National Semiconductor

November 1982

MA1026 Digital LED Alarm Clock/Thermometer Module

General Description

The MA1026 is a complete electronic digital clock/ thermometer module featuring a 4-digit LED display. A transformer, setting switches, and temperature sensor are required to produce a low-cost, full featured movement for use in thermometer, alarm clock, clock radio, instrument panel clock and appliance timer applications. Advanced packaging techniques allow minimum overall size and high volume production of finished products.

Key features include temperature display in both °C or °F, multiple 9-minute snooze, "one-finger" sleep setting, easy to use fast and slow setting controls, seconds display, PM, alarm ON, colon and degree indicators and time-set lockout. Included are components for on-board radio switching and speaker drive of an 800 Hz (nominal) alarm-tone output gated at a 2 Hz rate. Maximum flexibility is provided by user-programmable 12 or 24-hour display, 50 or 60 Hz input and fixed or flashing colon indicator. In addition, the display brightness level can be varied with a potentiometer for continuous control, or an SPST switch for bright/dim modes.

Applications

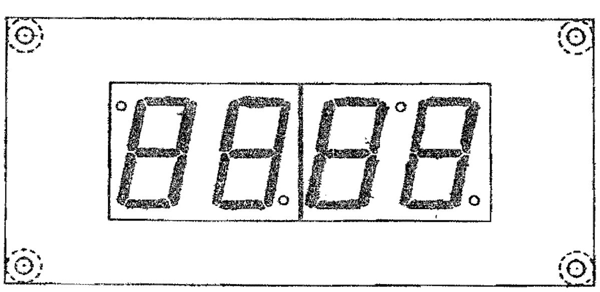
- Clock radio timers
- Alarm clocks
- Desk clocks
- TV/stereo timers
- Instrument panel clocks
- Thermometers (°C or °F)

Functional Features

- 0.7" – 4-digit LED display available with or without lens in red or clear surface color
- "One-finger" 59-minute sleep counter setting
- Multiple 9-minute snooze counter
- 24-hour alarm with ON-OFF control
- PM, colon, degree and alarm "On" LED indicators
- Entire display flashes to indicate power loss
- Simple fast/slow setting controls
- Time-set lockout feature eliminates accidental time-setting without inhibiting alarm or sleep setting
- 6 display modes (temperature, time, seconds, alarm, sleep and lamp test)
- User selectable °C/°F, 12/24-hour, 50/60 Hz and fixed/flashing colon functions
- Leading zero blanking
- Complete system requires the addition of transformer, setting switches and sensor
- Direct-drive LED display – no RFI
- Bright/dim or continuous display brightness control capability
- 800 Hz (nominal) alarm-tone output, gated at a 2 Hz rate
- Include buffering for alarm clock (8Ω speaker drive) or clock radio (power switch) applications
- 24-hour output signal for optional calendar circuit
- Separate inputs for all setting and display modes
- Back-up oscillator option for continuous timekeeping during a power failure

Display Outline

MA1026



Ordering Information

MA1026XX
- SURFACE COLOR
  - R = Red
  - W = Clear
- SURFACE TYPE
  - L = Plastic Lens Cover With Diffuser

Absolute Maximum Ratings

Voltage at All Pins Except 1, 3 and 32	V_{SS} – 0.3V to V_{SS} + 12V
Voltage at Pins 1 and 32	V_{SS} – 3V to V_{SS} + 6V
Voltage at Pin 3	V_{SS} – 17V to V_{SS} + 17V
Operating Temperature Range (Note 2)	0°C to 70°C
Storage Temperature Range	–20°C to +85°C
Terminal Temperature (Soldering, 5 seconds)	230°C

Electrical Characteristics T_A = 25°C, V_{AC} = 10.5 Vrms, V_{SS} = 0V, V_{LED} = 3.0V, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{AC} MOS Supply Voltage	Fully Operational Temp/Clock	9.0	10.5	12.0	Vrms
	Power Fail Detect (Note 1)		3	6	Vrms
I_{AC} MOS Supply Current			10	15	mA_{AVG}
V_{LED} LED Supply Voltage		2.5	3.0	3.5	Vrms x 2
I_{LED} LED Supply Current	Lamp Test (All 30 Segments ON) Pin 4 Open (Max Brightness)		300		mA_{AVG}
V_{BATT} MOS Supply Voltage	V_{AC} = 0V, V_{LED} = 0V, Timekeeping Maintained	7.5	9.0	12.0	V_{DC}
I_{BATT} MOS Supply Current	V_{BATT} = 9.0 V_{DC}		5.0	10.0	mA_{DC}
Control Input Signal Levels (Pins 10–22)					
Logical Low Level Voltage		V_{SS}		V_{SS} + 0.5	V
Logical High Level Voltage		V_{DD} – 3V		V_{DD}	V
Input Current	Internal Resistance to V_{DD}, V_{IN} = V_{SS}			–10	µA
Temp Sensor Input Voltage (Pin 7)	10 mV/°C (10k Input Resistance to V_{SS})	2.33	Note 3	3.63	V
Temp Sensor Input Current	1 µA/°C	233	Note 3	363	µA
Alarm/Sleep Output Current					
ALM/SLP ON, Sink Current	V_{OL} = V_{SS} + 2V	5			mA
ALM/SLP OFF, Source Current	V_{OH} = V_{DD} – 0.25V			–40	µA
24-Hour Output Current					
AM, ON/Sink Current	V_{OL} = V_{SS} + 2V	400			µA
PM, OFF/Source Current	V_{OH} = V_{DD} – 0.25V			–100	µA
Temperature Display Range		–40		89	°C
		–40		193	°F
Thermometer Resolution			1		°C or °F
Thermometer Accuracy	T_A = 25°C (Notes 2 and 3)		±0.5	±2	°C
	T_A Over Operating Range (Notes 2 and 3)		±1	±4	°F
Alarm Output Frequency	T_A and V_{AC} Over Operating Range		800		Hz
Radio Supply Input Current (Pin 27)				200	mA
Speaker Output Current	R_L = 8 Ω, 50% Duty Cycle	150			mA peak

Note 1: The power fail detect voltage is 0.25 volts or more above the voltage at which timekeeping data will be lost.

Note 2: Does not include temperature sensor.

Note 3: The sensor input current must remain between 233 µA and 363 µA at a 1 µA/°C slope for proper temperature display. Similarly, the sensor input voltage must remain between 2.33V and 3.63V at a 10 mV/°C slope for proper temperature display.

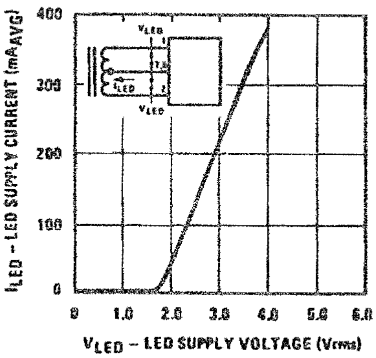
Optical Characteristics

$T_A = 25°C$, V_{AC} = 10.5 Vrms, V_{SS} = 0V, V_{LED} = 3.0 Vrms (MA1026), unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Segment Light Intensity	LR-Type Display	140	280		μcd
(Indicators Included)	LW-Type Display	175	350		μcd
Peak Wavelength			660		nm
Spectral Width, Half-Intensity			40		nm
Viewing Angle	Angle from Normal Axis		60		degrees
Intensity Matching	Pin 4 Open and at V_{SS} (Bright/Dim)		±33		%

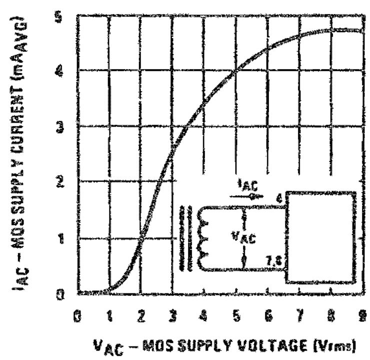
Typical Performance Characteristics

Typical LED Supply Current vs LED Supply Voltage

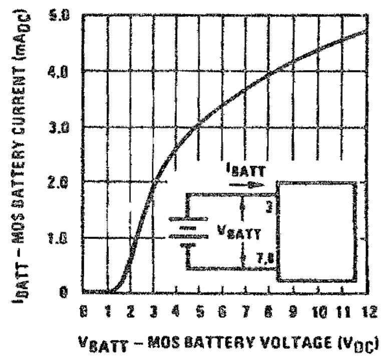


Conditions:
1. Lamp test (all segments driven)
2. Dislay dim (pin 6) open – maximum brightness

Typical MOS Supply Current vs MOS Supply Voltage

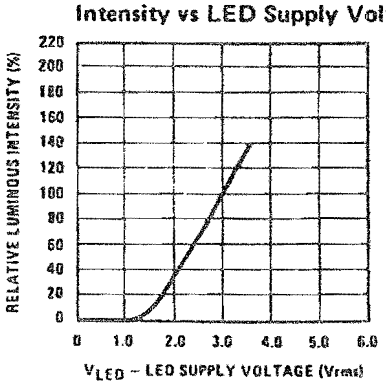


Typical MOS Battery Current vs MOS Battery Voltage



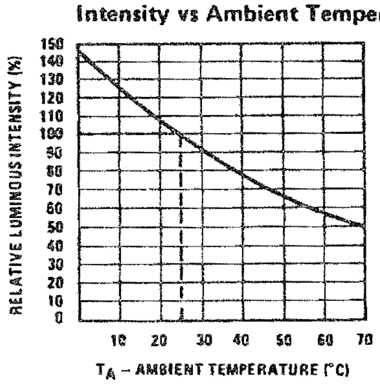
Conditions:
1. V_{AC} = 0V
2. V_{LED} = 0V

Typical Relative Luminous Intensity vs LED Supply Voltage



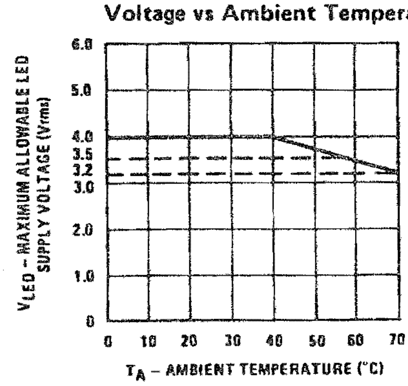
Conditions:
1. Lamp test (all segments driven)
2. Display dim (pin 6) open – maximum brightness

Typical Relative Luminous Intensity vs Ambient Temperature



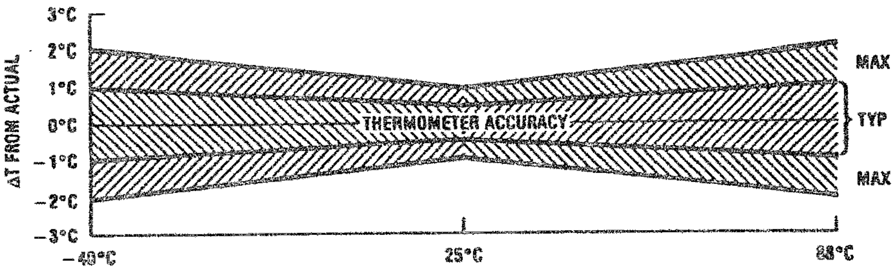
Conditions:
1. Lamp test (all segments driven)
2. Display dim (pin 6) open – maximum brightness

Maximum Allowable LED Supply Voltage vs Ambient Temperature

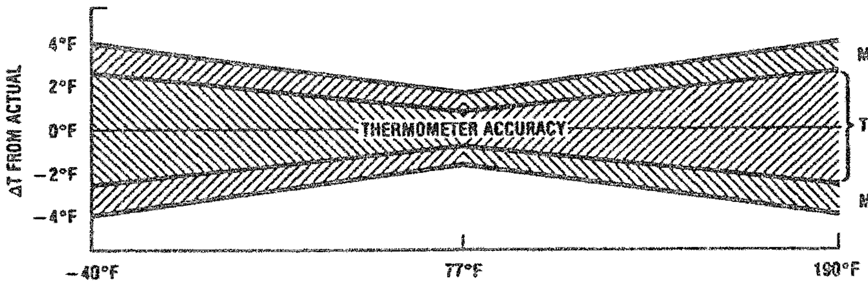


Conditions:
1. 6.5 Vrms $\leq V_{AC} \leq$ 9.0 Vrms
2. Display dim (pin 6) open – maximum brightness
3. Lamp test (all segments driven)

MA1026 THERMOMETER ACCURACY @ TYPICAL OPERATING CONDITIONS



MA1026 Temperature Accuracy Over Temperature Range Centigrade
(Calibrated at 25°C) (Does not include temperature sensor)



MA1026 Temperature Accuracy Over Temperature Range Fahrenheit
(Calibrated at 77°F) (Does not include temperature sensor)

Functional Description

The various display modes and their priorities are listed in Table I. The functions of the setting controls in combination with the selected display mode are summarized in Table II.

INPUTS

Display Mode Select Inputs (Pins 17, 18, 19 and 20): In the absence of these inputs (i.e., pin open), time-of-day (hours:minutes) information is displayed. The four inputs (DISPLAY SECONDS, DISPLAY ALARM, DISPLAY SLEEP, DISPLAY TEMPERATURE) have internal pull-up resistors to V_{DD}. Connection of any combination of these inputs to V_{SS} results in 1-of-6 display modes whose priorities and functions are listed in Table I. For example, seconds may be displayed by connecting pin 17 to V_{SS}; however, connecting pins 17 and 18 to V_{SS} results in the alarm time being displayed. Note that DISPLAY SLEEP (pin 19) and DISPLAY ALARM (pin 18) have equal priorities and when connected to V_{SS}, all display drivers are turned on, providing a lamp test display mode.

Time Setting Inputs (Pins 14, 15): FAST SET (pin 14) and SLOW SET (pin 15) inputs may be applied either singularly or in combination to obtain the control functions listed in Table II. Internal pull-up resistors to V_{DD} are provided as well as switch debounce circuitry on each input. Application of either or both inputs is made by connecting the appropriate pin to V_{SS}. Note that the control functions are dependent on the selected display mode. For example, a time reset to 12:00:00 AM may be made by selecting either time or seconds display mode and connecting pins 14, display mode, the contents of the sleep counter would be displayed and reset to :59 minutes.

Time Set Allow Input (Pin 16): This input enables fast or slow setting of time when the selected display mode is time or seconds. An internal pull-up resistor is provided on the input. To set time, connect pin 16 to V_{SS} in combination with pin 14 and/or pin 15 (provided time or seconds is the selected display mode). When the selected display mode is alarm or sleep, TIME SET ALLOW does not inhibit setting of either the alarm or sleep counters (i.e., pin 16 may be left open to set alarm or sleep time).

50/60 Hz Select Input (Pin 12): A programmable prescale counter divides the V_{AC} input line frequency by either 50 or 60 to obtain a 1 pps time base. To program the counter to divide by 60, simply leave pin 12 unconnected (a pull-up resistor to V_{DD} is provided). 50 Hz operation is obtained by connecting pin 12 to V_{SS}.

Colon Control Input (Pin 11): This input selects between a flashing or non-flashing colon. If left open or connected to V_{DD}, the colon will flash at a 1 Hz rate. Connection to V_{SS} will produce a non-flashing (always ON) colon. An internal pull-up resistor to V_{DD} is provided on the input.

12/24-Hour Select Input (Pin 13): This input selects between 12 and 24-hour display formats. If left open or connected to V_{DD}, the 12-hour format is selected. The PM indicator (in the upper left corner of the display) is then used to distinguish between AM and PM times. This indication applies for both time and alarm display

Functional Description (Continued)

selected. The PM indication is not active in this mode. An internal pull-up resistor to V_{DD} is provided on the input.

Snooze Input (Pin 22): Momentarily connecting pin 22 to V_{SS} disables the sleep output, turning off Q2 and the associated radio power supply. If the alarm has sounded just prior to this, the alarm output is also disabled and the sleep counter is reset to 9 minutes. Both outputs will be disabled for 8 to 9 minutes (depending upon the contents of the seconds counter) after which the alarm will again be sounded. The snooze feature may be used repeatedly during the 59 minutes in which the alarm latch remains set. A pull-up resistor to V_{DD} is provided on the input.

Alarm OFF Input (Pin 21): Connecting pin 21 to V_{SS} disables the alarm and sleep outputs, thereby silencing alarm and/or radio. Momentary connection to V_{SS} also readies the alarm latch for the next alarm time, in which case the alarm and/or radio will sound again at the next alarm setting. If it is desired to silence the alarm for a day or more, the ALARM OFF input should remain at V_{SS}. This input is returned to V_{DD} by an internal resistor. An alarm ON indicator in the lower right corner of the display is provided to indicate the alarm is enabled.

Display Dim Input (Pin 4): When left open, maximum gate drive to the display output drivers ensures maximum (100%) display brightness. Connecting pin 4 to V_{SS} reduces LED supply current by approximately 75%, resulting in 25% display brightness. A 10k potentiometer may be used in place of a switch to select any relative brightness level between 25% and 100%.

Temperature Sensor Input (Pin 7): This input is active when the selected display mode is temperature. Although the MOS input is a voltage comparator input, a 10k ±1% resistor is provided on the input to V_{SS} allowing the module to accept either voltage or current mode temperature sensors. If a voltage source is used, the input voltage must remain between 2.33V (−40°C) and 363V (+90°C). If a current source is used as the temperature sensor (e.g., LM334) the input current must remain between 233 μA (−40°C) and 363 μA (+90°C). Voltage sensitivity is 10 mV/°C and current sensitivity is 1 μA/°C. Sensor wire length will not affect thermometer accuracy if the current source sensor is used. Sensor input levels outside the limits mentioned result in maximum levels only being displayed.

°C/°F Select Input (Pin 10): This input selects between °C or °F display format in the temperature mode. If left open or connected to V_{DD}, the sensor temperature will be displayed in degrees Fahrenheit. If connected to V_{SS}, degrees Centigrade will be the selected mode. An internal resistance is provided on the input to V_{DD}.

Hold Input (Pin 31): This input is used to momentarily hold time from advancing when connected to V_{SS}. This input can also be used to feed in an external 50 or 60 Hz timebase signal when the user requires entirely DC operation. This may come from the 60 Hz output of an MM5369 when quartz crystal accuracy is required, for example. See Applications Information section of data sheet (Instrument Panel Thermometer Application).

Standby Oscillator Input (Pin 5): By connecting a 5 MΩ potentiometer between pin 26 and V_{DD}, and adjusting it correctly, timekeeping can be maintained during power failure, provided a 9V battery is used to power the MOS circuit (pin 2). Correct timing is obtained by trimming the input frequency (pin 26) to 20 Hz. Although the LED display will remain off during power failure, the correct time is held by the time counters and counting continues. When line power resumes, the display returns to normal brightness, displaying the correct time without flashing.

OUTPUTS

Sleep/Radio Supply Outputs (Pins 24, 27 and 28): The sleep output (pin 24) can be used to turn off a radio after a desired time interval of up to 59 minutes. The time interval is chosen by selecting the sleep display mode (Table I) and setting the desired time interval (Table II). Pin 24 sinks current, turning on Q2, and thus the radio (or other appliance) is enabled. When the sleep counter, which decrements, reaches :00 minutes, the sleep output drive is removed, disabling the radio. This turn-off may also be manually controlled by a momentary V_{SS} connection to the snooze input (pin 22). When the contents of the sleep counter reaches :00 minutes, displaying sleep automatically resets the contents of the sleep counter to :59 minutes. This enables the sleep output, causing radio turn-on. If a sleep time other than :59 minutes is desired, a manual set must be performed. Since most users desire the longest possible sleep time, this feature minimizes pre-bedtime setting operations. Note that :00 minutes on the sleep counter will never be displayed as displaying sleep automatically resets it to :59 minutes.

Alarm/Speaker Outputs (Pins 25, 29 and 30): When coincidence occurs between the alarm counter and the real time counter (hours and minutes only) a latch is set in the alarm circuit which enables the alarm tone to appear at the alarm output (pin 25). This output drives the base of Q1, which in turn can drive an 8 Ω to 16 Ω speaker (pins 29 and 30). The alarm latch remains set for 59 minutes, during which the alarm will sound if not inhibited by either the SNOOZE (pin 22) or ALARM OFF (pin 21) inputs. The alarm tone is generated by an internal alarm oscillator whose frequency is determined by the R4/C3 time constant on the module (approximately 800 Hz). The 800 Hz tone is gated by a 2 Hz square wave signal before being enabled at the ALARM OUTPUT. The alarm signal is further modulated by the 120 Hz full-wave rectified LED supply used to drive the speaker directly.

24-Hour Output (Pin 23): This output is driven by the real time counter chain and produces a 50% duty cycle square wave output which is V_{DD} (OFF) during PM time and V_{SS} (ON) during AM time. This output is provided to the user for date recording purposes and may drive a separate optional calendar circuit which records the day, date and/or month.

Functional Description (Continued)

TABLE I. MA1026 DISPLAY MODES

SELECTED DISPLAY MODES*	DIGIT NO. 4	DIGIT NO. 3	DIGIT NO. 2	DIGIT NO. 1
Time Display	Time 10's Hours, PM Ind.	Time Hours	Time 10's Minutes	Time Minutes, Alarm ON Ind.
Seconds Display	Blanked	Time Minutes	Time 10's Seconds	Time Seconds
Alarm Display	Alarm 10's Hours, PM Ind.	Alarm Hours	Alarm 10's Minutes	Alarm Minutes, Alarm ON Ind.
Sleep Display	Blanked	Blanked	Sleep 10's Minutes	Sleep Minutes
Temp. Display	100's Temp.	10's Temp.	1's Temp.	°C or °F
Alarm and Sleep	Lamp Test	Lamp Test	Lamp Test	Lamp Test

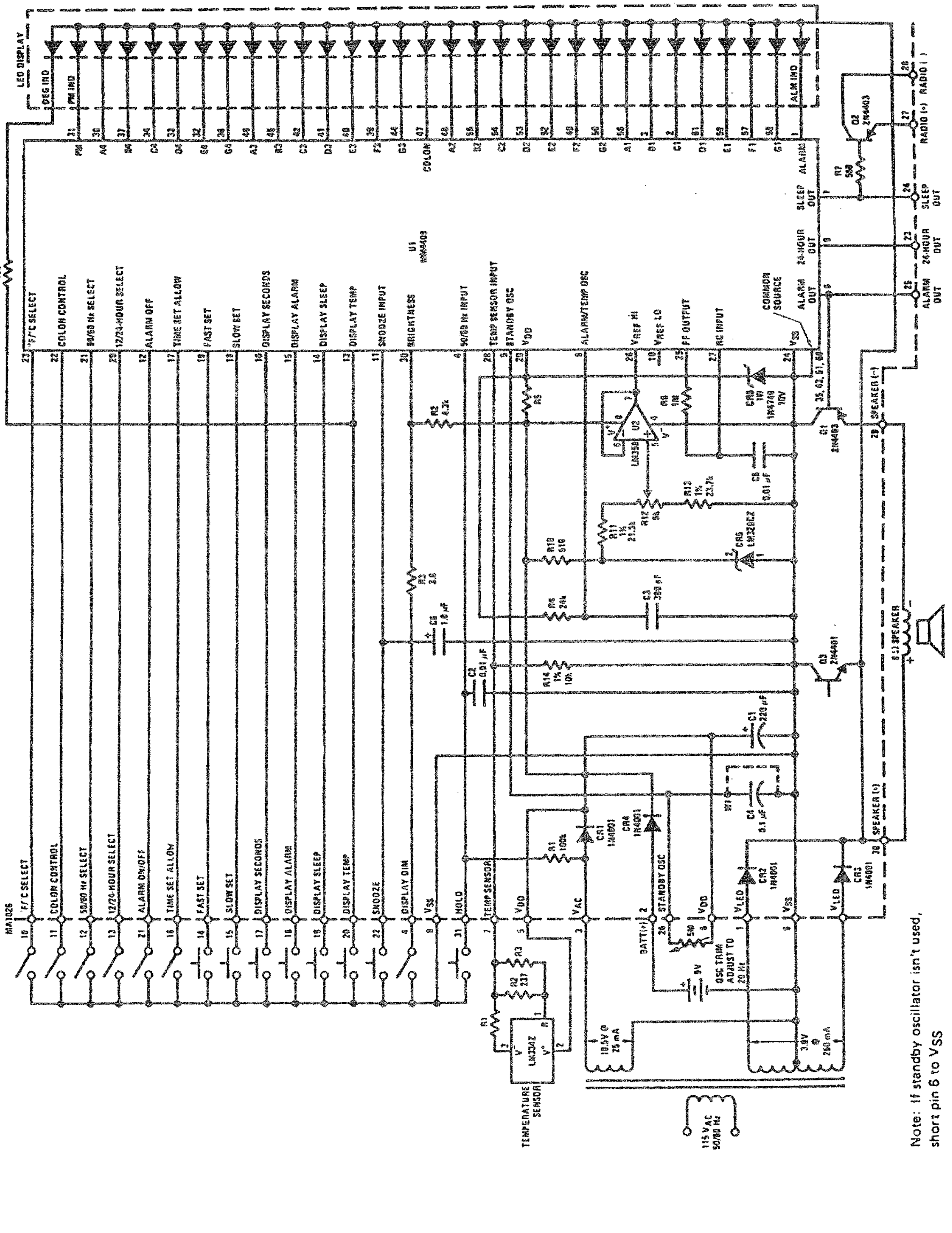
*If more than one display mode input is applied, the display priorities are in the order of temperature, alarm *or* sleep, seconds, then time. Alarm and sleep have equal priority over seconds; however, when both alarm and sleep are applied, all outputs are ON, providing a lamp test. This display mode has priority above all others.

TABLE II. MA1026 CONTROL SETTING FUNCTIONS

SELECTED DISPLAY MODE	CONTROL INPUT	CONTROL FUNCTION
Time and Seconds Display	Time Set Allow and Slow Set Simultaneously	Minutes advance at a 2 Hz rate and Seconds Counter is reset to :00.
	Time Set Allow and Fast Set Simultaneously	Minutes advance at a 60 Hz rate. Seconds Counter not affected.
	Time Set Allow and Fast and Slow Set Simultaneously	Hours, Minutes, and Seconds are reset to: 12:00:00 AM (12-Hour Mode) 0:00:00 (24-Hour Mode).
Alarm Display	Slow Set	Alarm Minutes Counter advances at a 2 Hz rate.
	Fast Set	Alarm Minutes Counter advances at a 60 Hz rate.
	Fast and Slow Set Simultaneously	Alarm Minutes and Hours Counters are reset to: 12:00 AM (12-Hour Mode) 0:00 (24-Hour Mode).
Sleep Display*	Slow Set	Sleep Counter is decremented at a 2 Hz rate.
	Fast Set	Sleep Counter is decremented at a 10 Hz rate.
	Fast and Slow Set Simultaneously	Sleep Counter is reset to 59 minutes.
Sleep Display and Alarm Display	All Outputs are Driven to Provide a Lamp Test.	

*When contents of sleep counter are zero *and* sleep is the selected display mode, the sleep counter is set to 59 minutes.

Schematic Diagram

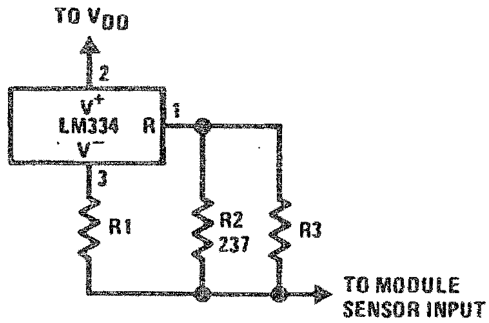


Note: If standby oscillator isn't used, short pin 6 to V_{SS}

Applications Information

LM334 TEMPERATURE SENSOR CALIBRATION PROCEDURE

The LM334 is a 3-terminal adjustable current source with a temperature coefficient of 1 μA/°C. Below is a pin configuration of the LM334. Refer to National Semiconductor Linear Databook for detailed information on the device.



A 10 kΩ (0.1%) low temperature coefficient resistor is provided in parallel with the sensor input on the MA1026 module. This network converts the 1 μA/°C sensitivity of the LM334 to a 10 mV/°C sensitivity at the integrated circuit input. Temperature calibration is accomplished by matching the current output of the LM334 to the current supplied by an adjustable voltage source. A resultant voltage difference, as indicated by a DVM, is a measure of sensor mismatch. Proper selection of a series (coarse adjust) and parallel (fine adjust) low temperature coefficient resistor will provide a typical accuracy of ±0.3°C.

During calibration insure that the reference voltage is adjusted to accurately represent ambient temperature, and a fan is blowing air over the LM334. The calibration procedure is as follows:

1. Insert the LM334 into the test circuit.
2. Insert a 237 Ω, 1% < 500 ppm metal film resistor (R2) into the circuit as shown in the Calibration Test Circuit.
3. Insure SW1 is in the shorted position and SW2 is in the open position.
4. Rotate SW1 until the DVM indicates the least negative voltage.
5. Rotate SW2 to the position indicating the least deviation from 0V. The sensor error is now 0.1 °C/mV, plus any error caused by the reference voltage setting.
6. Determine the value of resistance indicated by SW1 and mount an equivalent value resistor R1 on the sensor board.
7. Determine the value of resistance indicated by SW2 and mount an equivalent value resistor R3 on the sensor board.
8. Mount the 237 Ω resistor (R2 used in step 2) in parallel to R3 on the sensor board.

The sensor is now calibrated and ready for assembly with the MA1026 module.

In the event a calibration fixture is not convenient, an alternative calibration procedure is shown in *Figure 1*.

Requiring only a variable V_{REF} voltage source, a 230 Ω variable resistor and a 10 kΩ (0.1%) resistor, configure the circuit as illustrated below. Adjust V_{REF} as determined in the formula to represent ambient temperature. Adjust the 230 Ω variable resistor until the DVM indicates a null (0V). The sensor and the adjusted 230 Ω variable resistor are now ready for assembly with the MA1026 module as shown in *Figure 2*.

Potentiometer Calibration Circuit

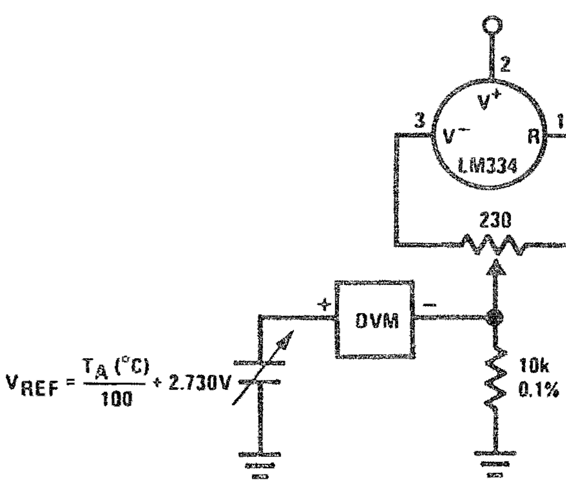


FIGURE 1

Electrical Connection Using Potentiometer

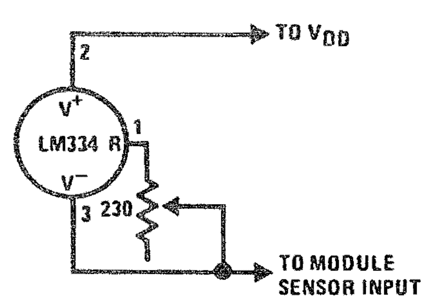
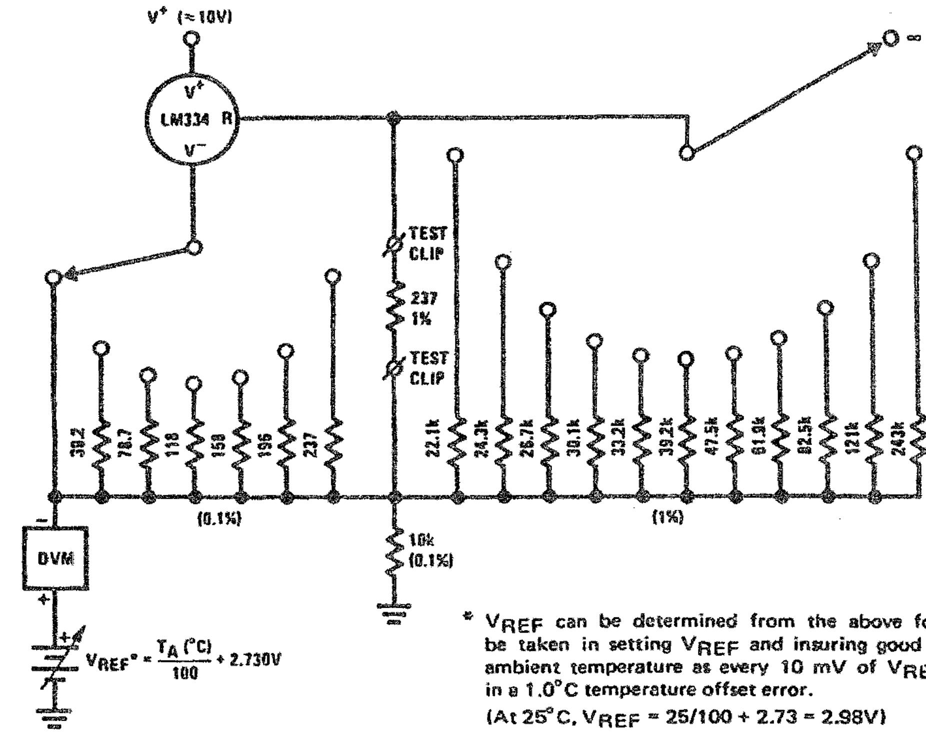


FIGURE 2

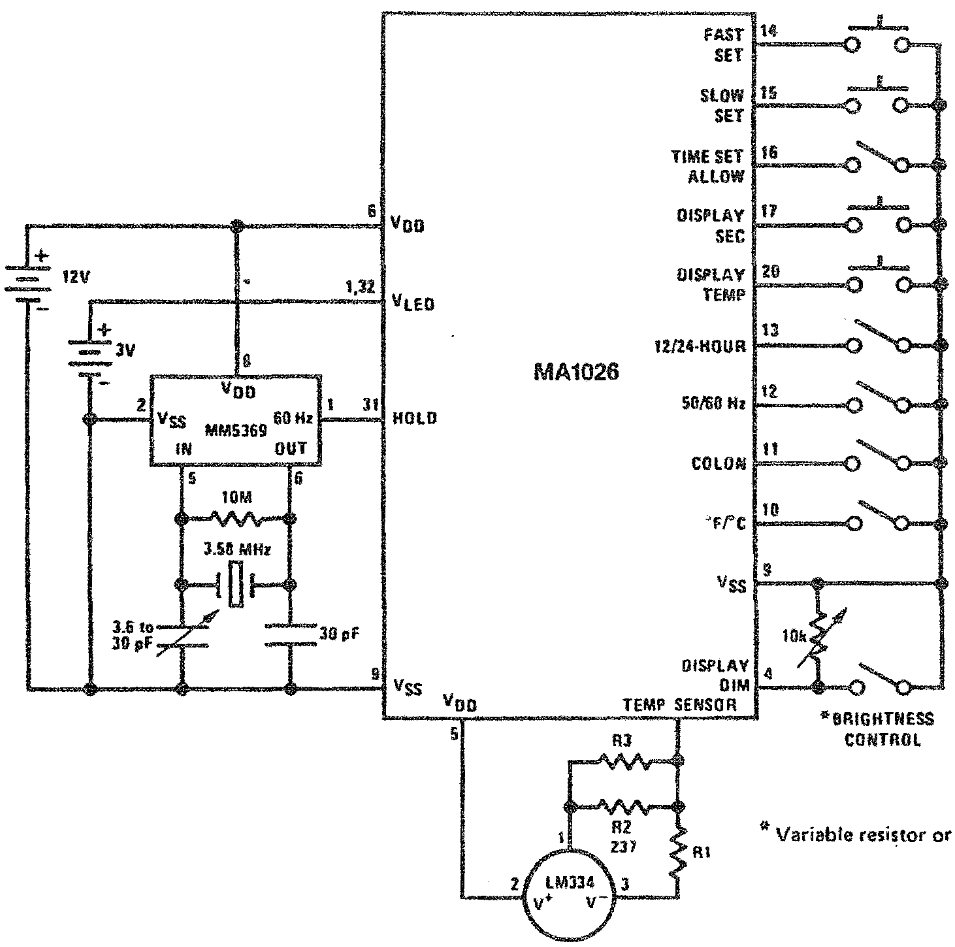
Applications Information (Continued)

Temperature Sensor Calibration Circuit



* V_{REF} can be determined from the above formula. Care must be taken in setting V_{REF} and insuring good correlation to the ambient temperature as every 10 mV of V_{REF} error will result in a 1.0°C temperature offset error.
(At 25°C, V_{REF} = 25/100 + 2.73 = 2.98V)

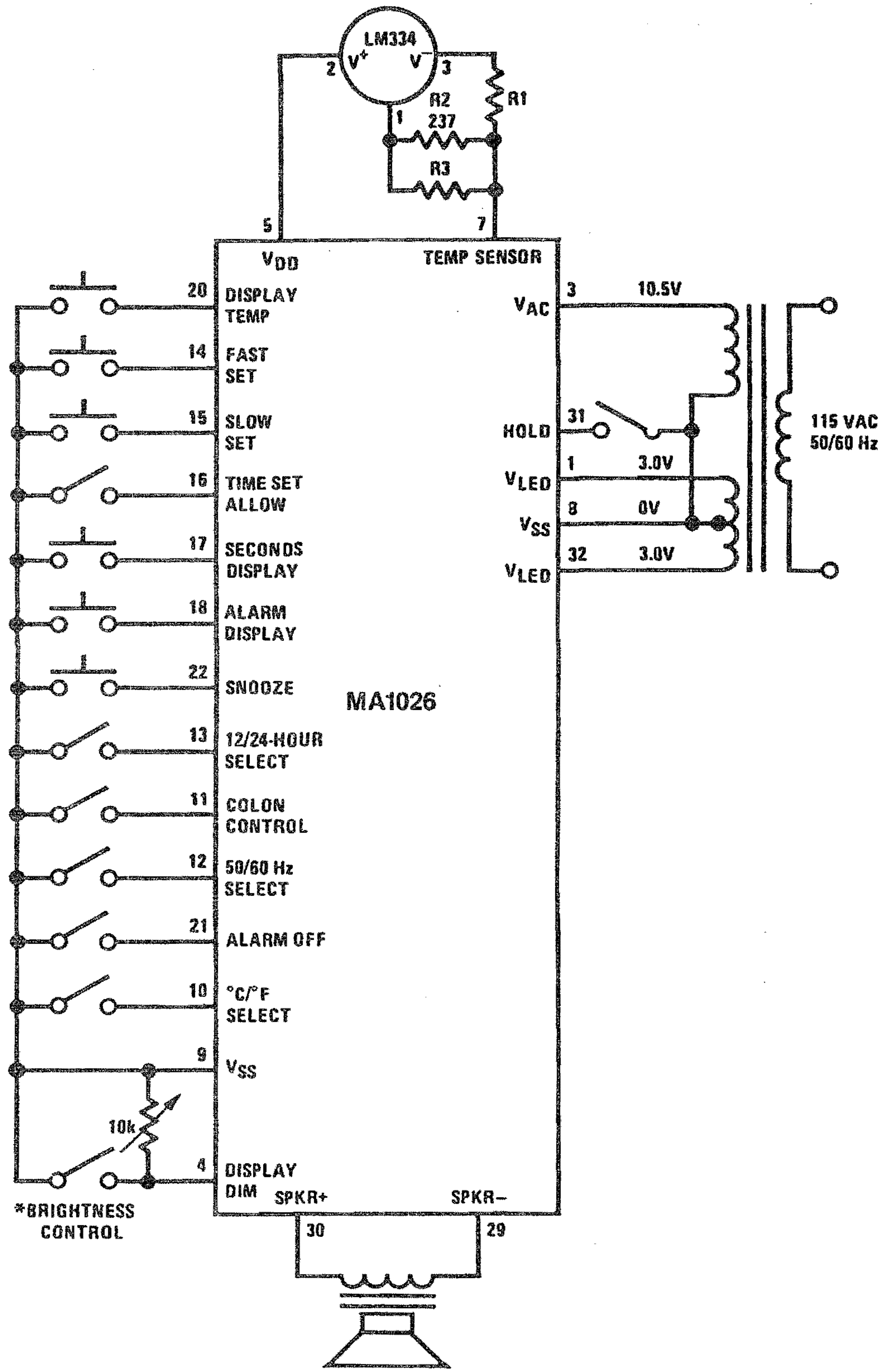
Instrument Panel Thermometer



* Variable resistor or switch may be used.

Applications Information (Continued)

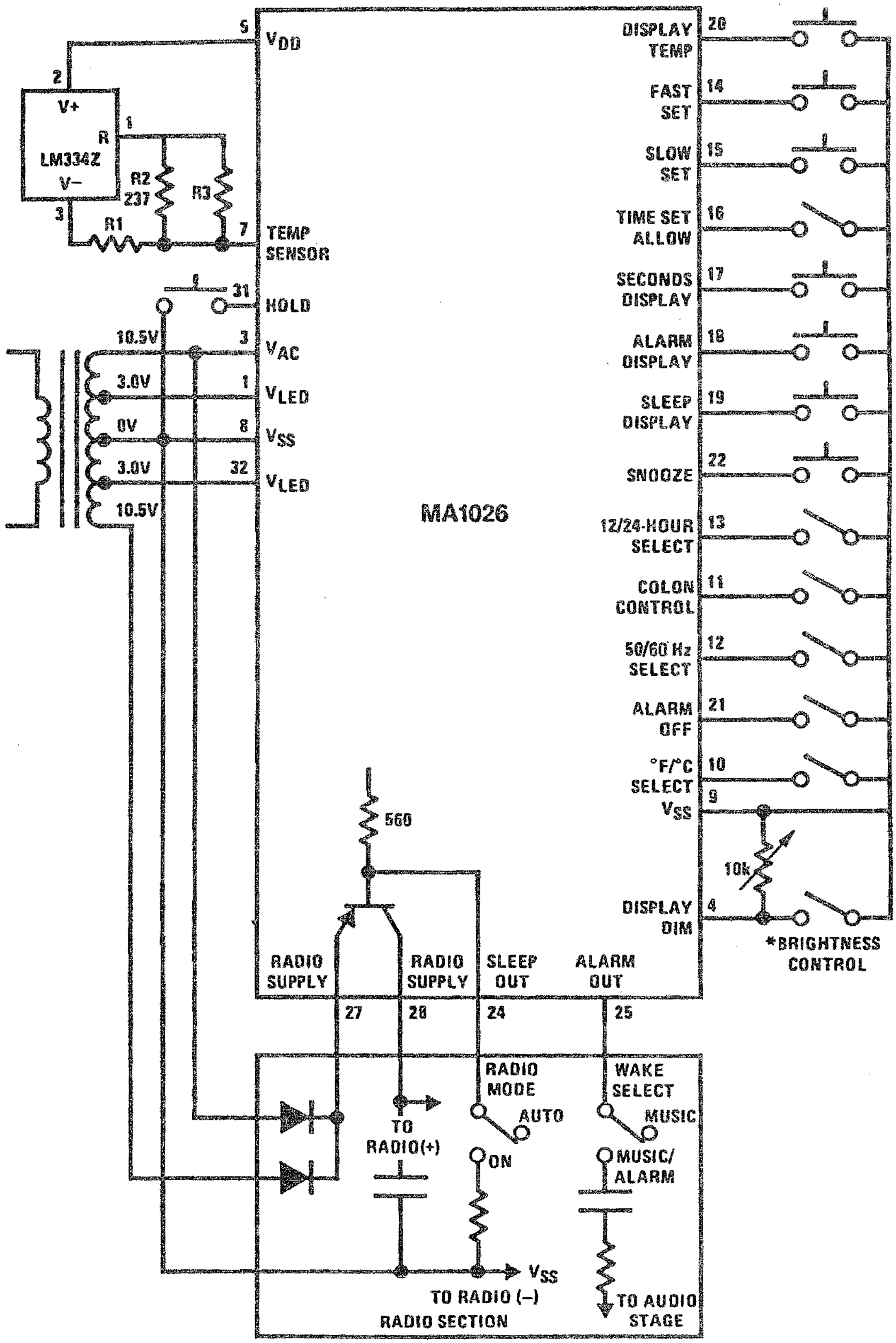
Alarm Clock/Thermometer



* Variable resistor or switch may be used.

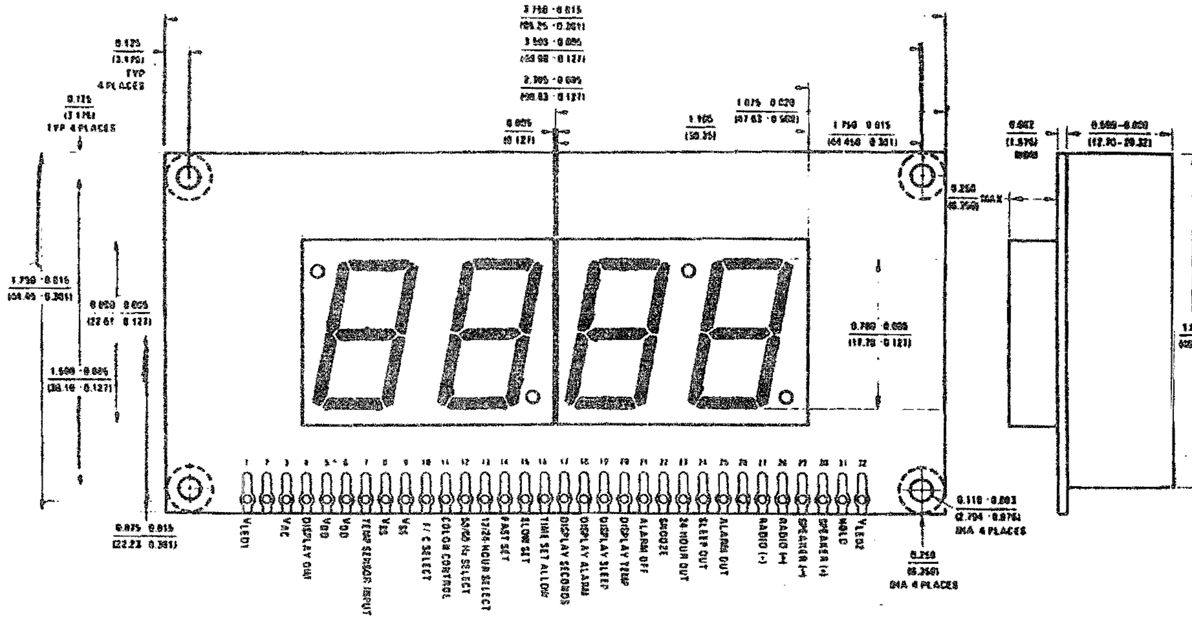
Applications Information (Continued)

Positive Supply Clock Radio/Thermometer



* Variable resistor or switch may be used.

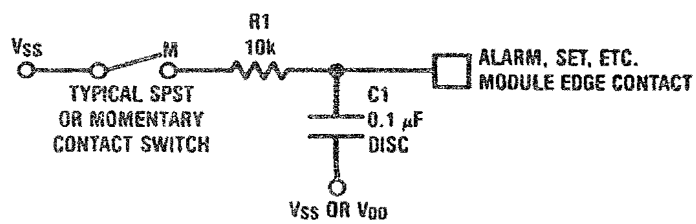
Physical Dimensions inches (millimeters)



Handling and Packaging Guidelines

MA1026 clock modules are manufactured using a CMOS integrated circuit. As shown in the Schematic Diagram and Applications Information, many of the CMOS inputs are directly accessible at the edge connector of the modules, therefore these modules must be handled in the same manner as any CMOS device during transport, storage, IQC and production assembly. Also, it is recommended, in accordance with acceptable engineering practice, that the module user provide adequate protection against static discharge in the design of his finished product. Since each module user may utilize unique packaging and design techniques for this end product, some general guidelines are offered. It is good practice to connect the "lever" of control switches to V_{DD} instead of to the CMOS inputs. Also, since the energy in static discharges exhibits a wide frequency spectrum, a resistor and RF type ceramic disc capacitor low pass filter network may be used to help protect the directly accessible CMOS inputs. It is good practice to place this RC network in close proximity to the module edge contact to obtain maximum protection. A typical RC filter is shown below.

Good practice dictates that metal buttons or metallized buttons not be used as they provide a path for static discharge leading closer to the internal circuitry. A typical application would use a plastic button with plastic pusher rod to the switch contacts located within the case.



WARNING: Clock modules are suitable for hand soldering only. Wave or dip soldering methods should not be used.