first. The microcontroller waits 100µs for the settlement of the hardware, then initializes itself by specifying stack, setting timer, clearing RAM, arranging interrupt, . . . , etc.

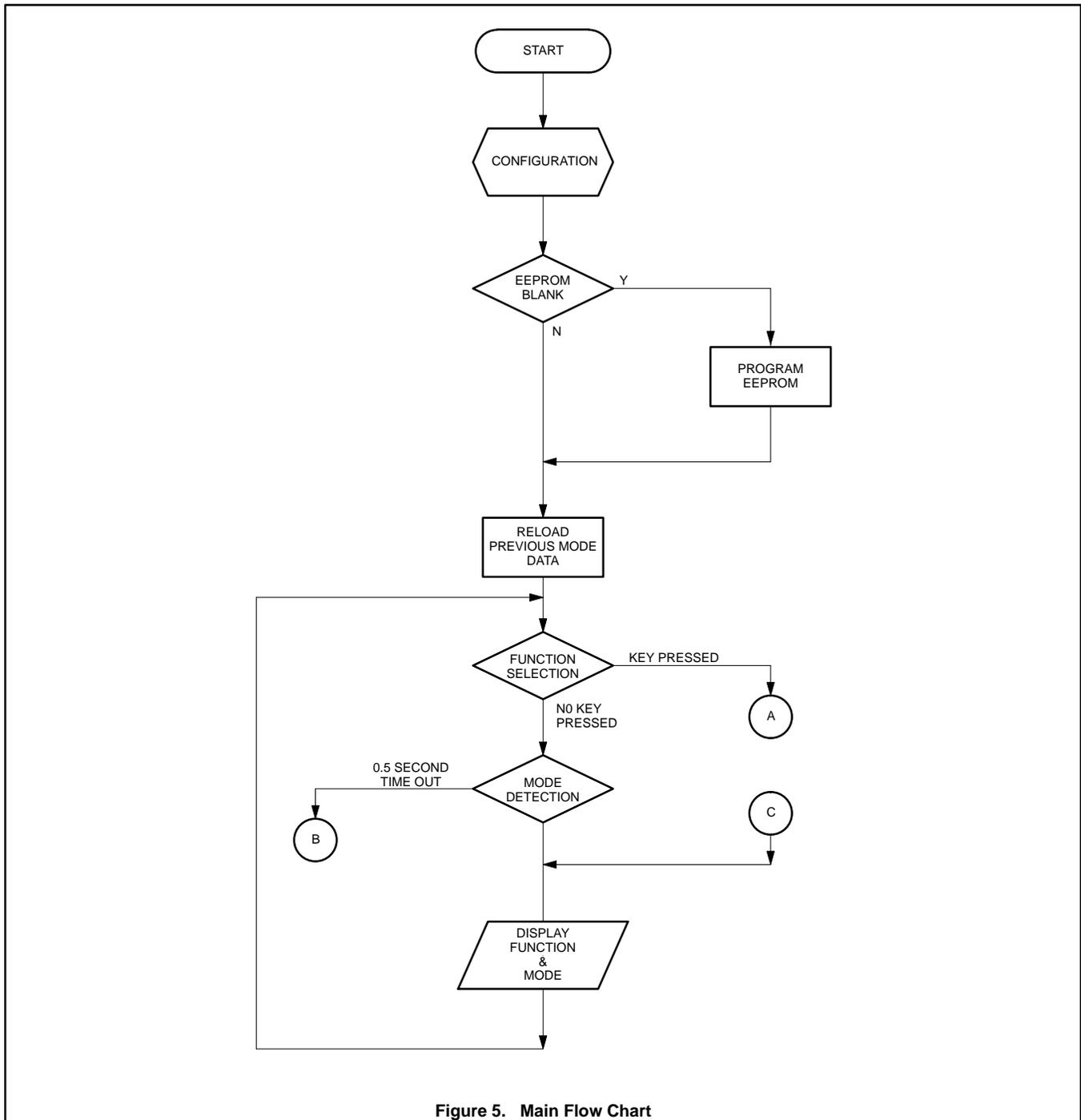


Figure 5. Main Flow Chart

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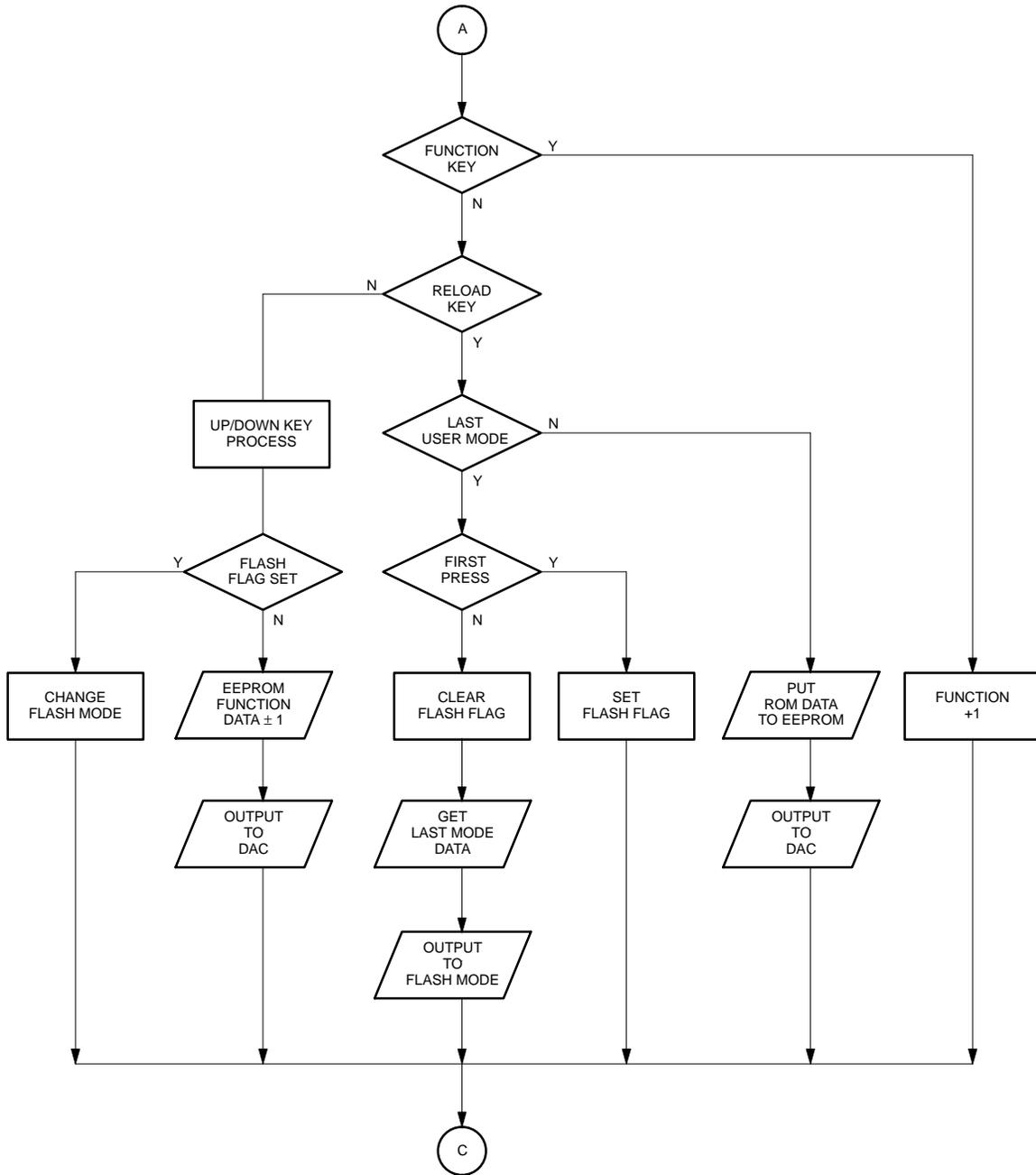


Figure 6. Function Selection Flow Chart

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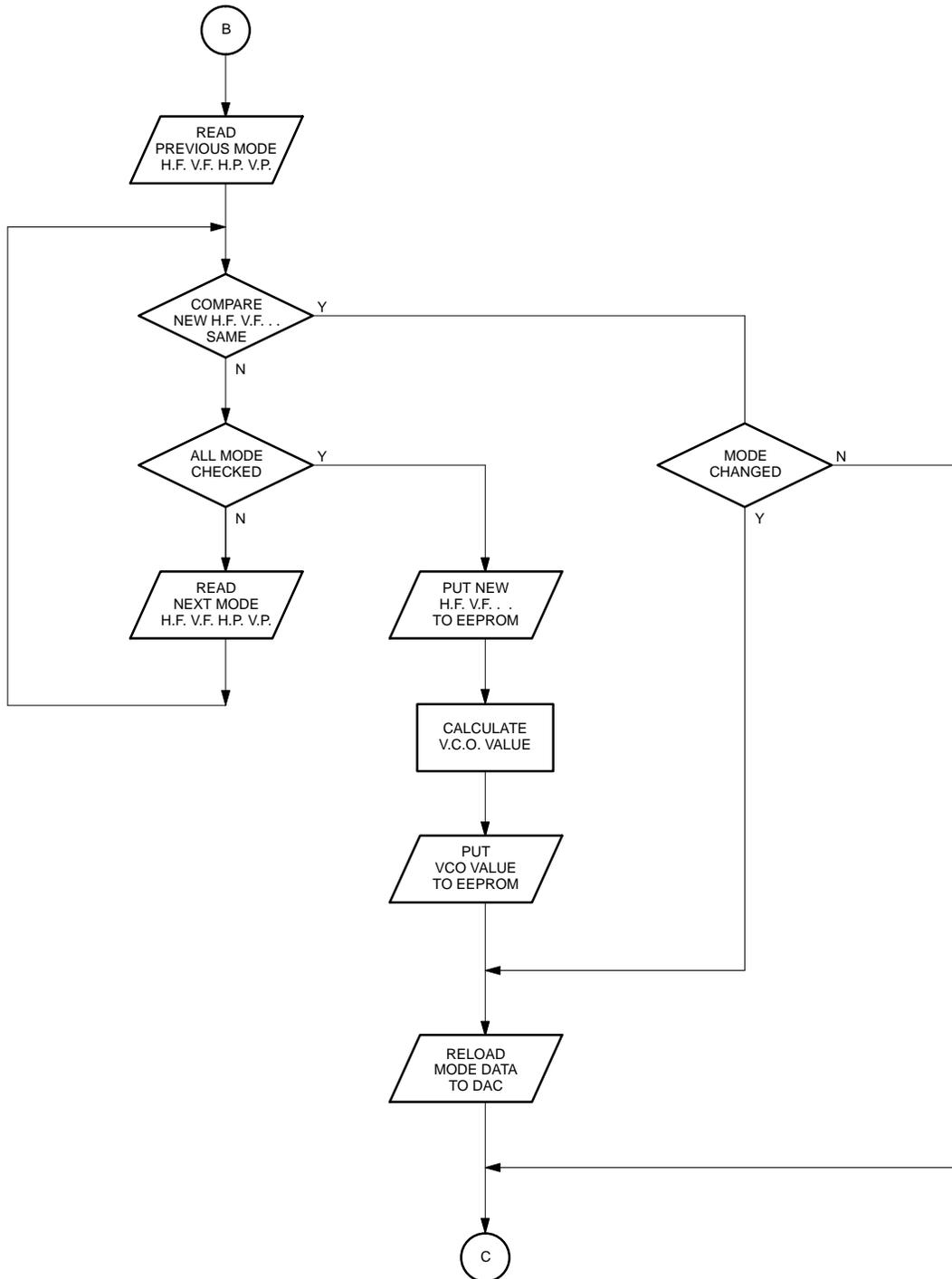


Figure 7. Mode Detection Flow Chart

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**Table 1.**

ADD DIODE		REMOVE DIODE
D1	Indirect ratio of VCO output (JP4)—See Figure 8.	Direct ratio of VCO output (JP4)—See Figure 8.
D2	10 user modes 10 factory modes (JP5)	1 user mode 19 factory modes (JP5)
D3	4 adjustable functions (JP6)	5 adjustable functions (JP6)
D4	Multiple Up/Down keys (JP7)	Single Up/Down keys (JP7)

Referring to previous section, *Function Selection and Change*, software can detect the hardware configuration by pulling 87C751 microcontroller pin P0.2 LOW to read the diode arrangement. Each diode denotes one change in the hardware configuration. Table 1 explains the usage of each diode.

After the configuration detection, then it goes to check EEPROM status. If the EEPROM is blank, the program will start to move all factory set data from the microcontroller's PROM to EEPROM. The last byte datum in the microcontroller's PROM is 66 used for blank check. First it reads address DD in the EEPROM, then compares it with 66. If they are equal, the software will skip the EEPROM

program procedure. If they are not equal, the software will program the EEPROM. This means that monitor makers can define their own factory modes by programming the EEPROM in advance.

The following programs are endless loops. Please refer to the main flow chart (Figure 5). There are three tasks in the endless loop.

The first task is Function Selection, basically a keyboard process program.

The second task is Mode Detection, which includes search mode and change mode.

The third task is Mode and Function Display, which includes flash mode display.

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### Mode Detection

Beginning with branch "B", Mode Detection Flow Chart (Figure 7), the block at the top of the flow chart is "Read Previous Mode" (the time before 0.5 second ago) and includes Horizontal Sync Frequency, Vertical Sync Frequency, Horizontal Sync Polarity, and Vertical Sync Polarity. The second block is a comparison test block. When current mode (from 0.5 second ago until now) parameters are the same as those in previous mode, the program will branch to the right test block. Since the mode is not changed, the second test block in the right part of the flow chart will branch to leave the Mode Detection section.

If the current mode (from 0.5 second ago until now) parameters are not the same as the previous mode (the time before 0.5 second ago), the first test block from the top of the flow chart will branch to search all mode parameters in the EEPROM to find out what the current mode should be. The left loop of the flow chart checks for the end of the search procedure, i.e., if all modes in the EEPROM are searched and checked, and

the outcome is the same, then this test block will branch to set up a new user mode (19), as per the 4 steps indicated in the central flow chart line.

The first step in setting up a new user mode is to "Put New Parameters" (such as Horizontal Sync Frequency, Vertical Sync Frequency, Horizontal Sync Polarity, and Vertical Sync Polarity) into the EEPROM. The new mode parameters are always saved in the last mode address. If the configuration allowing 10 user modes is selected, then diode 2 is added. If one was found to be the same, the program will branch to the right test block. If it then finds that there is a mode change, it will branch to Reload Mode Data to DAC to complete the mode change procedure.

When the mode change procedure is completed, the monitor will be working in a new mode. Since the program enters the Mode Detection task every 0.5 second, it takes from 0.5 to 1.0 second to finish the change of mode. To save the new user mode (mode 19) to other user mode (10-18), the

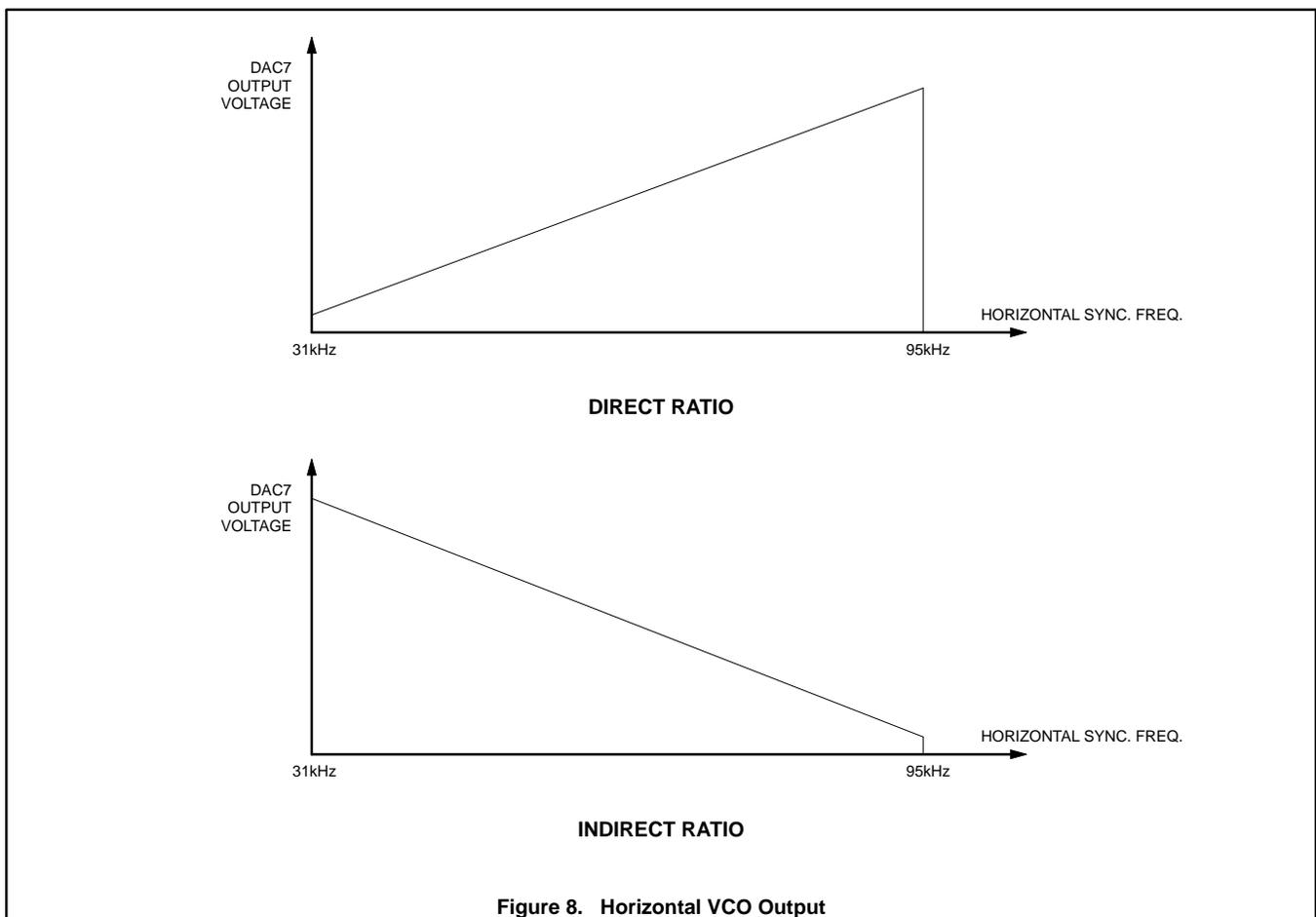
user can use the RELOAD key to save the new user mode to other user mode (modes 10 through 18).

If the configuration for 10 user modes is selected, it is highly recommended that you save new user mode to other user mode (10-18) because the last mode "mode 19", will be overwritten by any new user mode whenever a new user mode is detected, after new user mode parameters are detected.

The second step in setting up a new user mode is "Calculating VCO Output Value" (see Figure 8). There are two different curves for the designer to select. If diode 1 is removed, the VCO Output Voltage will be in direct ratio to the Horizontal Sync Frequency. If diode 1 is added, the VCO Output Voltage will have an indirect ratio.

The third step in setting up a new user mode is "Put VCO Value to EEPROM".

The last step is "Reload Mode Data to DAC". After reloading the DAC, the monitor is changed to the new user mode.



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### Key Function Selection

The first task is Function Selection (see Figure 6). When the program scans the keyboard, it first checks for the function key. If it is depressed, the program will branch right to change function VALUE(+1). the function LEDs are lit in sequence, i.e., when the second LED is lighting and the program detects a press in function key, the program will light the third LED and turn off the second LED. If the program detects that the last LED is lighting, it will turn on the first LED and turn off the last LED.

If the key pressed by the user is not a function key, the program will check if it is the reload key. If it is not, then the second test block will branch left to check Up/Down keys. both the Up and Down keys have two different definitions. When the user is updating function contents, Up and Down keys are used to change the function contents stored in the EEPROM. In that situation, the flash flag is not set; after the program branch left from the reload key test block, the program will test flash flag, then the program will change the output of DAC.

If a flash flag is set (see next paragraph, also), Up and Down keys will change the flashing mode displayed on two seven-segment LED displays. The flashing mode is valid between 10 and 19. The Up key will add one to the flashing mode unless the flashing mode is already 19, while the Down key will subtract one unless the flashing mode is already 10.

If the reload key is pressed while the program is in last mode (19), i.e., a new mode which is not the same as any mode entered in the EEPROM, the program will check to see if this is the first press. If this is the first press, the fourth test block in the middle will branch right to set the flash flag, after the flash flag is set, the mode displayed on the two seven-segment LED displays will start to flash.

Between the first press of the reload key and the second press of the reload key, the Up and Down keys can be used to change the flashing mode to a destination mode. When the program detects the second press of the reload key, the program will execute all the center blocks in the flow chart. First, starting to clear the flash flag; second, to get last mode data from EEPROM; and third, to put the mode data into a new address. The destination is decided by the user via Up and Down keys to select flashing mode, then pressing the reload key to make the flashing mode be a still mode. After mode display is still, the user finishes defining the destination user mode. This destination user mode will last forever unless the reload key is used to redefine it.

If the user presses the reload key, and the program is not in the last mode, it will branch right to reset mode data in EEPROM, starts to read original mode data in microcontroller's PROM, then puts these data to EEPROM, the outputs to DAC. This function is to help the user to restore the monitor when the monitor display is out of control. For example, if the user adjusts the Horizontal phase too broad, then monitor may become out of sync. As a consequence the screen will be a mess, and it is not easy for the user to re-adjust for correction. This feature will minimize possible complaints from customers.

### CIRCUIT DESCRIPTION

U1-87C751 is an 8-bit microcontroller and the heart of the Bus-Controlled Monitor. The 87C751 receives Vertical Sync and Horizontal Sync signals from pins P1.5 and P1.6. The R3,C5 in pin P1.5 is a low pass protection circuit. It can prevent the Vertical Sync signals, including Horizontal Sync Pulse, from interfering with the counting of the Vertical Sync Frequency. The R2 in pin P1.6 is only used for protection of 87C751.

The 87C751 automatically checks the mode parameters from these two pins, then switches the DAC from the old mode to a new mode. When 87C751 is checking the mode, it reads different mode parameters from the EEPROM via I<sup>2</sup>C bus, then decides whether there has been a change in mode. If a change is needed, the 87C751 will first mute video by sending a LOW to pin P0.2, then reads the correct mode data from the EEPROM via the I<sup>2</sup>C bus. It then puts the data to the DAC via I<sup>2</sup>C bus. Because of the I<sup>2</sup>C bus, the connections between the EEPROM, DAC, and the microcontroller are very simple.

The system clock is provided by a 12MHz crystal connected to Pins 10, 11 of the 87C751. Basically, port1 is used for input, but P1.4 and P1.7 are used for output. P1.0 to P1.3 are used for keyboard and configuration input.

Port0 has only three pins; P0.0 and P0.1 are used for I<sup>2</sup>C control. P0.2 is an output pin used to test configurations. Port3 is basically used for output; P3.0 to P3.4 are used for mode seven-segment LED display output; P3.5 to P3.7 are used for function display. Both mode display and function display need extra decoders, an HEF4511B seven-segment display driver is used to display the mode, while an HEF4556B dual 2-to-4 decoder is used to display function LEDs.

PCF8582 is a 2k-bit EEPROM. R4,C1 constructs an external R-C time to program the EEPROM. In normal operation the

EEPROM needs 30ms to program one byte. C2 is a decoupling capacitor to stabilize the DC supply voltage for PCF8582.

TDA8444 is an octal 6-bit DAC. R7,VR5,C# constructs a reference voltage to define the DAC's maximum output voltage. In practice, the reference voltage must be below 10.5 volts, so R7 is added to prevent the reference voltage from exceeding that limit. C4 is also a decoupling capacitor to stabilize the DC supply voltage for TDA8444.

The upper half of the HEF4556 is used to provide a switch signal to select Horizontal OSC time constant capacitors. The four outputs are Active-LOW. When the Horizontal Sync Frequency (H.S.F.) falls in one of the four ranges, the corresponding output pin will go low. The four ranges are:

(H.S.F. < 35kHz),  
(35kHz < H.S.F. < 40kHz),  
(40kHz < H.S.F. < 50kHz),  
(H.S.F. > 50kHz).

The enable input in the upper part of the HEF4556B can be used to extend the upper limit of the switch signal. The lower part of the HEF4556B is used to display function LEDs, the fifth LED is driven by an NPN transistor. When the transistor is turned on by the microcontroller, it also disables the lower part of the HEF4556B. If multiple Up/Down keys are configured, the function LEDs are replaced by five pairs of Up/Down keys.

Because the tenth digit of the mode display is either "1" or blank, the driver of the tenth digit uses only one transistor. The driver of the base digit employs an HEF4511B, it is a BCD seven-segment display driver with output Active-HIGH, so only common cathode types can be used. The factory can use one LED to replace a BCD display. When the LED is lit, the BCD display can display user mode, or factory mode. This is one way to reduce the system cost.

If multiple Up/Down keys are not configured, the keyboard has four keys:

Function key,  
Up key  
Down key  
Reload key.

If multiple Up/Down keys are configured, there will be no function key, but five pairs of Up/Down keys and one Reload key. the multiple Up/Down keys are configured by adding a diode in JP7. If adding a diode in JP6, there will be only four functions available, i.e., there will be only four pairs of Up/Down keys or four function LEDs.

LM7805 is a power regulator IC, it changes 12V to 5V to supply the whole circuit except TDA8444, which uses a 12V power supply to provide a wider range of DAC output.

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There is a table to explain the usage of each pin in the JP1 socket. JP2 and JP8 are connected together, JP3 is only used for future automatic alignment (including production line) if necessary. JP4 to JP7 are used to select hardware configurations as previously mentioned.

### SPECIFICATION OF THE SYSTEM

- The input signals to the system are Horizontal Sync and Vertical Sync. The system accepts standard TTL level signals, i.e.,  $V_{IH} > 2V$ , and  $V_{IL} < 0.4V$ . Horizontal Sync tolerance is  $\pm 0.5kHz$ , and Vertical Sync tolerance is  $\pm 2/-2$  Hz.
- There are eight DAC output signals. Their maximum output voltage can be preset by setting a voltage on the TDA8444's  $V_{MAX}$  pin. The voltage on the  $V_{MAX}$  pin must be below 10.5V and also below the voltage on the TDA8444's  $V_P$  pin. For other detailed output current characteristics, please refer to Philips data books IC02a, IC02b and *80C51 and Derivative Microcontrollers*.
- The Horizontal switch outputs have four pins. they are standard CMOS B-type buffered outputs. They are Active-LOW, i.e., there will be only one output active at any time. If the designers wants to add ranges in higher Horizontal Sync Frequency, the designer can put extra circuits onto the demo board. For example, an OPA can be added as a comparator to detect the VCO output. If the VCO output is higher than a certain voltage (VCO's 60kHz output voltage), the OPA will be triggered and the upper half of the HEF 4556 can be disabled by the OPA via HEF4556's Pin 1, when HEF4556 is disabled, the four Horizontal switch outputs will remain HIGH, then the OPA's output can be used as another switch output.
- Total current consumption is around 25-90mA, depending on the number of LED and seven-segment displays being lit.

### PARTS LIST

87C751 BUS CONTROLLED MONITOR  
TH-9102/4

Bill of Materials

November 7, 1991

Revised: November 7, 1991

Revision:

12:08:46

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ITEM	QUANTITY	REFERENCE	PART
1	1	C1	2700pF
2	6	C2, C3, C4, C8, C12, C13	0.1 $\mu$ F
3	1	C5	0.01 $\mu$ F
4	1	C6	100 $\mu$ F
5	2	C7, C11	1 $\mu$ F
6	2	C9, C10	33pF
7	5	D1, D2, D3, D4, D5	LED
8	3	JP1, JP2, JP8	Header 16
9	1	JP3	Header 4
10	4	JP4, JP5, JP6, JP7	Jumper (add diode)
11	2	Q1, Q2	BC548
12	1	R1	470R*7
13	11	R2, R3, R8, R9, R10, R11, R14, R15, R17, R19, R20	470R
14	6	R4, R6, R12, R13, R16, R18	22k
15	1	R5	VR10k
16	1	R7	2k
17	2	R21, R22	56R
18	5	S1, S2, S3, S4, S5	SW Pushbutton
19	1	U1	87C751
20	1	U2	HEF4556B
21	1	U3	PCF8582
22	1	U4	TDA8444
23	1	U5	HEF4511B
24	1	U6	LM7805
25	2	U7, U8	DISP-7
26	1	Y1	12MHz

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**PARTS LIST**

87C751 BUS CONTROLLED MONITOR

TH-9102/5

Bill of Materials

November 13, 1991

Revised: November 13, 1991

Revision:

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ITEM	QUANTITY	REFERENCE	PART
1	1	C1	2700pF
2	6	C2, C3, C4, C8, C12, C13	0.1μF
3	1	C5	0.01μF
4	1	C6	100μF
5	2	C7, C11	1μF
6	2	C9, C10	33pF
7	3	JP1, JP2, JP8	Header 16
8	1	JP3	Header 4
9	4	JP4, JP5, JP6, JP7	Jumper (add diode)
10	2	Q1, Q2	BC548
11	1	R1	470R*7
12	10	R2, R3, R8, R9, R10, R11, R14, R15, R19, R20	470R
13	6	R4, R6, R12, R13, R16, R18	22k
14	1	R5	VR10k
15	1	R7	2k
16	2	R21, R22	56R
17	12	S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12	SW Pushbutton
18	1	U1	87C751
19	1	U2	HEF4556B
20	1	U3	PCF8582
21	1	U4	TDA8444
22	1	U5	HEF4511B
23	1	U6	LM7805
24	2	U7, U8	DISP-7
25	1	Y1	12MHz

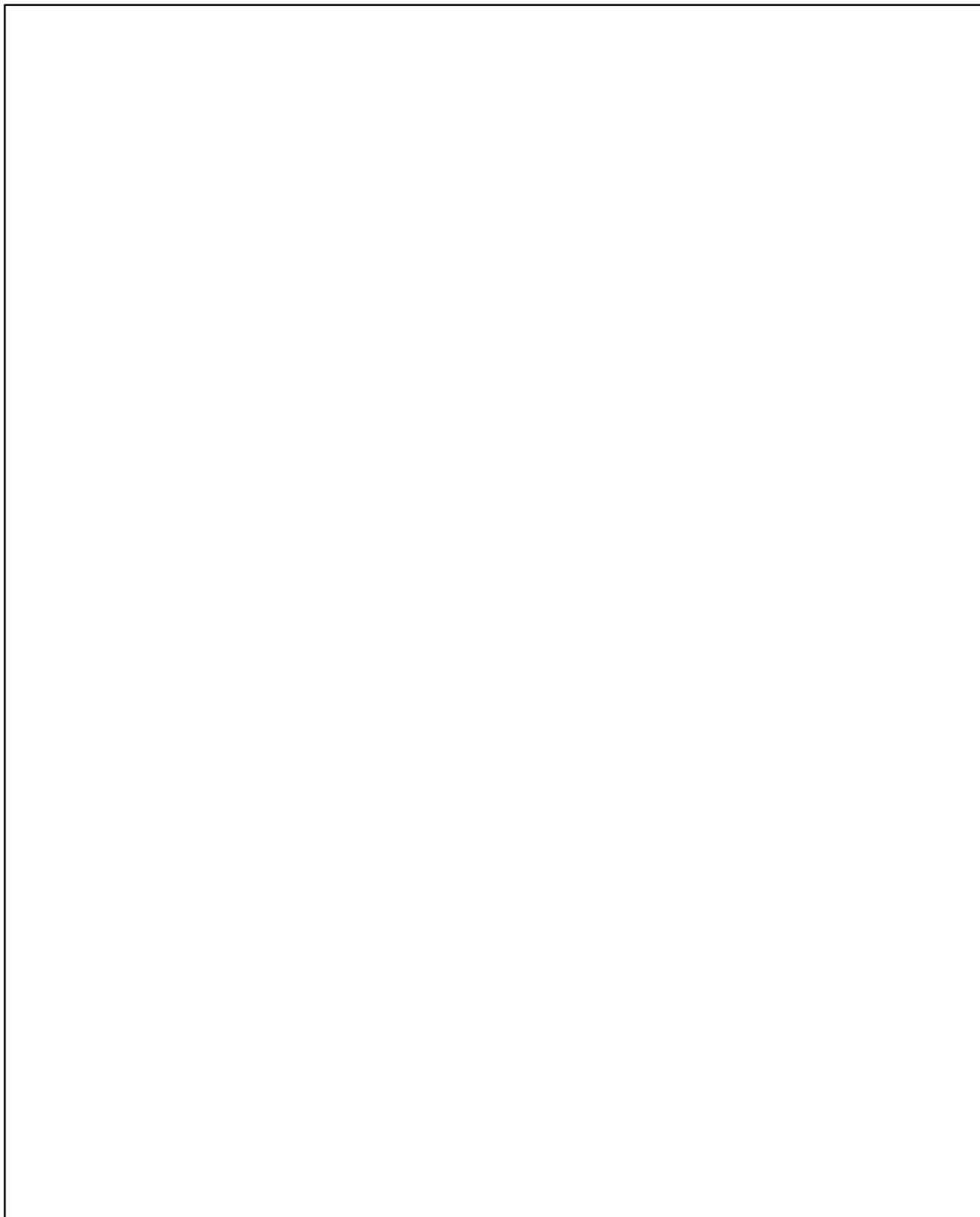
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**CIRCUIT DIAGRAM**



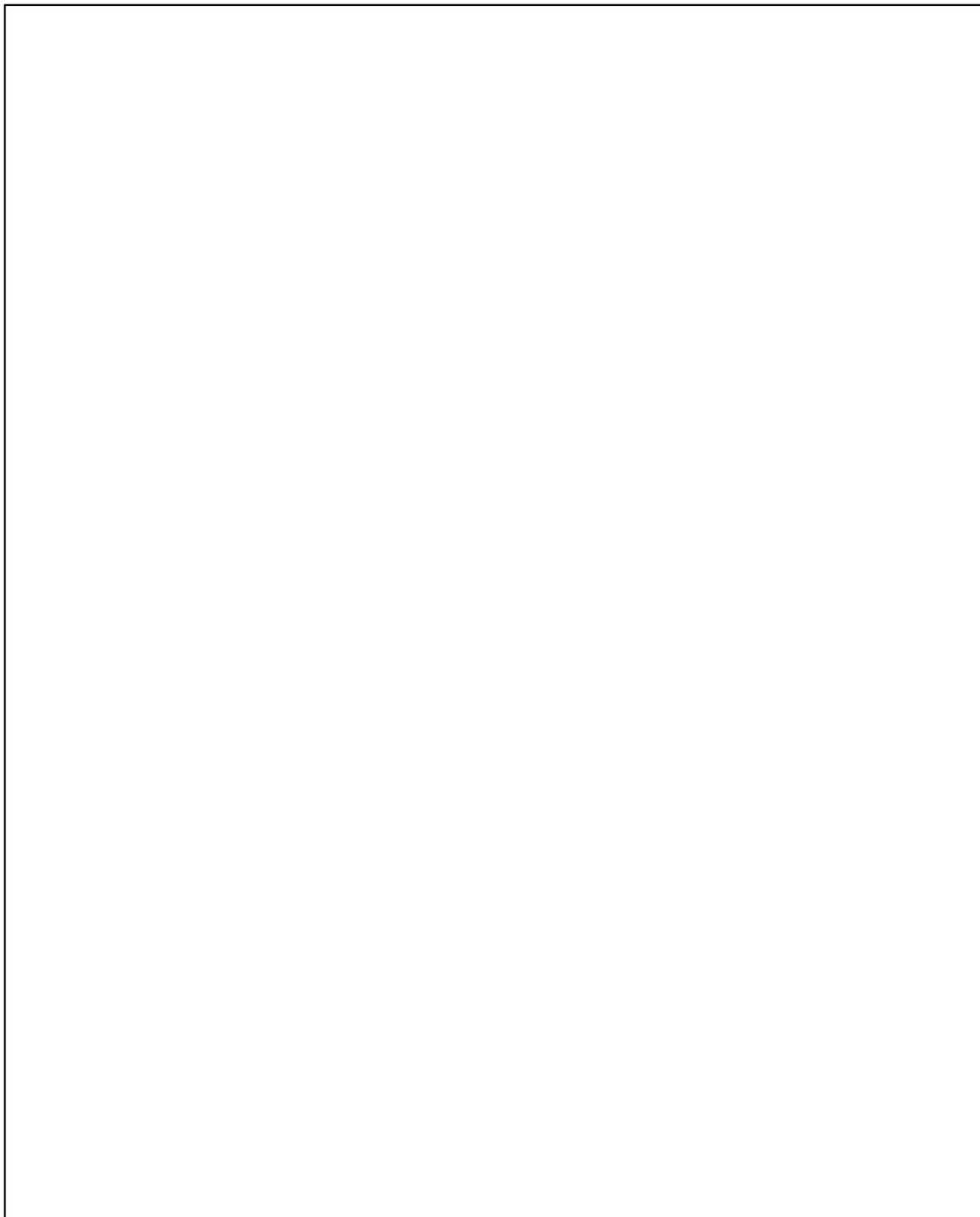
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**PRINTED CIRCUIT BOARD**



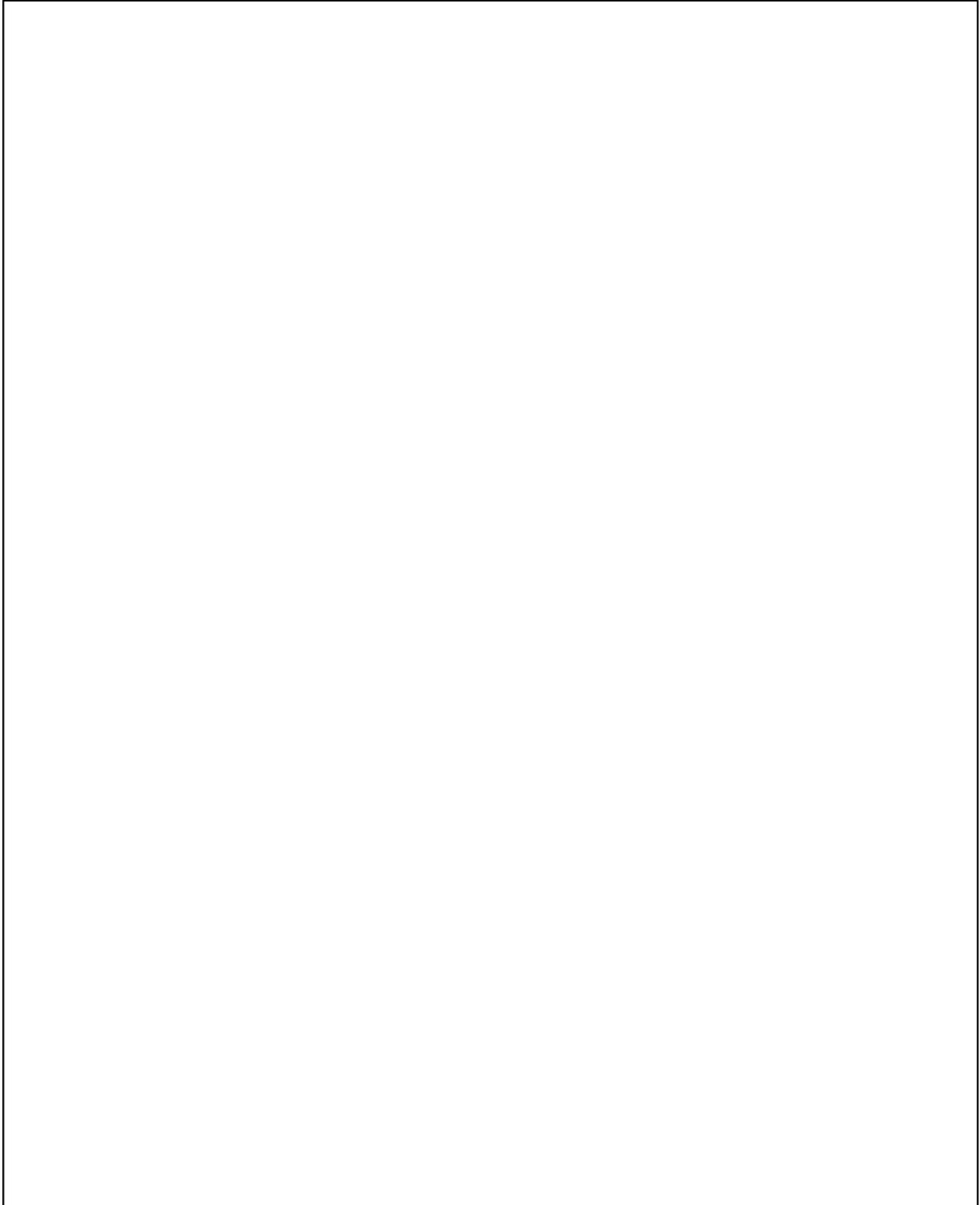
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**87C751 BUS CONTROLLED MONITOR (TH-9102/4)**



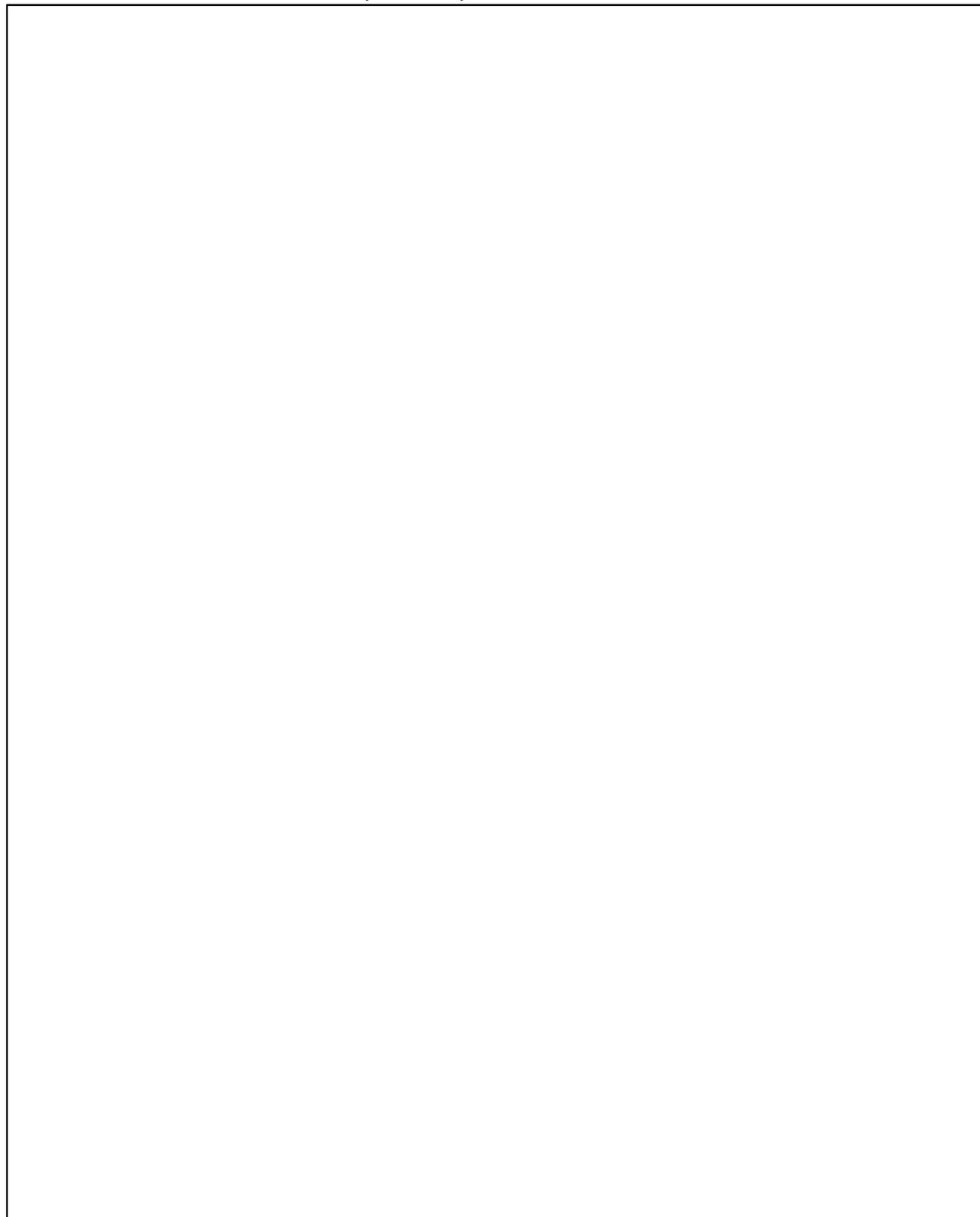
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**87C751 BUS CONTROLLED MONITOR (TH-9102/5)**



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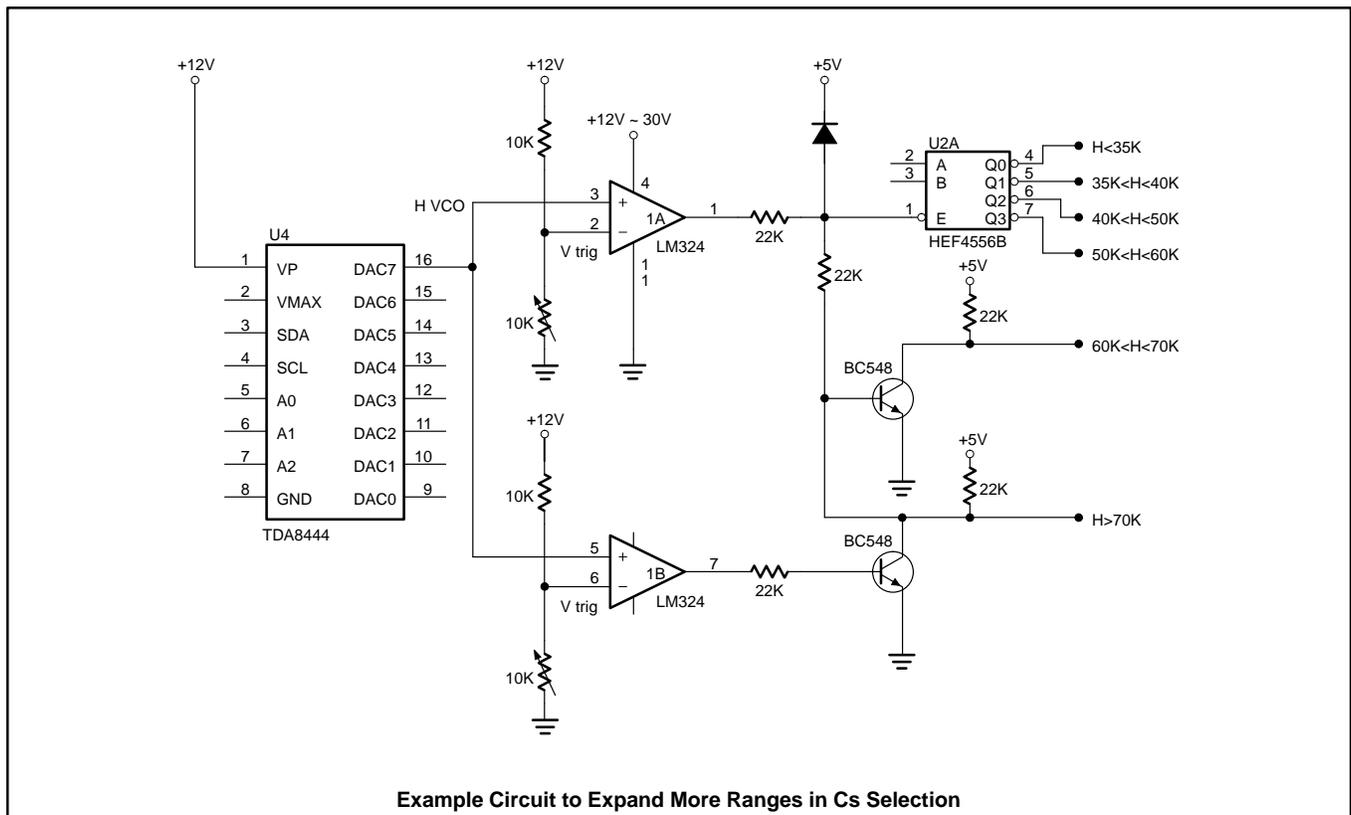
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## APPENDIX A

### References

- Philips Data Book IC02a, IC02b  
*Video and Associated Systems*
- Philips Data Book IC20  
*80C51 and Derivative Microcontrollers*  
Title: "AN422: Using the 8XC751 Microcontroller as an I<sup>2</sup>C bus Master"
- Philips Data Book  
*RF Communications*  
Title: "AN168: The Inter-Integrated (I<sup>2</sup>C) Serial Bus: Theory and Practical Consideration",  
Author: Carl Fenger
- Title: "ETV8831: Deflection Processor TDA8433 with I<sup>2</sup>C Control"  
Author: DJA Teuling
- Title: "ETV89008: VGA Monitor with the High Resolution Colour Tube M34ECL10X36"  
Author: H. Nerhees

## APPENDIX B



When you want to determine Vtrig signal, please disconnect Pulse Signal Generator (P.S.G.) Output to H. Sync demoboard from monitor and connect, and use input, set P.S.G. to 60kHz, TTL level output, then

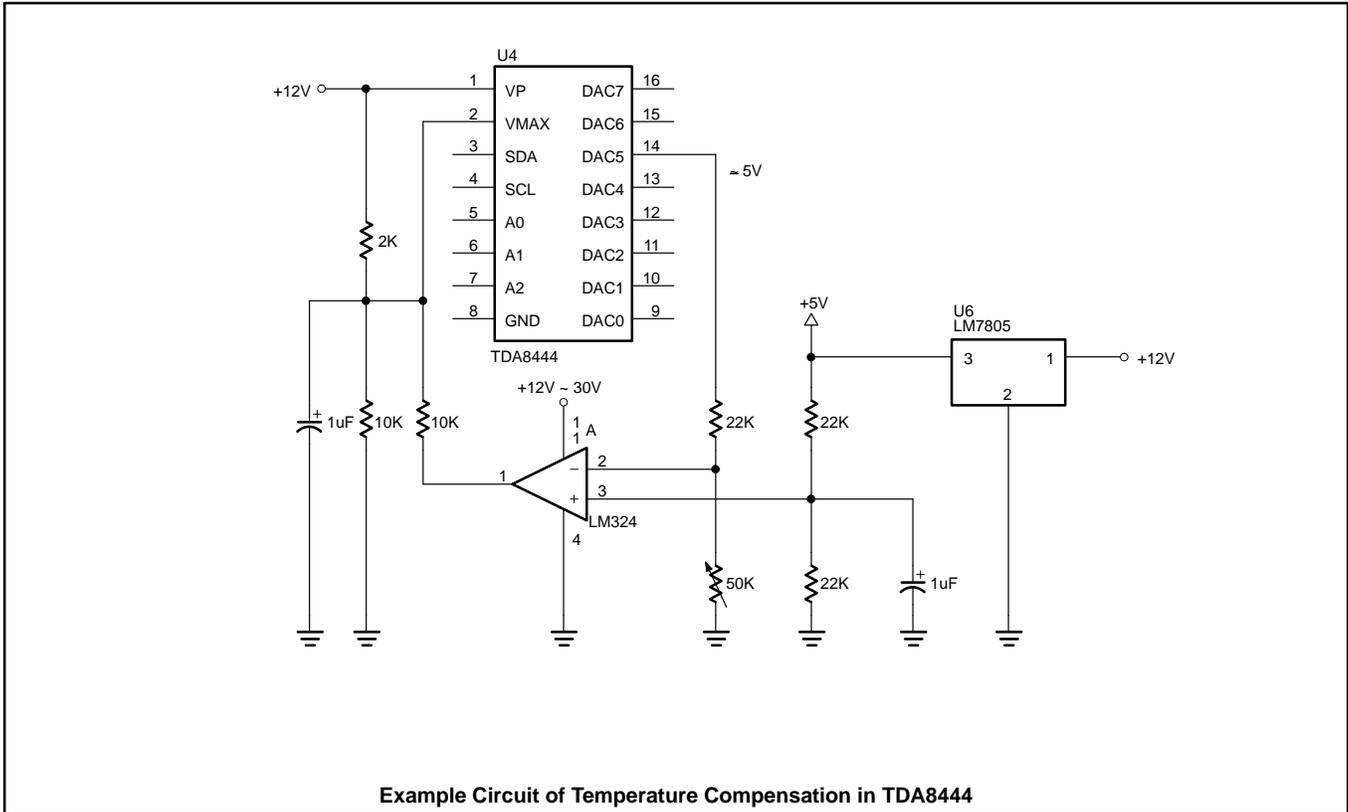
power on the demoboard, the mode display should display "19", the the voltage in DAC H-V output pin is the trigger level voltage of 60kHz.

You can set P.S.G to 70kHz to measure trigger level voltage of 70kHz.

# (BCM) 87C751 Specification for a bus-controlled monitor

AN442

## APPENDIX C



All VRs in this application note can be charged to fix resistors, when proper dividing voltage is determined.