THE USE OF MULTIPLE LED's IN A BAR-
graph fashion to display analog signals is
becoming increasingly popular. The
reasons include low cost, ruggedness,
high visibility, ease of interpretation,
fast response time, low voltage and cur-
rent requirements, and long life. No
other display technology combines all
those advantages. For example, electro-
mechanical meters can have better
resolution, but they respond less quick-
ly and are sensitive to shock and vibra-
tion. Liquid-crystal displays draw less
power but are slow, and difficult to read
in dim light. Bar graph displays based on
LED's are used in stereo amplifiers for
power meters, in tuners for signal-
strength indicators, and in cameras for
light meters. In all of those examples,
the display must be interpreted quickly
and easily, but high resolution is not
required.

Recently, IC's have been introduced
that considerably simplify the task of
driving a LED array with analog signals.
Examples of those include National
Semiconductor's LM3914 and LM3915
LED Dot/Bar Display Drivers. Those
extremely versatile devices have a
reference, a voltage divider, and ten
comparators all on one chip. Besides the
LED's, only a few resistors and a ca-
pacitor are required to complete the dis-
play circuit. Either a bar or dot display
(on only one LED on at a time) is possible.
The on-chip voltage reference is fully
regulated, remaining constant while the
power supply feeding the IC can be any-
where between 3 volts and 25 volts!

How it works
A block diagram of the LM3914 is
shown in Fig. 1 where the IC is wired up
as a simple 2.5 volt full-scale meter. The
IC's internal reference forces the volt-
age drop across R1 to 1.25 volts, causing
a current equal to 1.25V/R1 or 1.25 mA
to flow thru R1 and R2. The small 75-
muampere current from pin 8 can
usually be neglected so that the voltage
at pin 7 is approximately 1.25V × (1 +
R2/R1) or 2.5 volts. The display range is
set by the voltages at pins 6 and 4, the
top and bottom ends of the LM3914's
internal voltage divider. For the 0-to-
2.5-volt meter shown, pin 6 is wired to
the 2.5-volt reference while pin 4 is ground-
ed. The reference load current (I_ref) in
this example is equal to the 1.25 mA
flowing through R1 plus the 0.25 mA
flowing through the 10K divider or 1.5
milliamperes total.

The signal to be displayed is applied
to pin 5, where it is buffered by a high
impedance follower and fed to the in-
verting inputs of the ten comparators
that drive the LED's. The comparators' non-inverting inputs are connected to the
taps along the voltage divider. In the
LM3914, those taps are all equally spaced. Here, another comparator turns
on for every 250-mV increase of the in-
put voltage, lighting up another LED.

Current drive to each LED illum-
nated is set at ten times the reference-

FIG. 1—THE LM3914 consists primarily of a series of comparators and a voltage-divider network. The
trip point of each successive comparator is set higher than the previous comparator by the voltage
divider. As the input voltage applied to pin 5 increases, the comparators trip in sequence. The
comparators, in turn, illuminate their respective LED's.
FIG. 2—EXPANDED-SCALE VOLTOMETER for monitoring the output voltage of a 5-volt logic-power supply. Each LED corresponds to a predetermined voltage, as shown in the chart.

load current ($I_{REF}$) or 15 mA in this example. Generally, LED currents from 10 to 20 mA produce adequate brightness. A pot in series with a resistor connected from pin 7 to ground makes a simple intensity control, since it varies $I_{REF}$ without affecting the reference voltage. Trimming the reference output voltage can be accomplished by varying $R_2$.

For a dot-mode display, pin 9 may be left open; for bar-mode, pin 9 is connected to the LED supply, which can be different from the IC's $V^+$. Watch the IC's power dissipation in bar mode, however. At 15 mA per LED, the LED supply should be no higher than 6 volts. To power the LED's from a higher-supply voltage, place a dropping resistor between the LED anodes and the supply. The LED supply should always be bypassed with a 10 μF electrolytic capacitor to prevent oscillations. The LM3914's $5\,V$ supply (pin 3) must be at least 1.5 volts above the pin 7 reference output and can be as low as 3 volts when the reference is run at 1.25 volts (pin 8 grounded).

Simple voltage monitor for TTL

The LM3914's low voltage-requirements and flexibility make for some interesting applications. Figure 2 shows an expanded-scale voltage monitor for a TTL system that runs off the same single 5-volt supply it monitors! As shown in the table, each LED covers a 100-mV range from 4.5 to 5.5 volts. A simple two-step calibration is all that's required.

Here the supply voltage is attenuated by a factor of two and fed to the LM3914 signal input. Resistor $R_6$ sets the top of the internal divider network at 2.705 volts ($5.41\,V/2$) and potentiometer $R_4$ sets the bottom of the divider at 2.205 volts ($4.41\,V/2$). Adjust $R_6$ until LED10 just turns on with $V_{CC}$ set at 5.41 volts. Then adjust $R_4$ until LED1 just turns on with $V_{CC}$ set at 4.41 volts. There's a slight interaction so that running through that procedure a second time may improve accuracy.

TTL and CMOS-compatible undervoltage and overvoltage signals are provided, which can be used to shut down a system before damage (to either data or hardware) occurs. Optional diode $D_1$ protects the IC in the event the 5-volt supply leads are reversed. For a simple go/no-go display, use red LED's at pins 1 and 18 for undervoltage and overvoltage and wire-or pins 10 through 17 to the cathode of a single green LED.

Audio metering

A logarithmic scale using the decibel (dB) is a convenient and popular one for measuring audio levels. A 3-dB increase corresponds to a 41 percent voltage increase and a doubling of power. The LM3915 features a (22K ohm) logarithmic scale with a different number of steps compared to the LM3914, providing a more sensitive and detailed measurement of audio levels.
provides a logarithmic response.

**FIG. 4—PEAK-READING AUDIO-LEVEL METER** is obtained by using a peak-detecting circuit on input either a sine or triangular waveform as shown in a. The resulting display shown in b and c has twice the original resolution. (The display shown in b obtained in the DOT mode, while the display shown in c is obtained in the BAR GRAPH mode.) The same effect is obtained with the logarithmic LM3915 by using the configuration shown in d.

**FIG. 3—AUDIO-LEVEL METER** displays the instantaneous value of the audio input signal. The LM3915 provides a logarithmic response.

**FIG. 4—PEAK-READING AUDIO-LEVEL METER** is obtained by using a peak-detecting circuit on input pin 5.

**FIG. 5—INCREASED DISPLAY RESOLUTION** is obtained by modulating the input signal on pin 5 with either a sine or triangular waveform as shown in a. The resulting display shown in b and c has twice the original resolution. (The display shown in b obtained in the DOT mode, while the display shown in c is obtained in the BAR GRAPH mode.) The same effect is obtained with the logarithmic LM3915 by using the configuration shown in d.

**FIG. 3** illustrates how simple it is to construct an audio-level indicator with the LM3915. The audio is fed straight to the IC’s signal input without any rectification. Using the DOT mode, the LED illuminated represents the instantaneous value of the audio waveform. Both peak and average levels can be easily discerned. Since the dot will be constantly moving, the LED’s are run at 30 mA for adequate intensity. The full-scale reading (+3 dB) is 10 volts; that is easily altered by changing R2. The LM3915’s signal input can withstand signals up to ±35 volts, which corresponds to 150 watts peak into an 8-ohm load. If there is a chance that the audio input could exceed this range, either attenuate it or include enough series resistance to limit the current to 5 mA.

If a peak-reading meter is desired, Fig. 4 shows how it’s done. Since the thresholds for the first few LED’s are less than 1 volt, a simple diode-capacitor peak detector won’t do. The diode’s 600 mV turn-on threshold would not pass low-level signals. In the circuit shown, the voltage drop across D1 is canceled out by the emitter-base voltage of PNP transistor Q1, connected as an emitter follower. These voltages usually track within 100 mV, causing a small error at low input levels.

The LED connections in Fig. 4 illustrate a tricky way to get a bar-graph display with very low current drain. With pin 9 left open, the LM3915 thinks it’s in DOT mode, so only one output will be on at a time. For an input between −24 and −21 dB, the pin-1 current source turns on, lighting up LED1. When the input increases to −21 to −18 dB, the pin-18 current source turns on while pin 1 turns off. With the LED’s in series, the pin-18 output current flows through LED2 and LED1, lighting them both. For every 3-dB increase in input voltage, the current shifts over to mic voltage-divider for a 3-dB-per-step display; otherwise, it’s identical to the LM3914. The LM3915 is useful for displaying signals with wide dynamic range, such as RF signal strength, power level, or light intensity, in addition to audio level.
other display ideas

For increased resolution, modulate the LM3914's input signal with an AC voltage as in Fig. 5-a. The LED's will appear to turn on gradually, producing a display that changes smoothly like a meter. For the modulating voltage, a triangle wave works best, although a sinewave (60 Hz from a transformer, for example) can be used. The peak-to-peak amplitude of the AC voltage should be equal to the voltage step between LED's. Figures 5-b and 5-c depict the resulting displays in either the bar or dot mode. To obtain the same effect using an LM3915, where the voltage step between LED's varies, one should modulate the R11 voltage by 3 dB as in Figure 5-d.

Most program material has a dynamic range of over 40 dB. It's a simple matter to obtain a 60-dB display by cascading two LM3915's together, as shown in Fig. 6. A better peak-detector circuit is required because the threshold for the first LED is only 15 mV! The precision peak detector uses op-amp IC3 to overcome diode offset error. Operational amplifier IC4 is run at a gain of 30 dB or 31.6. BiFET op-amps, such as the
FIG. 8—TEN-STEP TIMER CIRCUIT. The LED's turn off sequentially, with each LED representing the time constant of R1—C1.

FIG. 9—NINE-STEP SEQUENCER is a variation of the principle used in the ten-step timer shown in Fig. 8 and can be used to turn various loads on and off sequentially.

Timers and sequencers

Use an LM3915 to monitor the voltage on a discharging capacitor, as in Fig. 8, and you’ve got a simple timer. Even though the capacitor voltage decays to zero logarithmically, displaying it via an LM3915 results in equal time steps. Each time step is approximately \( R_1 \times C_1 \).

The sequencer shown in Fig. 9 is a variation on that. Capacitor C1 is charged linearly by the current source made up of Q1, LED11 and R1. When output 10 starts to turn on, Q2 and Q3 conduct and C1 is rapidly discharged. Cycle time is about \( 10 \times R_1 \times C_1 \). The LM3914 outputs could be used to drive relays, opto-isolators, or logic circuits, for example.

Other ideas

Don’t think the LM3914 and LM3915 can drive only bars of LEDs. The LED’s can be arranged in circles, or as X-Y displays, for instance. LCD’s, vacuum fluorescents, and low-current incandescent bulbs can also be driven. As the examples show, outputs may interface with CMOS, TTL, opto-isolators and relays for a variety of automatic measurement and control functions. The decibel display of the LM3915 is especially attractive for audiophiles. Like the op-amp, applications of those display drivers are limited only by the imagination of the designer.