

## LM3914 Dot/Bar Display Driver

### General Description

The LM3914 is a monolithic integrated circuit that senses analog voltage levels and drives 10 LEDs, providing a linear analog display. A single pin changes the display from a moving dot to a bar graph. Current drive to the LEDs is regulated and programmable, eliminating the need for resistors. This feature is one that allows operation of the whole system from less than 3V.

The circuit contains its own adjustable reference and accurate 10-step voltage divider. The low-bias-current input buffer accepts signals down to ground, or  $V^-$ , yet needs no protection against inputs of 35V above or below ground. The buffer drives 10 individual comparators referenced to the precision divider. Indication non-linearity can thus be held typically to  $\frac{1}{2}\%$ , even over a wide temperature range.

Versatility was designed into the LM3914 so that controller, visual alarm, and expanded scale functions are easily added on to the display system. The circuit can drive LEDs of many colors, or low-current incandescent lamps. Many LM3914s can be "chained" to form displays of 20 to over 100 segments. Both ends of the voltage divider are externally available so that 2 drivers can be made into a zero-center meter.

The LM3914 is very easy to apply as an analog meter circuit. A 1.2V full-scale meter requires only 1 resistor and a single 3V to 15V supply in addition to the 10 display LEDs. If the 1 resistor is a pot, it becomes the LED brightness control. The simplified block diagram illustrates this extremely simple external circuitry.

When in the dot mode, there is a small amount of overlap or "fade" (about 1 mV) between segments. This assures that at no time will all LEDs be "OFF", and thus any ambiguous display is avoided. Various novel displays are possible.

Much of the display flexibility derives from the fact that all outputs are individual, DC regulated currents. Various effects can be achieved by modulating these currents. The individual outputs can drive a transistor as well as a LED at the same time, so controller functions including "staging" control can be performed. The LM3914 can also act as a programmer, or sequencer.

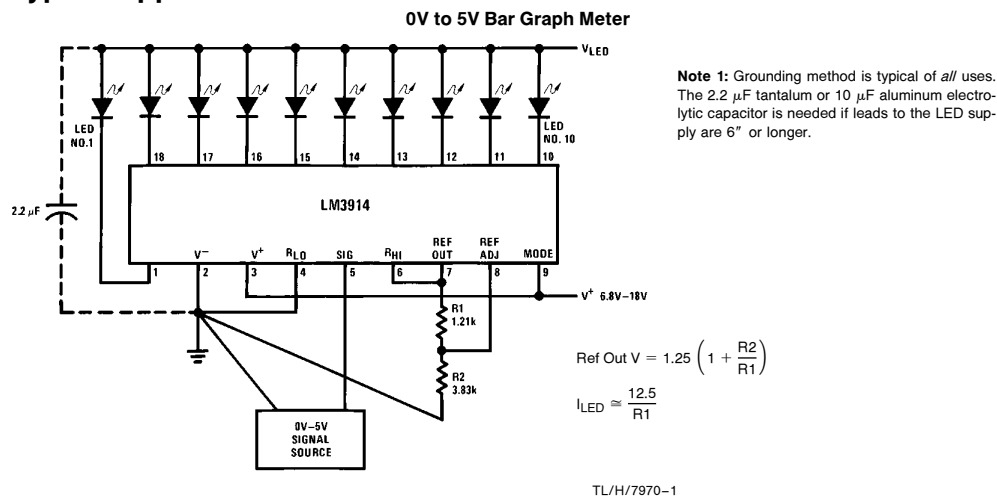
The LM3914 is rated for operation from 0°C to +70°C. The LM3914N is available in an 18-lead molded (N) package.

The following typical application illustrates adjusting of the reference to a desired value, and proper grounding for accurate operation, and avoiding oscillations.

### Features

- Drives LEDs, LCDs or vacuum fluorescents
- Bar or dot display mode externally selectable by user
- Expandable to displays of 100 steps
- Internal voltage reference from 1.2V to 12V
- Operates with single supply of less than 3V
- Inputs operate down to ground
- Output current programmable from 2 mA to 30 mA
- No multiplex switching or interaction between outputs
- Input withstands  $\pm 35V$  without damage or false outputs
- LED driver outputs are current regulated, open-collector
- Outputs can interface with TTL or CMOS logic
- The internal 10-step divider is floating and can be referenced to a wide range of voltages

### Typical Applications



## Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Power Dissipation (Note 5)	
Molded DIP (N)	1365 mW
Supply Voltage	25V
Voltage on Output Drivers	25V
Input Signal Overvoltage (Note 3)	± 35V
Divider Voltage	– 100 mV to V+
Reference Load Current	10 mA

Storage Temperature Range –55°C to +150°C

Soldering Information	
Dual-In-Line Package	
Soldering (10 seconds)	260°C
Plastic Chip Carrier Package	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

## Electrical Characteristics (Notes 1 and 3)

Parameter	Conditions (Note 1)	Min	Typ	Max	Units
<b>COMPARATOR</b>					
Offset Voltage, Buffer and First Comparator	$0V \leq V_{RLO} = V_{RHI} \leq 12V$ , $I_{LED} = 1 \text{ mA}$		3	10	mV
Offset Voltage, Buffer and Any Other Comparator	$0V \leq V_{RLO} = V_{RHI} \leq 12V$ , $I_{LED} = 1 \text{ mA}$		3	15	mV
Gain ( $\Delta I_{LED}/\Delta V_{IN}$ )	$I_{L(REF)} = 2 \text{ mA}$ , $I_{LED} = 10 \text{ mA}$	3	8		mA/mV
Input Bias Current (at Pin 5)	$0V \leq V_{IN} \leq V^+ - 1.5V$		25	100	nA
Input Signal Overvoltage	No Change in Display	–35		35	V
<b>VOLTAGE-DIVIDER</b>					
Divider Resistance	Total, Pin 6 to 4	8	12	17	kΩ
Accuracy	(Note 2)		0.5	2	%
<b>VOLTAGE REFERENCE</b>					
Output Voltage	$0.1 \text{ mA} \leq I_{L(REF)} \leq 4 \text{ mA}$ , $V^+ = V_{LED} = 5V$	1.2	1.28	1.34	V
Line Regulation	$3V \leq V^+ \leq 18V$		0.01	0.03	%/V
Load Regulation	$0.1 \text{ mA} \leq I_{L(REF)} \leq 4 \text{ mA}$ , $V^+ = V_{LED} = 5V$		0.4	2	%
Output Voltage Change with Temperature	$0^\circ\text{C} \leq T_A \leq +70^\circ\text{C}$ , $I_{L(REF)} = 1 \text{ mA}$ , $V^+ = 5V$		1		%
Adjust Pin Current			75	120	μA
<b>OUTPUT DRIVERS</b>					
LED Current	$V^+ = V_{LED} = 5V$ , $I_{L(REF)} = 1 \text{ mA}$	7	10	13	mA
LED Current Difference (Between Largest and Smallest LED Currents)	$V_{LED} = 5V$	$I_{LED} = 2 \text{ mA}$	0.12	0.4	mA
		$I_{LED} = 20 \text{ mA}$	1.2	3	
LED Current Regulation	$2V \leq V_{LED} \leq 17V$	$I_{LED} = 2 \text{ mA}$	0.1	0.25	mA
		$I_{LED} = 20 \text{ mA}$	1	3	
Dropout Voltage	$I_{LED(ON)} = 20 \text{ mA}$ , $V_{LED} = 5V$ , $\Delta I_{LED} = 2 \text{ mA}$			1.5	V
Saturation Voltage	$I_{LED} = 2.0 \text{ mA}$ , $I_{L(REF)} = 0.4 \text{ mA}$		0.15	0.4	V
Output Leakage, Each Collector	(Bar Mode) (Note 4)		0.1	10	μA

## Electrical Characteristics (Note 1) (Continued)

Parameter	Conditions (Note 1)	Min	Typ	Max	Units	
<b>OUTPUT DRIVERS (Continued)</b>						
Output Leakage	(Dot Mode) (Note 4)	Pins 10–18		0.1	10	$\mu\text{A}$
		Pin 1	60	150	450	$\mu\text{A}$
<b>SUPPLY CURRENT</b>						
Standby Supply Current (All Outputs Off)	$V^+ = 5\text{V}, I_{L(\text{REF})} = 0.2\text{ mA}$			2.4	4.2	$\text{mA}$
	$V^+ = 20\text{V}, I_{L(\text{REF})} = 1.0\text{ mA}$			6.1	9.2	$\text{mA}$

**Note 1:** Unless otherwise stated, all specifications apply with the following conditions:

$$\begin{array}{ll} 3 V_{\text{DC}} \leq V^+ \leq 20 V_{\text{DC}} & V_{\text{REF}}, V_{\text{RHI}}, V_{\text{RLO}} \leq (V^+ - 1.5\text{V}) \\ 3 V_{\text{DC}} \leq V_{\text{LED}} \leq V^+ & 0\text{V} \leq V_{\text{IN}} \leq V^+ - 1.5\text{V} \\ -0.015\text{V} \leq V_{\text{RLO}} \leq 12 V_{\text{DC}} & T_{\text{A}} = +25^\circ\text{C}, I_{L(\text{REF})} = 0.2\text{ mA}, V_{\text{LED}} = 3.0\text{V}, \text{pin 9 connected to pin 3 (Bar Mode).} \\ -0.015\text{V} \leq V_{\text{RHI}} \leq 12 V_{\text{DC}} & \end{array}$$

For higher power dissipations, pulse testing is used.

**Note 2:** Accuracy is measured referred to  $+10.000 V_{\text{DC}}$  at pin 6, with  $0.000 V_{\text{DC}}$  at pin 4. At lower full-scale voltages, buffer and comparator offset voltage may add significant error.

**Note 3:** Pin 5 input current must be limited to  $\pm 3\text{ mA}$ . The addition of a 39k resistor in series with pin 5 allows  $\pm 100\text{V}$  signals without damage.

**Note 4:** Bar mode results when pin 9 is within 20 mV of  $V^+$ . Dot mode results when pin 9 is pulled at least 200 mV below  $V^+$  or left open circuit. LED No. 10 (pin 10 output current) is disabled if pin 9 is pulled 0.9V or more below  $V_{\text{LED}}$ .

**Note 5:** The maximum junction temperature of the LM3914 is  $100^\circ\text{C}$ . Devices must be derated for operation at elevated temperatures. Junction to ambient thermal resistance is  $55^\circ\text{C}/\text{W}$  for the molded DIP (N package).

## Definition of Terms

**Accuracy:** The difference between the observed threshold voltage and the ideal threshold voltage for each comparator. Specified and tested with 10V across the internal voltage divider so that resistor ratio matching error predominates over comparator offset voltage.

**Adjust Pin Current:** Current flowing out of the reference adjust pin when the reference amplifier is in the linear region.

**Comparator Gain:** The ratio of the change in output current ( $I_{\text{LED}}$ ) to the change in input voltage ( $V_{\text{IN}}$ ) required to produce it for a comparator in the linear region.

**Dropout Voltage:** The voltage measured at the current source outputs required to make the output current fall by 10%.

**Input Bias Current:** Current flowing out of the signal input when the input buffer is in the linear region.

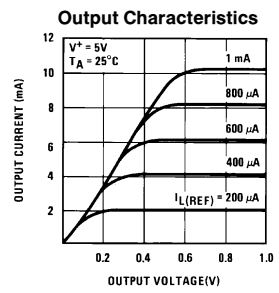
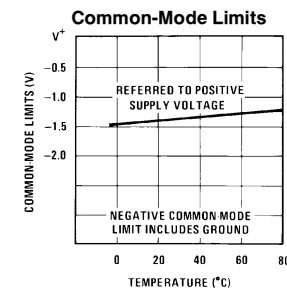
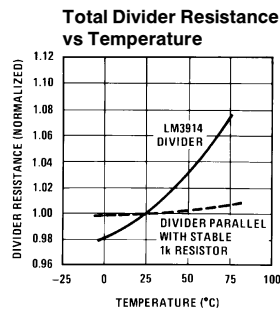
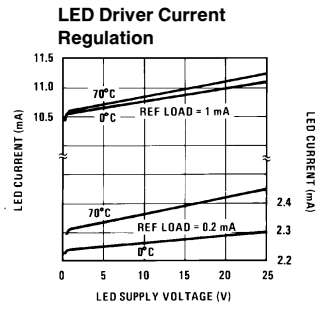
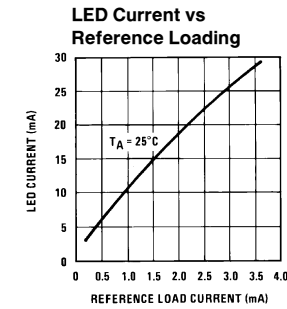
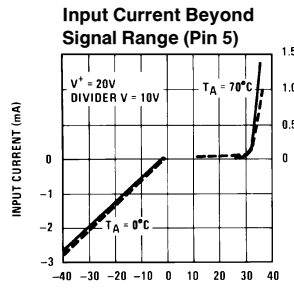
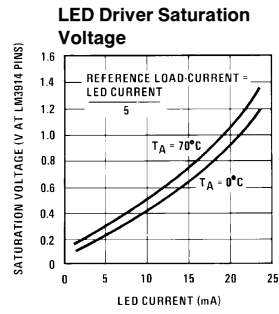
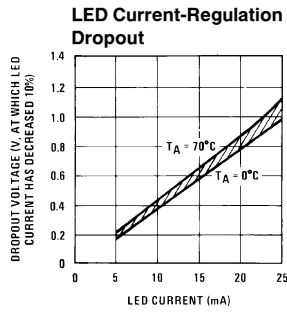
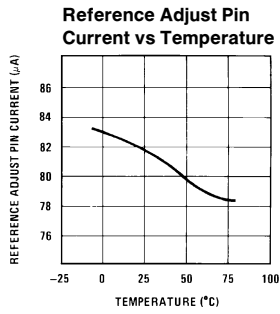
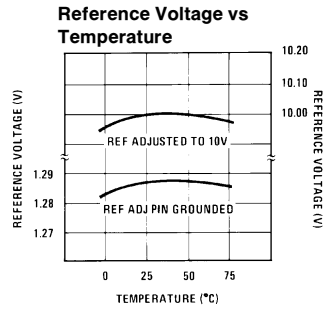
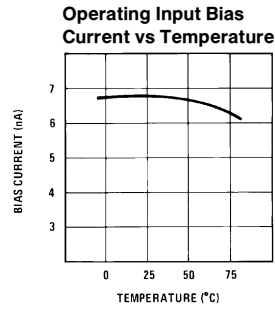
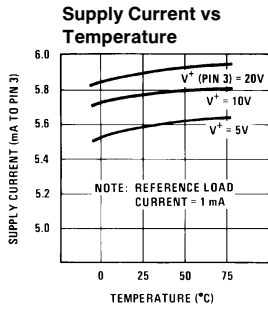
**LED Current Regulation:** The change in output current over the specified range of LED supply voltage ( $V_{\text{LED}}$ ) as measured at the current source outputs. As the forward voltage of an LED does not change significantly with a small change in forward current, this is equivalent to changing the voltage at the LED anodes by the same amount.

**Line Regulation:** The average change in reference output voltage over the specified range of supply voltage ( $V^+$ ).

**Load Regulation:** The change in reference output voltage ( $V_{\text{REF}}$ ) over the specified range of load current ( $I_{L(\text{REF})}$ ).

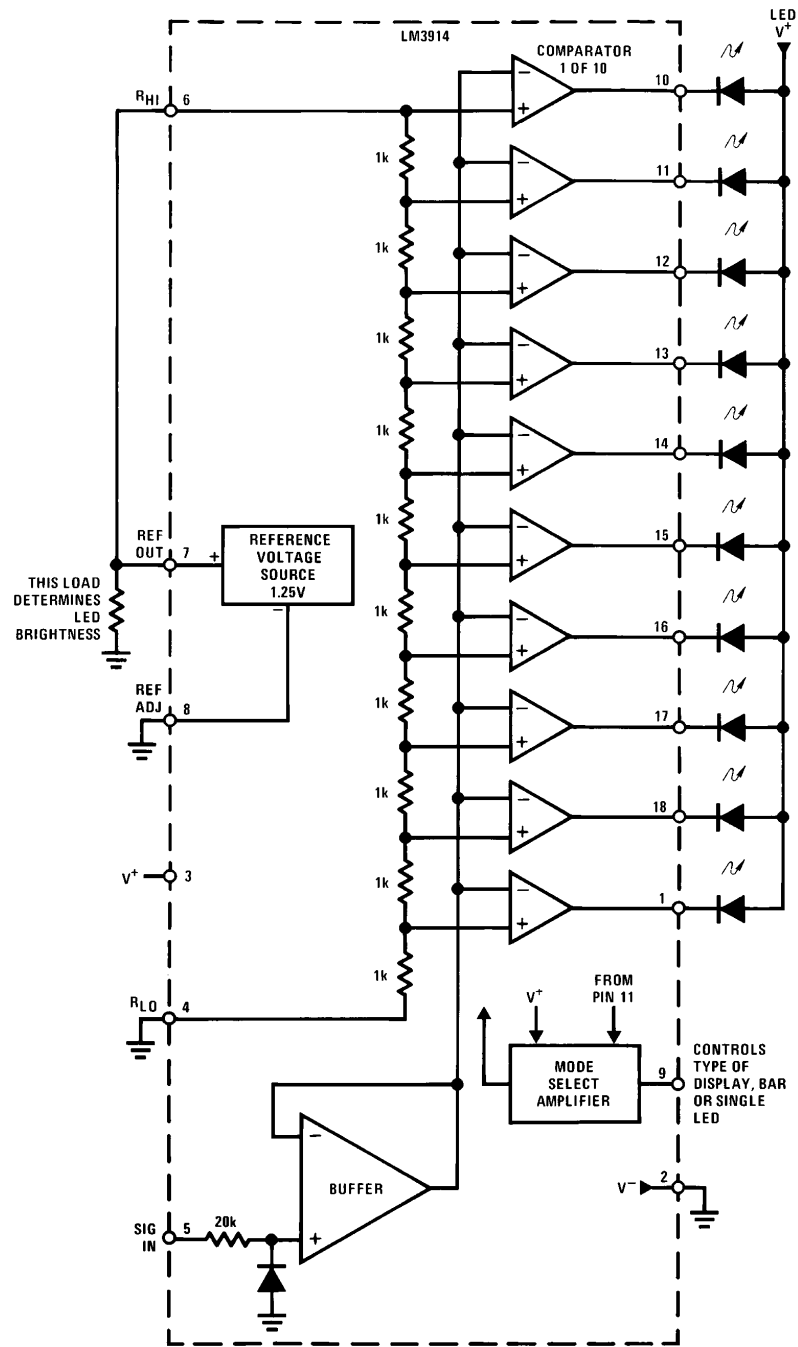
**Offset Voltage:** The differential input voltage which must be applied to each comparator to bias the output in the linear region. Most significant error when the voltage across the internal voltage divider is small. Specified and tested with pin 6 voltage ( $V_{\text{RHI}}$ ) equal to pin 4 voltage ( $V_{\text{RLO}}$ ).

# Typical Performance Characteristics



TL/H/7970-2

### Block Diagram (Showing Simplest Application)



TL/H/7970-3



## Mode Pin Functional Description (Continued)

### DOT OR BAR MODE SELECTION

The voltage at pin 9 is sensed by comparator C1, nominally referenced to ( $V^+ - 100$  mV). The chip is in bar mode when pin 9 is above this level; otherwise it's in dot mode. The comparator is designed so that pin 9 can be left open circuit for dot mode.

Taking into account comparator gain and variation in the 100 mV reference level, pin 9 should be no more than 20 mV below  $V^+$  for bar mode and more than 200 mV below  $V^+$  (or open circuit) for dot mode. In most applications, pin 9 is either open (dot mode) or tied to  $V^+$  (bar mode). In bar mode, pin 9 should be connected directly to pin 3. Large currents drawn from the power supply (LED current, for example) should not share this path so that large IR drops are avoided.

### DOT MODE CARRY

In order for the display to make sense when multiple LM3914s are cascaded in dot mode, special circuitry has been included to shut off LED No. 10 of the first device when LED No. 1 of the second device comes on. The connection for cascading in dot mode has already been described and is depicted below.

As long as the input signal voltage is below the threshold of the second LM3914, LED No. 11 is off. Pin 9 of LM3914 No. 1 thus sees effectively an open circuit so the chip is in dot mode. As soon as the input voltage reaches the threshold of LED No. 11, pin 9 of LM3914 No. 1 is pulled an LED drop (1.5V or more) below  $V_{LED}$ . This condition is sensed by comparator C2, referenced 600 mV below  $V_{LED}$ . This forces the output of C2 low, which shuts off output transistor Q2, extinguishing LED No. 10.

$V_{LED}$  is sensed via the 20k resistor connected to pin 11. The very small current (less than 100  $\mu$ A) that is diverted from LED No. 9 does not noticeably affect its intensity.

An auxiliary current source at pin 1 keeps at least 100  $\mu$ A flowing through LED No. 11 even if the input voltage rises high enough to extinguish the LED. This ensures that pin 9 of LM3914 No. 1 is held low enough to force LED No. 10 off when *any* higher LED is illuminated. While 100  $\mu$ A does not normally produce significant LED illumination, it may be noticeable when using high-efficiency LEDs in a dark environment. If this is bothersome, the simple cure is to shunt LED No. 11 with a 10k resistor. The 1V IR drop is more than the 900 mV worst case required to hold off LED No. 10 yet small enough that LED No. 11 does not conduct significantly.

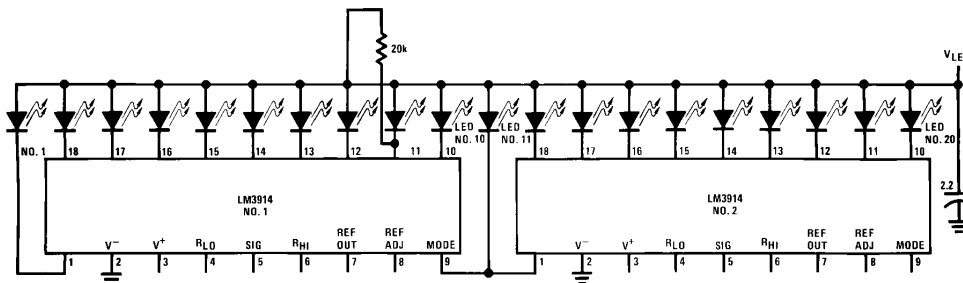
### OTHER DEVICE CHARACTERISTICS

The LM3914 is relatively low-powered itself, and since any number of LEDs can be powered from about 3V, it is a very efficient display driver. Typical standby supply current (all LEDs OFF) is 1.6 mA (2.5 mA max). However, any reference loading adds 4 times that current drain to the  $V^+$  (pin 3) supply input. For example, an LM3914 with a 1 mA reference pin load (1.3k), would supply almost 10 mA to every LED while drawing only 10 mA from its  $V^+$  pin supply. At full-scale, the IC is typically drawing less than 10% of the current supplied to the display.

The display driver does not have built-in hysteresis so that the display does not jump instantly from one LED to the next. Under rapidly changing signal conditions, this cuts down high frequency noise and often an annoying flicker. An "overlap" is built in so that at no time between segments are all LEDs completely OFF in the dot mode. Generally 1 LED fades in while the other fades out over a mV or more of range (Note 2). The change may be much more rapid between LED No. 10 of one device and LED No. 1 of a *second* device "chained" to the first.

The LM3914 features individually current regulated LED driver transistors. Further internal circuitry detects when any driver transistor goes into saturation, and prevents other circuitry from drawing excess current. This results in the ability of the LM3914 to drive and regulate LEDs powered from a pulsating DC power source, i.e., largely unfiltered. (Due to possible oscillations at low voltages a nominal bypass capacitor consisting of a 2.2  $\mu$ F solid tantalum connected from the pulsating LED supply to pin 2 of the LM3914 is recommended.) This ability to operate with low or fluctuating voltages also allows the display driver to interface with logic circuitry, opto-coupled solid-state relays, and low-current incandescent lamps.

Cascading LM3914s in Dot Mode



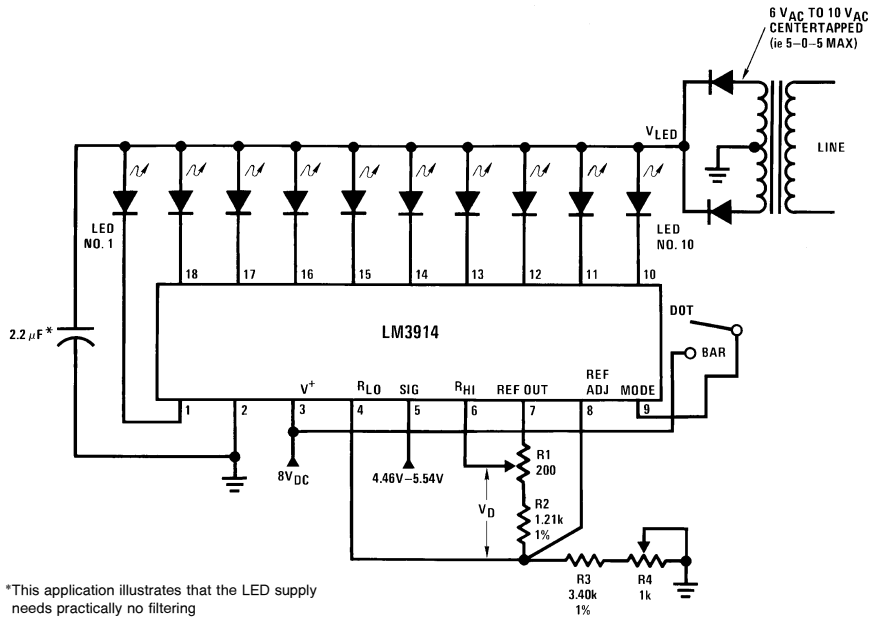
TL/H/7970-6





# Typical Applications (Continued)

## Expanded Scale Meter, Dot or Bar



\*This application illustrates that the LED supply needs practically no filtering

**Calibration:** With a precision meter between pins 4 and 6 adjust R1 for voltage  $V_D$  of 1.20V. Apply 4.94V to pin 5, and adjust R4 until LED No. 5 just lights. The adjustments are non-interacting.

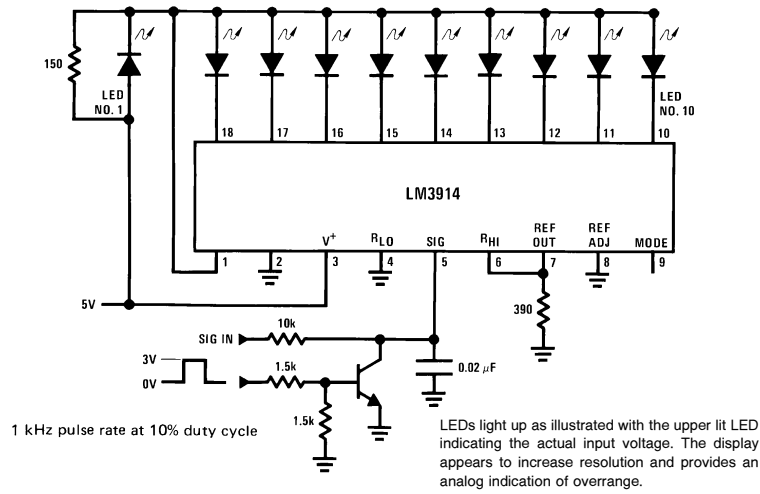
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### Application Example: Grading 5V Regulators

Highest No. LED on	Color	$V_{OUT(MIN)}$
10	Red	5.54
9	Red	5.42
8	Yellow	5.30
7	Green	5.18
6	Green	5.06
5V		
5	Green	4.94
4	Green	4.82
3	Yellow	4.7
2	Red	4.58
1	Red	4.46

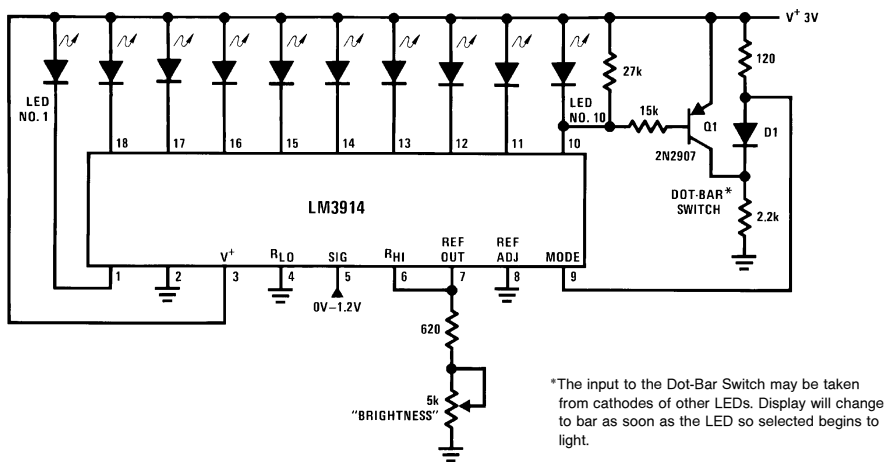
## Typical Applications (Continued)

### "Exclamation Point" Display



TL/H/7970-9

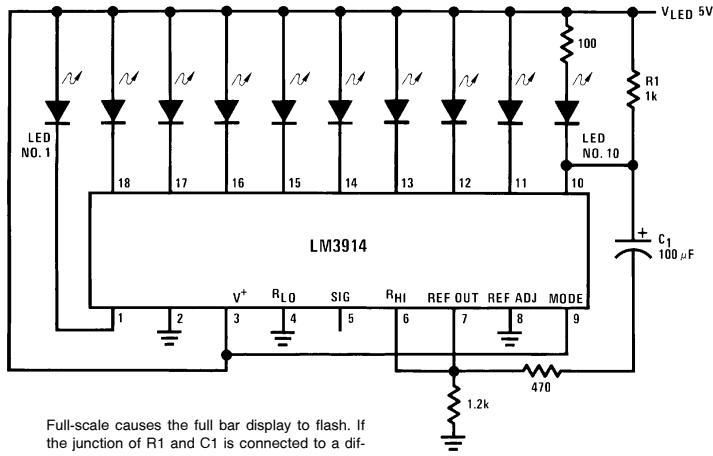
### Indicator and Alarm, Full-Scale Changes Display from Dot to Bar



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## Typical Applications (Continued)

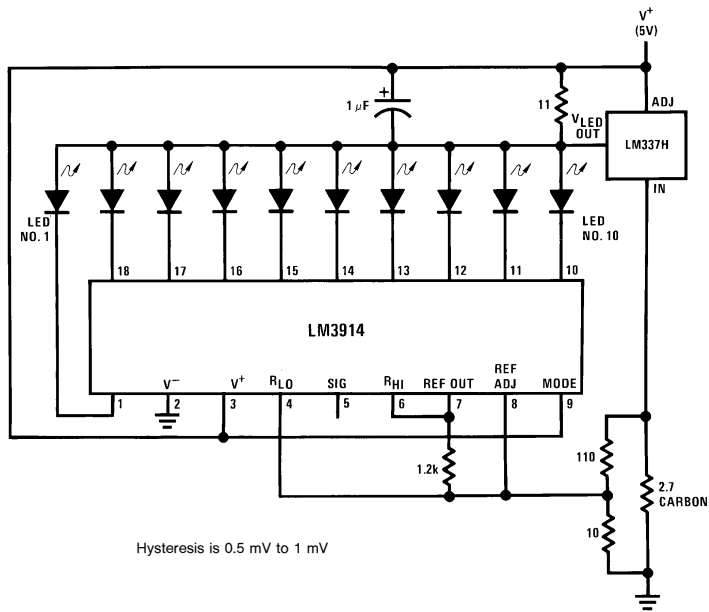
### Bar Display with Alarm Flasher



Full-scale causes the full bar display to flash. If the junction of R1 and C1 is connected to a different LED cathode, the display will flash when that LED lights, and at any higher input signal.

TL/H/7970-11

### Adding Hysteresis (Single Supply, Bar Mode Only)



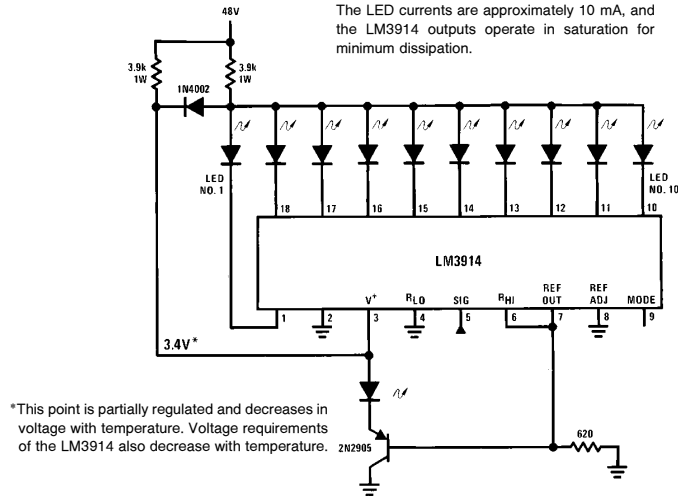
Hysteresis is 0.5 mV to 1 mV

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## Typical Application (Continued)

### Operating with a High Voltage Supply (Dot Mode Only)

The LED currents are approximately 10 mA, and the LM3914 outputs operate in saturation for minimum dissipation.

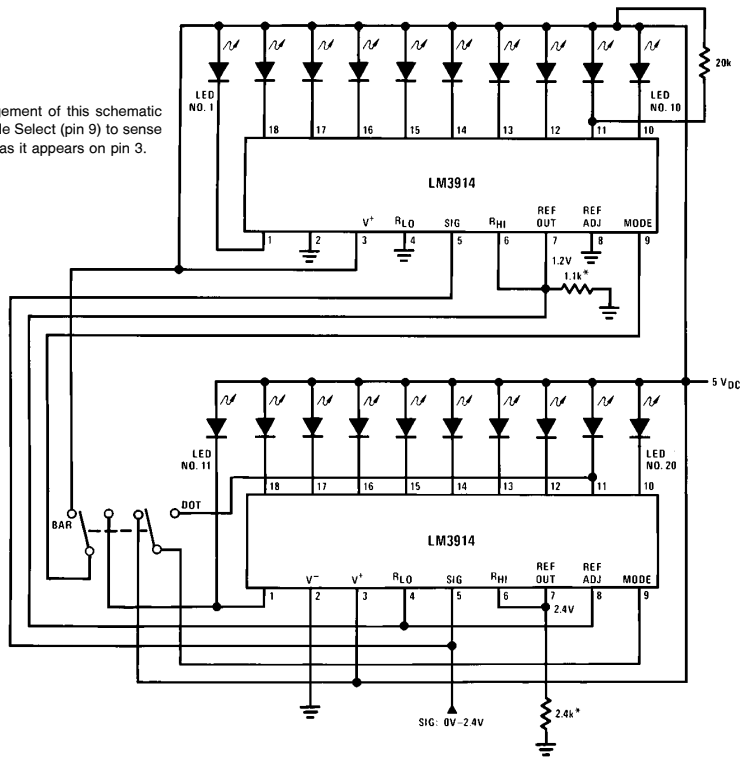


\*This point is partially regulated and decreases in voltage with temperature. Voltage requirements of the LM3914 also decrease with temperature.

TL/H/7970-13

### 20-Segment Meter with Mode Switch

\*The exact wiring arrangement of this schematic shows the need for Mode Select (pin 9) to sense the  $V^+$  voltage exactly as it appears on pin 3.



\*Programs LEDs to 10 mA

TL/H/7970-14

## Application Hints

Three of the most commonly needed precautions for using the LM3914 are shown in the first typical application drawing (see page 9-108) showing a 0V–5V bar graph meter. The most difficult problem occurs when large LED currents are being drawn, especially in bar graph mode. These currents flowing out of the ground pin cause voltage drops in external wiring, and thus errors and oscillations. Bringing the return wires from signal sources, reference ground and bottom of the resistor string (as illustrated) to a single point very near pin 2 is the best solution.

Long wires from  $V_{LED}$  to LED anode common can cause oscillations. Depending on the severity of the problem 0.05  $\mu\text{F}$  to 2.2  $\mu\text{F}$  decoupling capacitors from LED anode common to pin 2 will damp the circuit. If LED anode line wiring is inaccessible, often similar decoupling from pin 1 to pin 2 will be sufficient.

If LED turn ON seems slow (bar mode) or several LEDs light (dot mode), oscillation or excessive noise is usually the problem. In cases where proper wiring and bypassing fail to stop oscillations,  $V^+$  voltage at pin 3 is usually below suggested limits (see Note 2, page 9-108). Expanded scale meter applications may have one or both ends of the internal voltage divider terminated at relatively high value resistors. These high-impedance ends should be bypassed to pin 2 with at least a 0.001  $\mu\text{F}$  capacitor, or up to 0.1  $\mu\text{F}$  in noisy environments.

Power dissipation, especially in bar mode should be given consideration. For example, with a 5V supply and all LEDs programmed to 20 mA the driver will dissipate over 600 mW. In this case a 7.5 $\Omega$  resistor in series with the LED supply will cut device heating in half. The negative end of the resistor should be bypassed with a 2.2  $\mu\text{F}$  solid tantalum capacitor to pin 2 of the LM3914.

Turning OFF of most of the internal current sources is accomplished by pulling positive on the reference with a current source or resistance supplying 100  $\mu\text{A}$  or so. Alternatively, the input signal can be gated OFF with a transistor switch.

Other special features and applications characteristics will be illustrated in the following applications schematics. Notes have been added in many cases, attempting to cover any special procedures or unusual characteristics of these applications. A special section called "Application Tips for the LM3914 Adjustable Reference" has been included with these schematics.

### APPLICATION TIPS FOR THE LM3914 ADJUSTABLE REFERENCE

#### GREATLY EXPANDED SCALE (BAR MODE ONLY)

Placing the LM3914 internal resistor divider in parallel with a section ( $\approx 230\Omega$ ) of a stable, low resistance divider greatly reduces voltage changes due to IC resistor value changes with temperature. Voltage  $V_1$  should be trimmed to 1.1V first by use of R2. Then the voltage  $V_2$  across the IC divider string can be adjusted to 200 mV, using R5 without affecting  $V_1$ . LED current will be approximately 10 mA.

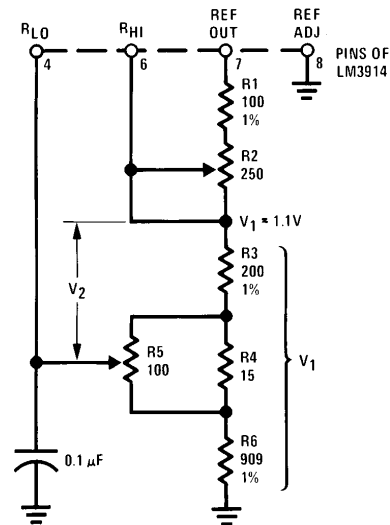
### NON-INTERACTING ADJUSTMENTS FOR EXPANDED SCALE METER (4.5V to 5V, Bar or Dot Mode)

This arrangement allows independent adjustment of LED brightness regardless of meter span and zero adjustments.

First,  $V_1$  is adjusted to 5V, using R2. Then the span (voltage across R4) can be adjusted to exactly 0.5V using R6 without affecting the previous adjustment.

R9 programs LED currents within a range of 2.2 mA to 20 mA after the above settings are made.

#### Greatly Expanded Scale (Bar Mode Only)



TL/H/7970-15

### ADJUSTING LINEARITY OF SEVERAL STACKED DIVIDERS

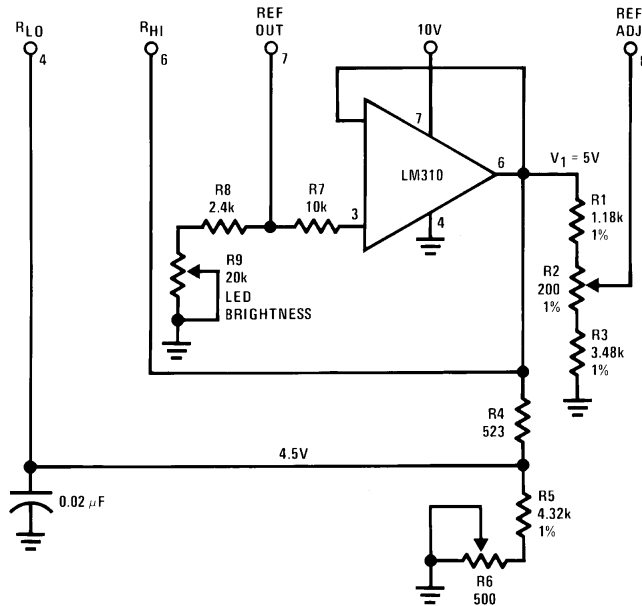
Three internal voltage dividers are shown connected in series to provide a 30-step display. If the resulting analog meter is to be accurate and linear the voltage on each divider must be adjusted, preferably without affecting any other adjustments. To do this, adjust R2 first, so that the voltage across R5 is exactly 1V. Then the voltages across R3 and R4 can be independently adjusted by shunting each with selected resistors of 6 k $\Omega$  or higher resistance. This is possible because the reference of LM3914 No. 3 is acting as a constant current source.

The references associated with LM3914s No. 1 and No. 2 should have their Ref Adj pins (pin 8) wired to ground, and their Ref Outputs loaded by a 620 $\Omega$  resistor to ground. This makes available similar 20 mA current outputs to all the LEDs in the system.

If an independent LED brightness control is desired (as in the previous application), a unity gain buffer, such as the LM310, should be placed between pin 7 and R1, similar to the previous application.

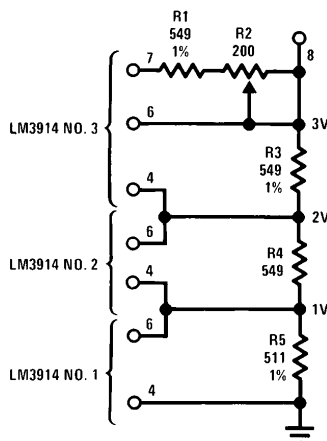
## Application Hints (Continued)

### Non-interacting Adjustments for Expanded Scale Meter (4.5V to 5V, Bar or Dot Mode)



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### Adjusting Linearity of Several Stacked Dividers



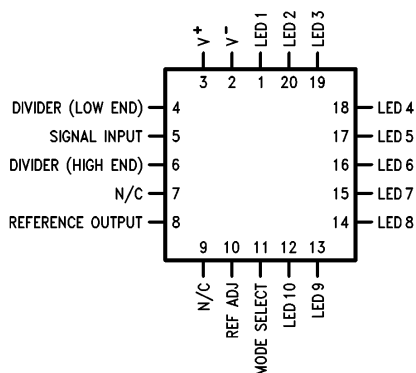
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### Other Applications

- "Slow"—fade bar or dot display (doubles resolution)
- 20-step meter with single pot brightness control
- 10-step (or multiples) programmer
- Multi-step or "staging" controller
- Combined controller and process deviation meter
- Direction and rate indicator (to add to DVMs)
- Exclamation point display for power saving
- Graduations can be added to dot displays. Dimly light every other LED using a resistor to ground
- Electronic "meter-relay"—display could be circle or semi-circle
- Moving "hole" display—indicator LED is dark, rest of bar lit
- Drives vacuum-fluorescent and LCDs using added passive parts

## Connection Diagrams

Plastic Chip Carrier Package

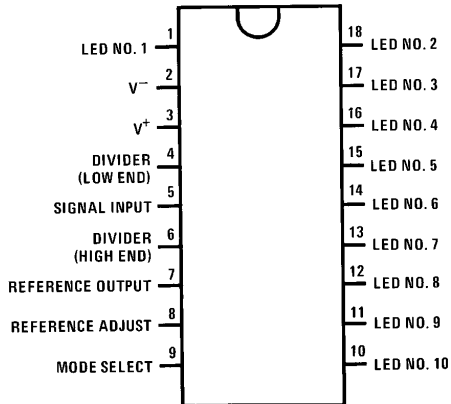


TL/H/7970-18

Top View

Order Number LM3914V  
See NS Package Number V20A

Dual-In-Line Package

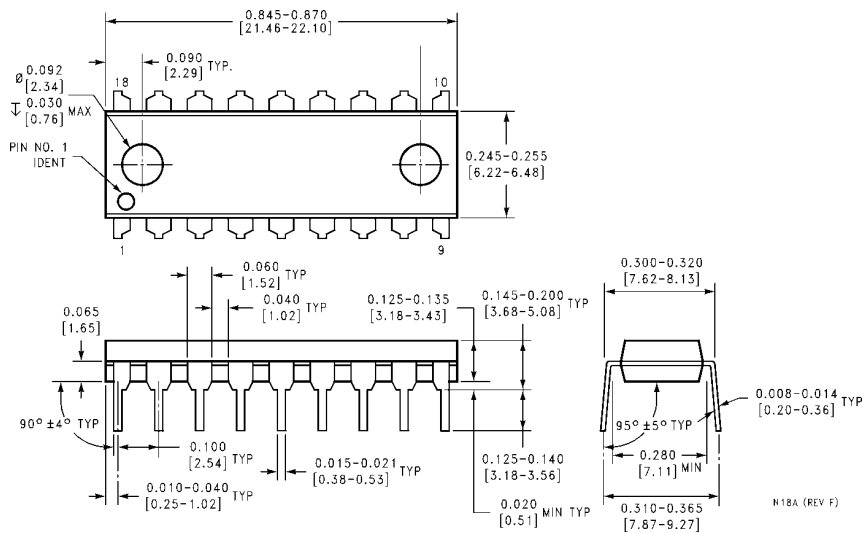


TL/H/7970-19

Top View

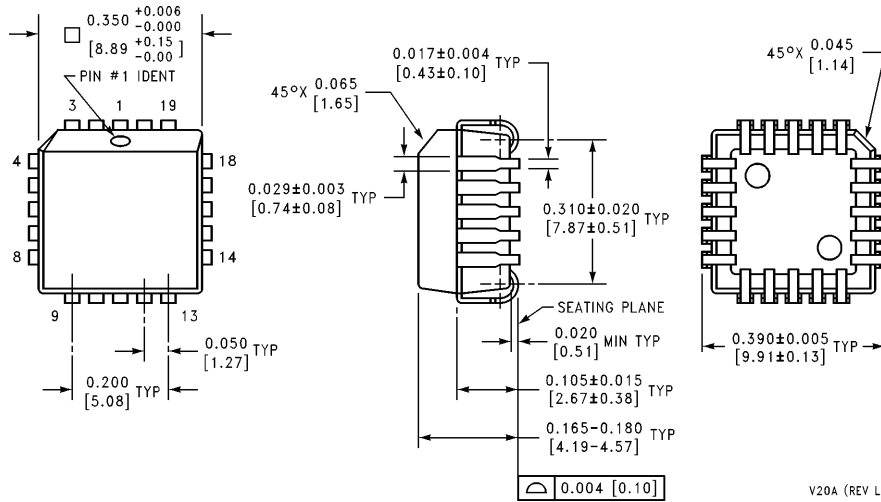
Order Number LM3914N  
See NS Package Number N18A

## Physical Dimensions inches (millimeters)



Dual-In-Line Package (N)  
Order Number LM3914N  
NS Package Number N18A

**Physical Dimensions** inches (millimeters) (Continued)



**Plastic Chip Carrier Package (V)**  
**Order Number LM3914V**  
**NS Package Number V20A**

V20A (REV L)

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