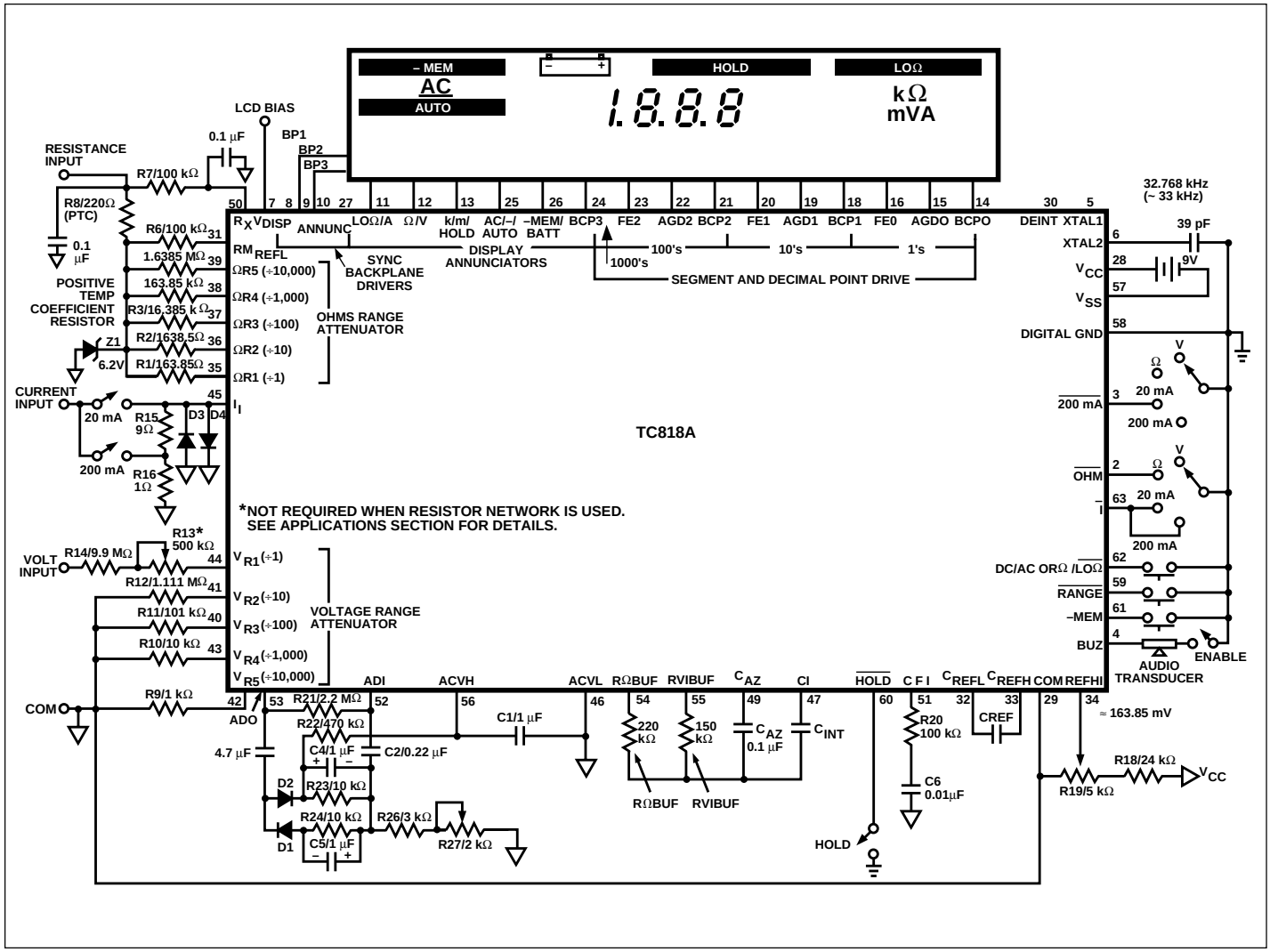
Auto-Ranging Analog-To-Digital Converter with 3-1/2 Digit Display

FEATURES

- Auto-Ranging Analog-to-Digital Converter with 3-1/2 Digit Display
- Annunciator Outputs Permit Customizing of LCD
- Auto-Range Operation for AC and DC Voltage and Resistance Measurements
- Two User-Selected AC/DC Current Ranges ..... 20mA and 200mA
- 22 Operating Ranges ..... 9 DC/AC Voltage, 4 AC/DC Current, 9 Resistance and Low-Power Ohms
- Display Hold Function
- 3-1/2 Digit Resolution in Auto-Range Mode 1/2000
- Extended Resolution in Manual Range Mode 1/3000
- Internal AC-to-DC Conversion Op Amp
- Triplex LCD Drive for Decimal Points, Digits, Bar-Graphs, and Annunciators
- Continuity Detection and Piezoelectric Transducer Driver
- Low-Drift Internal Reference ..... 75ppm/°C
- 9V Battery Operation 10mW
- Low Battery Detection and LCD Annunciator

FUNCTIONAL BLOCK DIAGRAM



TC818A

GENERAL DESCRIPTION

The TC818A is an integrating analog-to-digital converter (ADC) with a 3-1/2 digit numeric LCD driver, automatic ranging, and single 9V battery operation. The numeric display provides 0.05% resolution and a full set of annunciators that spell out the TC818A's many operating modes.

Automatic range selection is provided for both voltage (DC and AC) and ohms (high and low power) measurements. Expensive and bulky mechanical range switches are not required. Five full-scale ranges are available, with automatic selection of external volt/ohm attenuators over a 1 to 10,000 range. Two current ranges, 20 mA and 200 mA, can be manually selected. The auto-range feature can be bypassed, allowing input attenuator selection through a single line input.

During manual mode operation, resolution is extended to 3000 counts full-scale. Extended resolution is also available during 2000kΩ and 2000V full-scale auto-range operation. The extended range operation is indicated by a flashing 1 MSD and by the fully-extended bar-graph.

The TC818A includes an AC-to-DC converter for AC voltage and current measurements. Only external diodes/resistors/capacitors are required. Other features include a memory mode, low-battery detection, display $\overline{\text{HOLD}}$ input, and continuity buzzer driver.

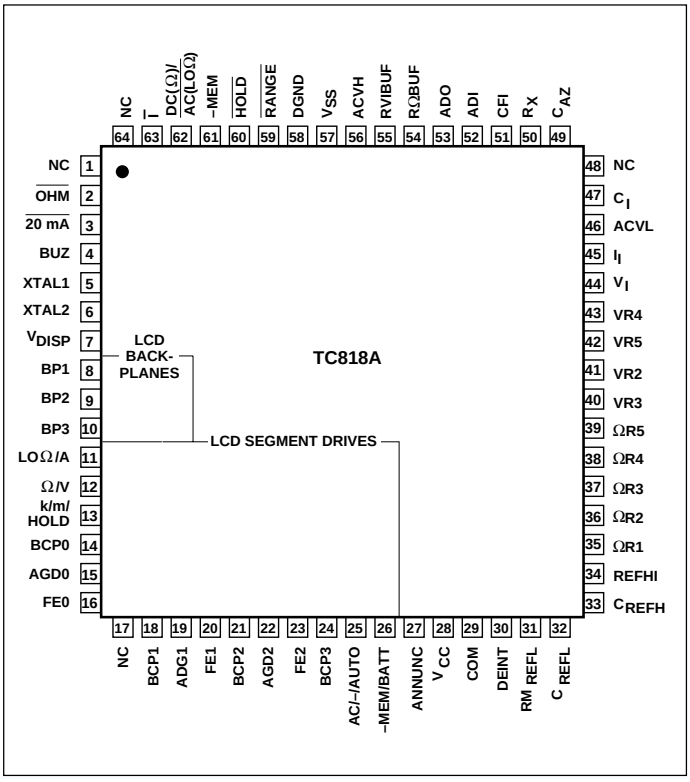
The 3-1/2 digit numeric display includes a full set of annunciators. Decimal points are adjusted as automatic or manual range changes occur, and voltage, current, and ohms operating modes are displayed. Additional annunciators are activated for manual, auto, memory, $\overline{\text{HOLD}}$, AC, low-power ohms, and low-battery conditions.

The TC818A is available in a surface-mounted 64-pin flat package. Combining a numeric display driver, single 9V battery operation, internal range switching, and compact surface mounting, the TC818A is ideal for advanced portable instruments.

ORDERING INFORMATION

Part No.	Package	Temperature Range
TC818ACBU	64-Pin Plastic Quad Flat Package	0°C to +70°C

PIN CONFIGURATIONS



ABSOLUTE MAXIMUM RATINGS *

Supply Voltage ..... +15V
Analog Input Voltage ..... V_{CC} to V_{SS}
Reference Input Voltage ..... V_{CC} to V_{SS}
Voltage at Pin 43 ..... Common ±0.7V
Power Dissipation 800mW
Operating Temperature Range ..... 0°C to +70°C
Storage Temperature Range ..... –65°C to +150°C
Lead Temperature (Soldering, 10 sec) ..... +300°C

* Static-sensitive device. Unused devices must be stored in conductive material. Protect devices from static discharge and static fields. Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to Absolute Maximum Rating Conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS: V_S = 9V, T_A = +25°C, Figure 1 Test Circuit

Symbol	Parameter	Test Conditions	TC818A Min	TC818A Typ	TC818A Max	Unit
	Zero Input Reading	200 mV Range Without 10 MΩ Resistor 200 mV Range With 10 MΩ Resistor 20 mA and 200 mA Range	–0000 –0001 –0000	0000 — 0000	+0000 +0001 +0000	Digital Reading
RE	Roll-Over Error	200 mV Range Without 10 MΩ Resistor 200 mV Range With 10 MΩ Resistor 20 mA and 200 mA Range	— — —	— — —	±1 ±3 ±1	Counts
NL	Linearity Error	Best Case Straight Line	—	—	±1	Count
I_{IN}	Input Leakage Current		—	—	10	pA
e_N	Input Noise	BW = 0.1 to 10 Hz	—	20	—	μV_{P-P}
	AC Frequency Response	±1% Error ±5% Error	— —	40 to 500 40 to 2000	— —	Hz
	Open Circuit Voltage for Ohm Measurements	Excludes 200Ω Range	—	570	660	mV
	Open Circuit Voltage for $\overline{LO}$ Ohm Measurements	Excludes 200Ω Range	—	285	350	mV
V_{COM}	Analog Common Voltage	(V_{CC} – V_{COM})	2.8	3	3.3	V
V_{CTC}	Common Voltage Temperature Coefficient		—	—	50	ppm/°C
		Display Multiplex Rate	—	100	—	Hz
V_{IL}	Low Logic Input	$\overline{20mA}$, AC, I, $\overline{LO\Omega}$, HOLD Range, – MEM, Ohms (Relative to DIGITAL GND, Pin 55)	—	—	1	V
	Logic 1 Pull-Up	$\overline{20mA}$, AC, I, $\overline{LO\Omega}$, HOLD Range, – MEM, Ohms (Relative to DIGITAL GND, Pin 55)	—	25	—	µA
V_{OL}	Low Logic Output	ANNUNC, DEINT; I_L = 100µA	—	DGND+0.1	—	V
V_{OH}	High Logic Output	ANNUNC, DEINT; I_L = 100 A	—	V_{CC} –0.1	—	V
	Buzzer Driver Frequency		—	4	—	kHz
	Low Battery Flag Voltage	V_{CC} to V_{SS}	6.3	6.6	7	V
	Operating Supply Current		—	0.8	1.5	mA

TC818A

TC818A PIN DESCRIPTION

Pin No. (Plastic Quad Flat Package)	Symbol	Description
2	$\overline{OHM}$	Logic input. "0" (digital ground) for resistance measurement.
3	$\overline{20mA}$	Logic Input. "0" (digital ground) for 20mA full-scale current measurement.
4	BUZ	Buzzer. Audio frequency, 4kHz, output for continuity indication during resistance measurement. A noncontinuous 4kHz signal is output to indicate an input overrange during voltage or current measurements.
5	XTAL1	32.768kHz crystal connection.
6	XTAL2	32.768kHz crystal connection.
7	V_{DISP}	Sets peak LCD drive signal: $V_P = V_{CC} = V_{DISP}$. V_{DISP} may also be used to compensate for temperature variation of LCD crystal threshold voltage.
8	BP1	LCD backplane #1.
9	BP2	LCD backplane #2.
10	BP3	LCD backplane #3.
11	LOΩ/A	LCD annunciator segment drive for low ohms resistance measurement and current measurement.
12	Ω/V	LCD annunciator segment drive for resistance measurement and voltage measurement.
13	k/m/HOLD	LCD annunciator segment drive for k ("kilo-Ohms"), m ("milli-Amps" and "milli-Volts") and HOLD mode.
14	BCP0 (Ones Digit)	LCD segment drive for "b," "c" segments and decimal point of least significant digit (LSD).
15	ADG0	LCD segment drive for "a," "g," "d" segments of LSD.
16	FE0	LCD segment drive for "f" and "e" segments of LSD.
18	BCP1	LCD segment drive for "b," "c" segments and decimal point of second LSD.
19	ADG1	LCD segment drive for "a," "g," "d" segments of second LSD.
20	FE1	LCD segment drive for "f" and "e" segments of second LSD.
21	BCP2	LCD segment drive for "b," "c" segments and decimal point of third LSD (hundreds digit).
22	ADG2	LCD segment drive for "a," "g," "d" segments of third LSD.
23	FE2	LCD segment drive for "f" and "e" segments of third LSD.
24	BCP3	LCD segment drive for "b," "c" segments and decimal point of MSD (thousands digit).
25	AC/–/AUTO	LCD annunciator segment drive for AC measurements, polarity, and auto-range operation.
26	–MEM/BATT	LCD annunciator segment drive for low-battery indication and memory (relative measurement).
27	ANNUNC	Square-wave output at the backplane frequency, synchronized to BP1. ANNUNC can be used to control display annunciators. Connecting an LCD segment to ANNUNC turns it on; connecting it to its backplane turns it off.
28	V_{CC}	Positive battery supply connection.
29	COM	Analog circuit ground reference point. Nominally 3V below V_{CC}.
30	DEINT	Deintegrate output.
31	RM_{REFL}	Ratiometric (resistance measurement) reference low voltage.
32	C_{REFL}	Reference capacitor negative terminal, C_{REF} = 0. 1µF.
33	C_{REFH}	Reference capacitor positive terminal, C_{REF} = 0.1µF.
34	REFHI	Reference voltage for voltage and current measurement. Nominally 163.85mV.
35	ΩR1	Standard resistor connection for 200Ω full-scale.
36	ΩR2	Standard resistor connection for 2000Ω full-scale.
37	ΩR3	Standard resistor connection for 20kΩ full-scale.
38	ΩR4	Standard resistor connection for 200kΩ full-scale.

TC818A PIN DESCRIPTION (Cont.)

Pin No. (Plastic Quad Flat Package)	Symbol	Description
39	ΩR5	Standard resistor connection for 2000kΩ full-scale.
40	VR3	Voltage measurement ÷100 attenuator.
41	VR2	Voltage measurement ÷10 attenuator.
42	VR5	Voltage measurement ÷10,000 attenuator.
43	VR4	Voltage measurement ÷1000 attenuator.
44	V_I	Unknown voltage input ÷ attenuator.
45	I_I	Unknown current input.
46	ACVL	Low output of AC-to-DC converter.
47	C_I	Integrator capacitor connection. Nominally 0.1µF. (Must have low dielectric absorption. Polypropylene dielectric suggested.)
49	C_{AZ}	Auto-zero capacitor connection. Nominally 0.1µF.
50	R_X	Unknown resistance input.
51	CFI	Input filter connection.
52	ADI	Negative input of internal AC-to-DC operational amplifier.
53	ADO	Output of internal AC-to-DC operational amplifier.
54	RΩBUF	Active buffer output for resistance measurement. Integration resistor connection. Nominally 220kΩ.
55	RVIBUF	Active buffer output for voltage and current measurement. Integration resistor connection. Nominally 15 kΩ.
56	ACVH	Positive output of AC-to-DC converter.
57	V_{SS}	Negative supply connection. Connect to negative terminal of 9V battery.
58	DGND	Internal logic digital ground. Ground connection for the logic "0" level. Nominally 4.7V below V_{CC}.
59	$\overline{\text{RANGE}}$	Input to set manual operation and change ranges.
60	$\overline{\text{HOLD}}$	Input to hold display. Connect to DGND to "freeze" display.
61	–MEM	Input to enter memory measurement mode for relative measurements. The two LSDs are stored and subtracted from future measurements.
62	DC (Ω)/ AC ($\overline{\text{LOΩ}}$)	Input that selects AC or DC option during voltage/current measurements. For resistance measurements, the ohms or low power (voltage) ohms option can be selected.
63	$\overline{\text{I}}$	Input to select measurement. Connect to logic "0" (digital ground) for current measurement.

* NOTE: Pins 1, 7, 48, 64 = No Connection

TC818A

THEORY OF OPERATION

Analog-to-Digital Converter (ADC)

The TC818A includes an integrating ADC with auto-ranging resolution of 2000 counts and manual range resolution of 3000 counts. Figure 1 shows a simplified schematic of the analog section. In auto-ranging mode, internal logic will adjust the input voltage or ohms attenuators so that measurements will always be made in the appropriate range. Measurement ranges, logic control inputs, 3-1/2 digit LCD formatting, and other features are identical to the TC815 auto-ranging A/D converter. However, the TC818A is not pin-compatible with, and is not a replacement for, the TC815.

A display annunciator output (ANNUNC) can be used to customize the LCD. ANNUNC is a square wave at the backplane frequency. Connecting an annunciator segment to the ANNUNC driver turns the segment on; connecting the segment to its backplane turns it off.

Resistance, Voltage, Current Measurement Selection

The TC818A is designed to measure voltage, current, and resistance. Auto-ranging is available for resistance and voltage measurements. The $\overline{OHM}$ (pin 2) and $\bar{I}$ (pin 63) input controls are normally pulled internally to V_{CC}.

By tying these pins to DGND (pin 58), the TC818A is configured internally to measure resistance, voltage, or current.

Table II. TC818A Measurement Selection Logic

Function Select Pin $\overline{OHM}$ (Pin 2)	Function Select Pin $\bar{I}$ (Pin 63)	Selected Measurement
0	0	Voltage
0	1	Resistance
1	0	Current
1	1	Voltage

0 = Digital Ground 1 = Floating or Tied to V_{CC}

NOTES: 1. $\overline{OHM}$ and $\bar{I}$ are normally pulled internally high to V_{CC} (pin 28). This is considered a logic "1".
2. Logic "0" is the potential at digital ground (pin 58).

Resistance Measurements — Ohms and Low Power Ohms

The TC818A can be configured to reliably measure in-circuit resistances shunted by semiconductor junctions. The TC818A low-power ohms measurement mode limits the probe open circuit voltage. This prevents semiconductor junctions in the measured system from turning on.

In the resistance measurement mode, the $\Omega/\overline{LO\Omega}$ (pin 62) input selects the low-power ohms measurement mode. For low-power ohms measurements, $\Omega/\overline{LO\Omega}$ (pin 62) is momentarily brought LOW to digital ground potential. The TC818A sets up for a low-power ohms measurement with a maximum open circuit probe voltage of 0.35V above analog common. In the low-power ohms mode, an LCD annunciator, $\overline{LO\Omega}$, will be activated. On power-up, the low-power ohms mode is not active.

If the manual operating mode has been selected, toggling $\Omega/\overline{LO\Omega}$ resets the TC818A back to auto-range mode. In manual mode, the decision to make a normal or low-power ohms measurement should be made before selecting the desired range.

The low-power ohms measurement is not available on the 200Ω full-scale range. Open-circuit voltage on this range is below 2.8V.

The standard resistance values are listed in Table III.

Table III. Ohms Range Ladder Network

Full-Scale Range	Standard Resistance	Low-Power Ohms Mode
200Ω	163.85Ω (R1)	No
2000Ω	1638.5Ω (R2)	Yes
20 kΩ	16,385Ω (R3)	Yes
200 kΩ	163,850Ω (R4)	Yes
2000 kΩ	1,638,500Ω (R5)	Yes

R8, a positive temperature coefficient resistor, and the 6.2V zener, Z1, provide input voltage protection during ohms measurement.

Ratiometric Resistance Measurements

The TC818A measures resistance ratiometrically. Accuracy is set by the external standard resistors connected to pins 35 through 39. A low-power ohms mode may be selected on all but the 200Ω full-scale range. The low-power ohms mode limits the voltage applied to the measured system. This allows accurate "in-circuit" measurements when a resistor is shunted by semiconductor junctions.

Full auto-ranging is provided. External precision standard resistors are automatically switched to provide the proper range.

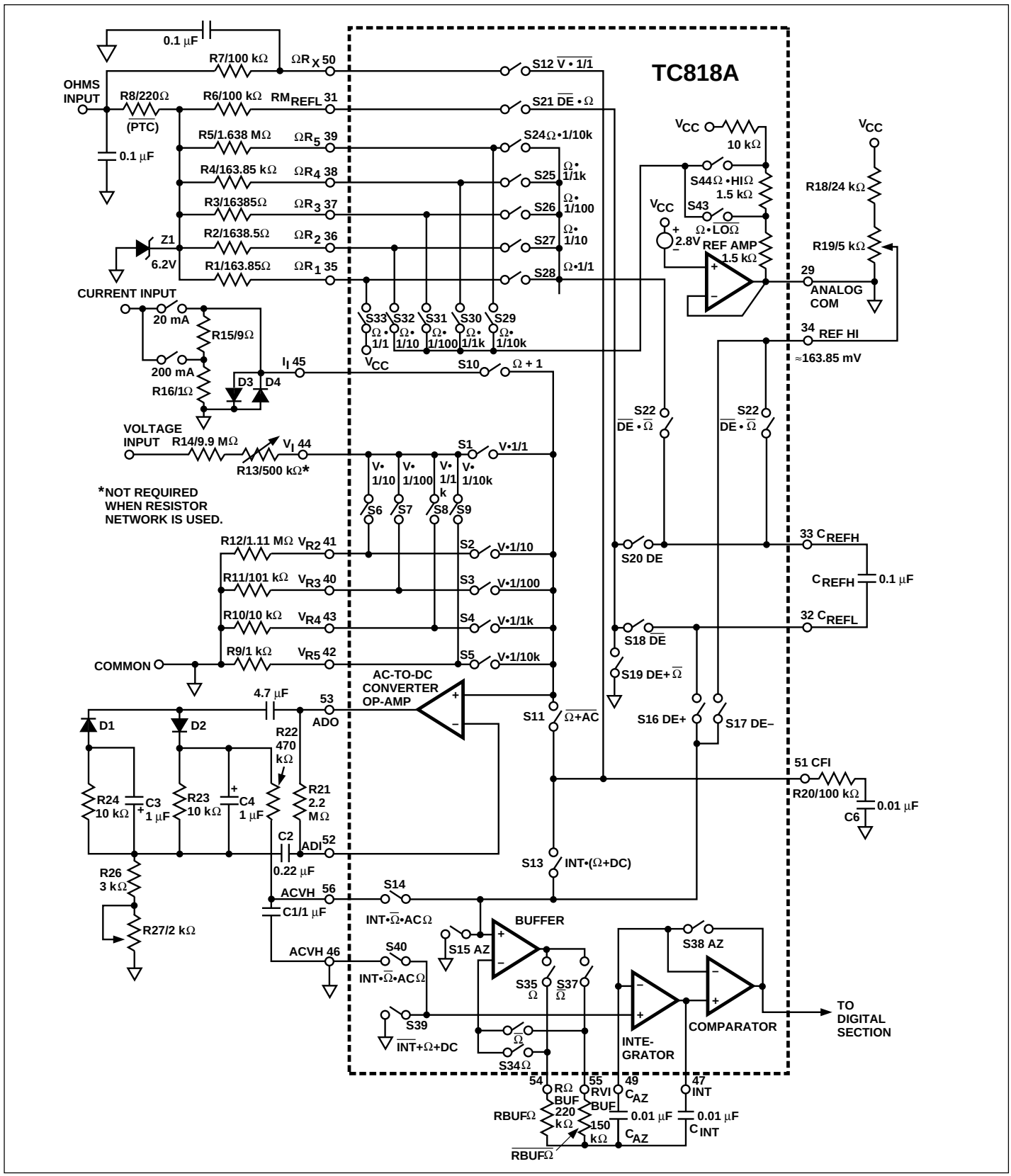


Figure 1. TC818A Analog Section

TC818A

Figure 3 is a detailed block diagram of the TC818A configured for ratiometric resistance measurements. During the signal integrate phase, the reference capacitor charges to a voltage inversely proportional to the measured resistance, R_X. Figure 4 shows that the conversion accuracy relies only on the accuracy of the external standard resistors.

Normally, the required accuracy of the standard resistances will be dictated by the accuracy specifications of the user's end product. Table IV gives the equivalent ohms per count for various full-scale ranges to allow users to judge the required resistor accuracy.

Table IV. Reference Resistors

Full-Scale Range (Ω)	Reference Resistor	Ω/Count
200	163.85	0.1
2k	1638.5	1
20k	16385	10
200k	163,850	100
2M	1,638,500	1000

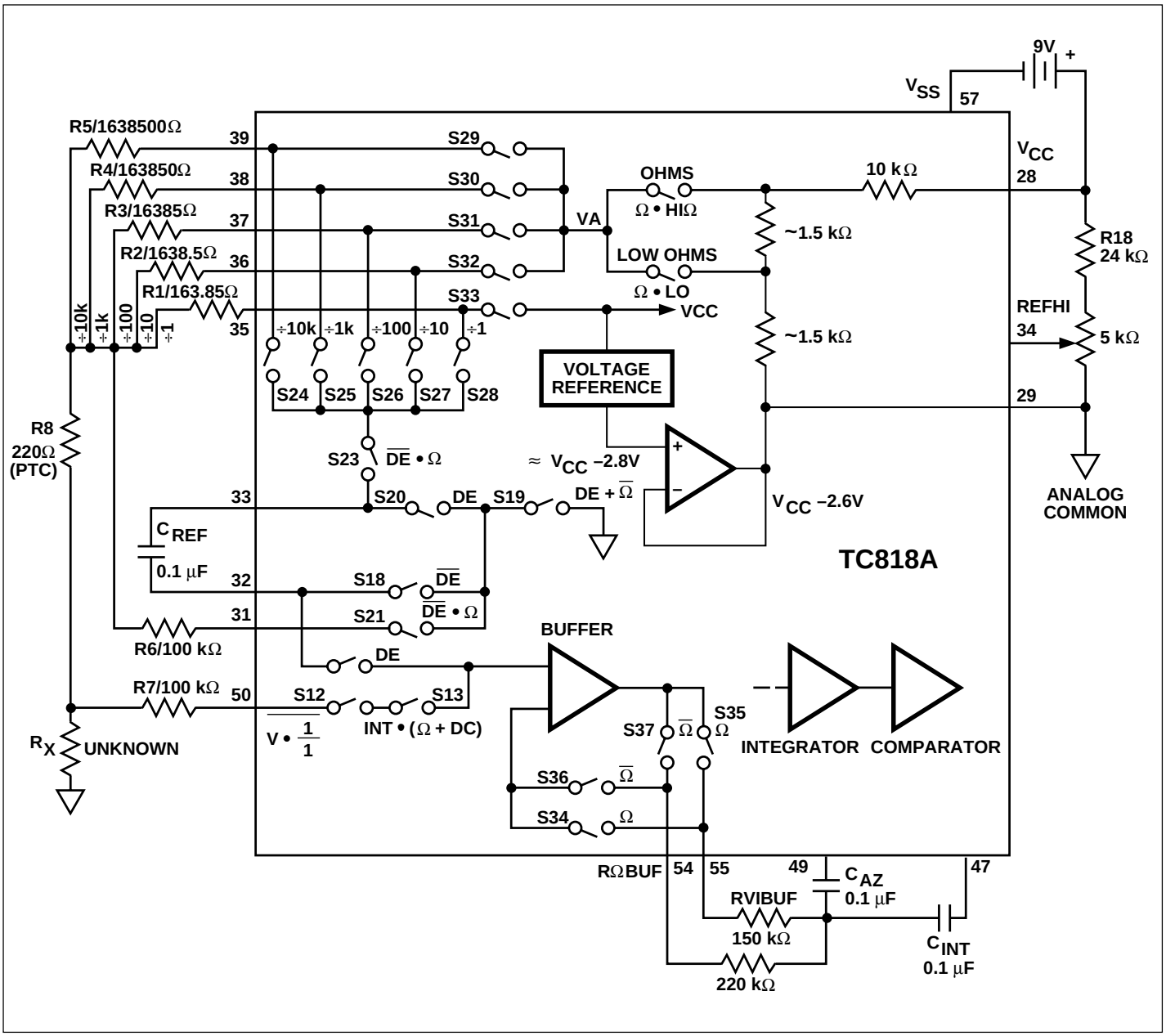
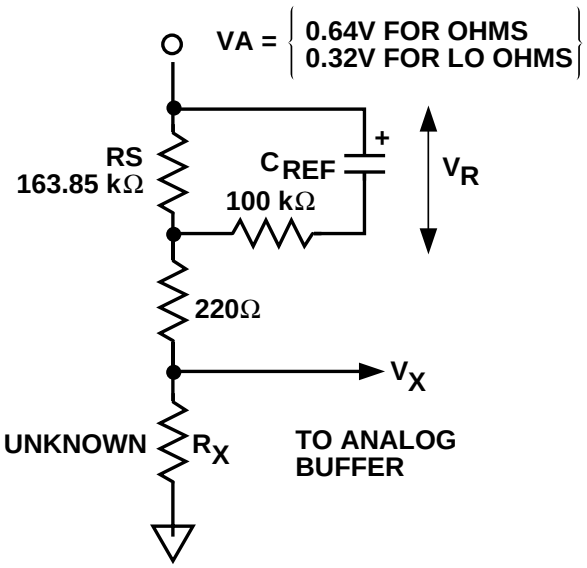


Figure 3. Ratiometric Resistance Measurement Functional Diagram



Example: 200kΩ Full-Scale Measurement

(a) $V_R = \frac{163.85k\Omega}{163.85 + 220 + R_X} \times 0.64$

(b) $V_X = \frac{R_X}{163.85\ k\Omega + 220\Omega + R_X} \times 0.64$

(c) "Ramp-Up Voltage" = "Ramp-Down Voltage"

$$\therefore \frac{V_X}{R_I C_I} \times t_I = \frac{V_R}{R_I C_I} t_{DE}$$

where:

R_I = Integrating Resistor, t_I = Integrate Time

C_I = Integrating Capacitor, t_{DE} = Deintegrate Time

(d) $R_X = 163.85 \left(\frac{t_{DE}}{t_I} \right)$

Independent of R_I, C_I or internal voltage reference.

Figure 4. Resistance Measurement Accuracy Set by External Standard Resistor

Voltage Measurement

Resistive dividers are automatically changed to provide in-range readings for 200mV to 2000V full-scale readings (Figure 1). The input resistance is set by external resistors R14/R13. The divider leg resistors are R9–R12. The divider leg resistors give a 200mV signal at V_I (pin 44) for full-scale voltages from 200mV to 2000V.

For applications that do not require a 10MΩ input impedance, the divider network impedances may be lowered. This will reduce voltage offset errors induced by switch leakage currents.

Current Measurement

The TC818A measures current only under manual range operation. The two user-selectable, full-scale ranges are 20mA and 200mA. Select the current measurement mode by holding the $\overline{I}$ input (pin 63) LOW at digital ground potential. The $\overline{OHM}$ input (pin 2) is left floating or tied to the positive supply.

Two ranges are possible. The 200mA full-scale range is selected by connecting the 20mA input (pin 3) to digital ground. If left floating, the 200mA full-scale range is selected.

External current-to-voltage conversion resistors are used at the current input (I_I, pin 45). For 20mA measurements, a 10Ω resistor is used. The 200mA range requires a 1Ω resistor. Full scale is 200mV

Printed circuit board trace resistance between analog common and R16 must be minimized. In the 200mA range, for example, a 0.05Ω trace resistance causes a 5% current-to-voltage conversion error at I_I (pin 45).

The extended resolution measurement option operates during current measurements.

To minimize roll-over error, the potential difference between ANALOG COM (pin 29) and system common must be minimized.

AC-to-DC Measurements

In voltage and current measurements, the TC818A can be configured for AC measurements. An on-chip operational amplifier and external rectifier components perform the AC-to-DC conversion.

When power is first applied, the TC818A enters the DC measurement mode. For AC measurements (current or voltage), AC/DC (pin 62) is momentarily brought LOW to digital ground potential; the TC818A sets-up for AC measurements and the AC liquid crystal display annunciator activates. Toggling AC/DC to LOW again returns the TC818A to DC operation.

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If manual operating mode has been selected, toggling AC/DC resets the TC818A back to auto-range mode. In manual mode operation, AC or DC should be selected first, then the desired range.

The minimum AC full-scale voltage range is 2V. The DC full-scale minimum voltage is 200mV.

AC current measurements are available on the 20 mA and 200mA full-scale ranges.

Conversion Timing

The TC818A uses the conventional dual-slope integrating conversion technique with an added phase that automatically eliminates zero offset errors. The TC818A gives a zero reading with a 0V input.

This device is designed to operate with a low-cost, readily-available 32.768kHz crystal. It serves as a time-base oscillator crystal in many digital clocks. (See external crystal sources, page 16.)

The external clock is divided by two. The internal clock frequency is 16.348 kHz, giving a clock period of 61.04 µsec. The total conversion — auto-zero phase, signal integrate, and reference deintegrate — requires 8000 clock periods (or 488.3mecs). There are approximately two complete conversions per second.

The integration time is fixed at 1638.5 clock periods (or 100msec), giving a rejection of 50/60Hz AC line noise.

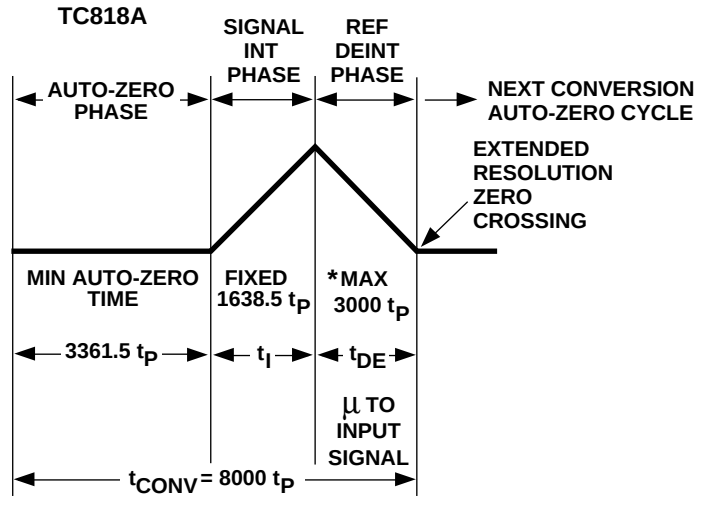
The maximum reference deintegrate time, representing a full-scale analog input, is 3000 clock periods (or 183.1 msec) during manual extended resolution operation. The 3000 counts are available in manual mode, extended resolution operation only. In auto-ranging mode, the maximum dein-tegrate time is 2000 clock periods. The 1000 clock periods are added to the auto-zero phase. An auto-ranging or manual conversion takes 8000 clock periods. After a zero crossing is detected in the reference deintegrate mode, the auto-zero phase is entered.

Figure 5 shows the basic TC818A timing relationships.

Manual Range Selection

The TC818A's voltage and resistance auto-ranging feature can be disabled by momentarily bringing $\overline{\text{RANGE}}$ (pin 59) to digital ground potential (pin 58). When the change from auto to manual ranging occurs, the first manual range selected is the last range in the auto-ranging mode.

The TC818A's power-up circuit initially selects auto-range operation. Once the manual-range option is entered, range changes are made by momentarily grounding the $\overline{\text{RANGE}}$ control input. The TC818A remains in the manual-range mode until the measurement function (voltage or resistance) or measurement option (AC/DC, $\Omega/\overline{\text{LO}\Omega}$) changes, causing the TC818A to return to auto-ranging operation.



External Crystal = 32.768 kHz

Internal Clock Period = t_P = 2/32.768 = 61.04µsec

Total Conversion Time = t_{CONV} = 8000 (t_P)
= 488.3msec ≈ 2 conv/sec

Integration Time = t_I = 1638.5 (t_P) = 100 msec

Maximum Reference Deintegrate Time
= t_{DE} = 3000 (t_P) = 183.1msec (manual, extended resolution)
= 2000 (t_P) = 122.1mse c (auto-range)

Minimum Auto-Zero Time
= (8000 – 3000 – 1638.5) (t_P) = 205.1msec (manual, extended resolution)
= (8000–2000 –1638.5) (t_P) = 266.2msec (auto-range)

Figure 5. Basic TC818A Conversion Timing

The "Auto" LCD annunciator driver is active only in the auto-range mode.

Figure 6 shows typical operation where the manual range selection option is used. Also shown is the extended resolution display format.

Extended Resolution Manual Operation

When operated in the manual-range mode, the TC818A extends resolution by 50% for current, voltage, and resistance measurements. Resolution increases to 3000 counts from 2000 counts. The extended resolution feature operates only in the 2000kΩ and 2000V ranges during auto-range operation.

In the extended resolution operating mode, readings above 1999 are displayed with a blinking "1" most significant digit. The blinking "1" should be interpreted as the digit 2. The three least significant digits display data normally. The bar-graph LCD will be fully extended.

An input overrange condition causes the most significant digit (MSD) to blink and sets the three least significant digits (LSDs) to display "000." The buzzer output is enabled for input voltage and current signals with readings greater than 2000 counts in both manual- and auto-range operations.

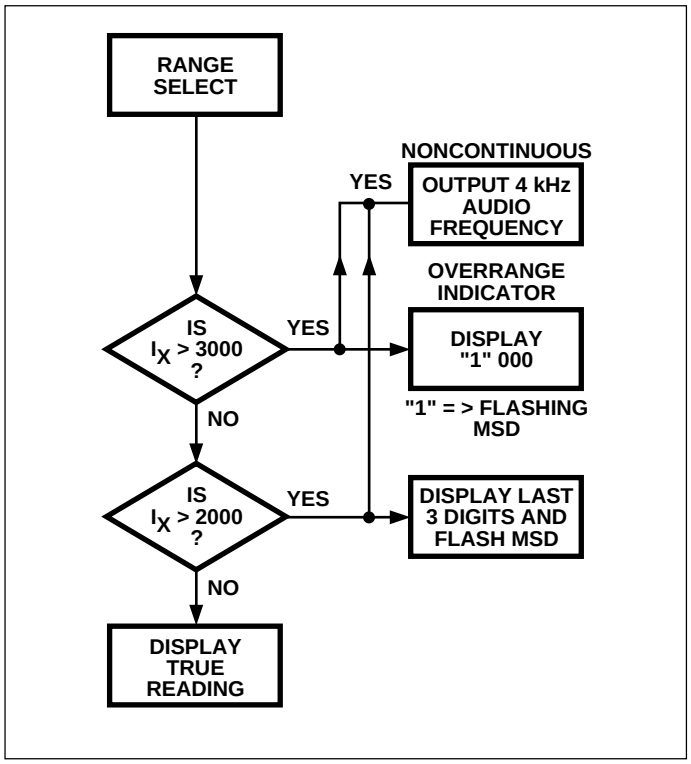


Figure 7. Manual Range Selection; Current Measurement

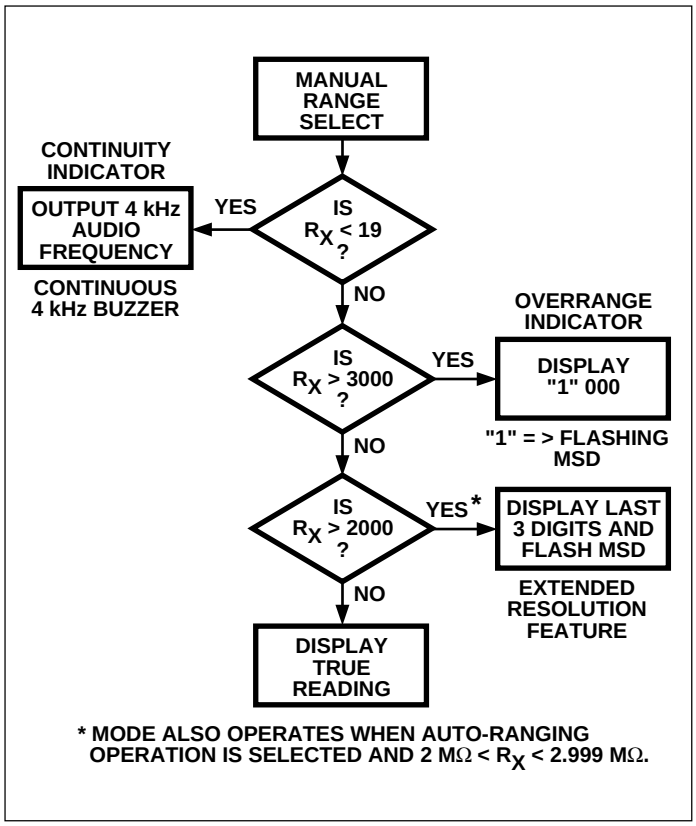


Figure 6. Manual Range Selection; Resistance Measurement

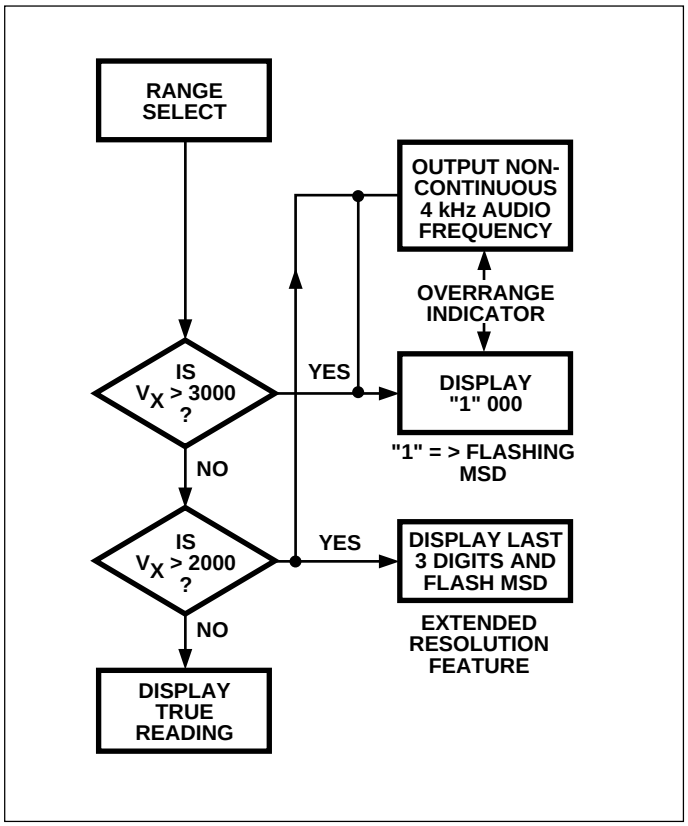


Figure 8. Manual Range Selection; Voltage Measurement

For resistance measurements, the buzzer signal does not indicate an overrange condition. The buzzer is used to indicate continuity. Continuity is defined as a resistance reading less than 19 counts.

–MEM Operating Mode

Bringing –MEM (Pin 61) momentarily LOW configures the "–MEM" operating mode. The –MEM LCD annunciator becomes active. In this operating mode subsequent measurements are made relative to the last two digits (≤ 99) displayed at the time MEM is LOW. This represents 5% of full-scale. The last two significant digits are stored and subtracted from all the following input conversions.

A few examples clarify operation:

Example 1: *In Auto-Ranging*

R_I (N) = 18.21kΩ (20 kΩ Range) ≥ Display 18.21kΩ
MEM ≥ Store 0.21kΩ

R_I (N + 1) = 19.87kΩ (20kΩ Range)
≥ Display 19.87 – 0.21 = 19.66 kΩ

R_I (N + 2) = 22.65kΩ (200 kΩ Range)
≥ Display 22.7kΩ and MEM Disappears

Example 2: *In Fixed Range 200Full Scale*

R_I (N) = 18.2Ω ≥ Display 18.2Ω
MEM ≥ Store 8.2Ω

R_I (N + 1) = 36.7Ω
≥ Display 36.7 – 8.2 = 28.5Ω

R_I (N + 2) = 5.8Ω
≥ Display 5.8 – 8.2 = –2.4Ω*

*Will display minus resistance if following input is less than offset stored at fixed range.

Example 3: *In Fixed Range 20V Full Scale*

V_I (N) = 0.51V ≥ Display 0.51V
MEM ≥ Store 0.51V

V_I (N + 1) = 3.68V
≥ Display 3.68 – 0.51 = 3.17V

V_I (N + 2) = 0.23V
≥ Display 0.23 – 0.51 = –0.28V

V_I (N + 3) = –5.21V
≥ Display –5.21 – 0.51 = –5.72V

On power-up the, –MEM mode is not active. Once the –MEM is entered, bringing MEM to LOW again returns the TC818A to normal operation.

The –MEM mode is also cancelled whenever the measurement type (resistance, voltage, current, AC/DC, Ω/$\overline{\text{LO}}$Ω) or range is changed. The LCD –MEM annunciator will be OFF in normal operation.

In auto-range operation, if the following input signal cannot be converted on the same range as the stored value, the – MEM mode is cancelled. The LCD annunciator is turned OFF.

The – MEM operating mode can be very useful in resistance measurements where lead length resistance would cause measurement errors.

Automatic Range Selection Operation

When power is first applied, the TC818A enters the auto-range operating state. The auto-range mode may be entered from manual mode by changing the measurement function (resistance or voltage) or by changing the measurement option (AC/DC, Ω/$\overline{\text{LO}}$Ω).

The automatic voltage range selection begins on the most sensitive scale first: 200 mV for DC or 2V for AC measurements. The voltage range selection flow chart is given in Figure 9.

Internal input protection diodes to V_{CC} (pin 28) and V_{SS} (pin 57) clamp the input voltage. The external 10MΩ input resistance (see R14 and R13, Functional Diagram) limits current safely in an overrange condition.

The voltage range selection is designed to maximize resolution. For input signals less than 9% of full scale (count reading <180), the next most sensitive range is selected.

An overrange voltage input condition is flagged, whenever the internal count exceeds 2000, by activating the buzzer output (pin 4). This 4kHz signal can directly drive a piezoelectric acoustic transducer. An out-of-range input signal causes the 4 kHz signal to be on for 122msec, off for 122msec, on for 122msec, and off for 610 msec (see Figure 15).

During voltage auto-range operation, the extended resolution feature operates on the 2000V range only. (See extended resolution operating mode discussion.)

The resistance auto-range selection procedure is shown in Figure 10. The 200Ω range is the first range selected unless the low ohms resistance measurement option is selected. In low ohms operation, the first full-scale range tried is 2kΩ.

The resistance range selected maximizes sensitivity. If the conversion results in a reading less than 180, the next most sensitive full-scale range is tried.

If the conversion is less than 19 in auto-range operation, a continuous 4kHz signal is output at BUZ (pin 4). An overrange input does not activate the buzzer.

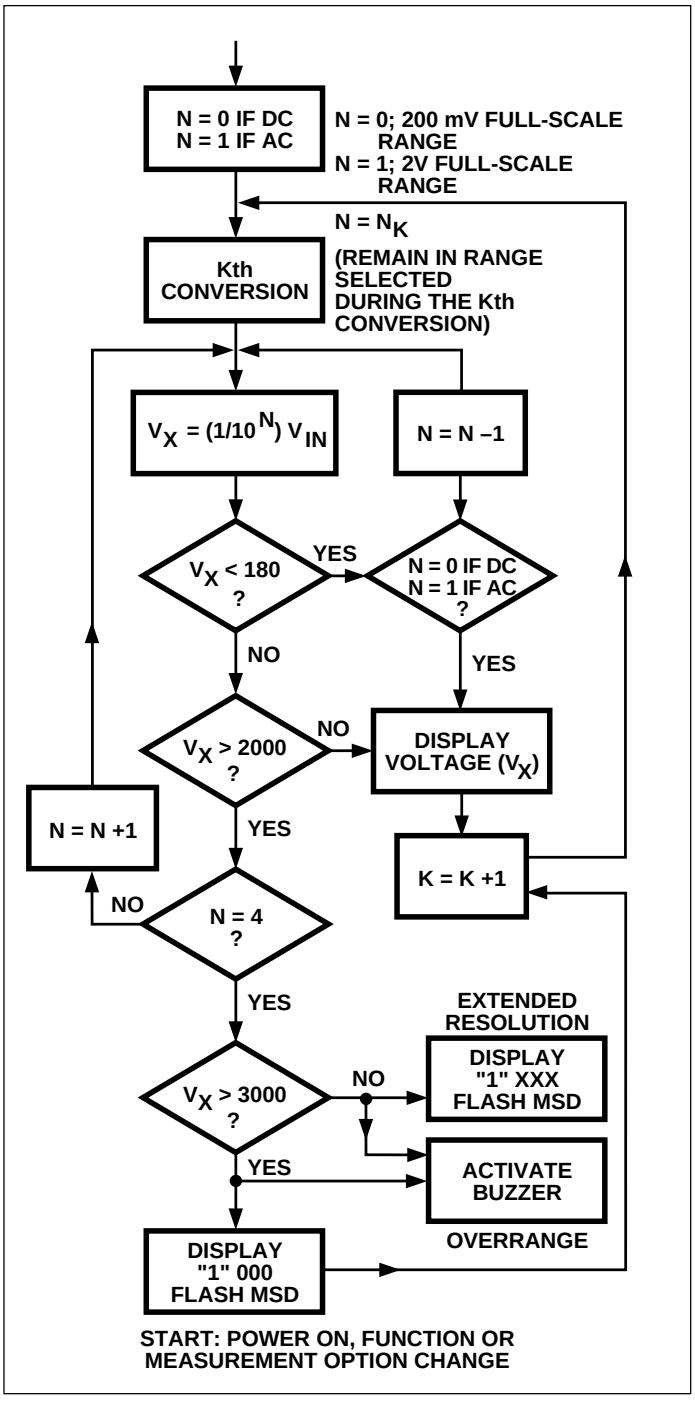


Figure 9. Auto-Range Operation; Voltage Measurement

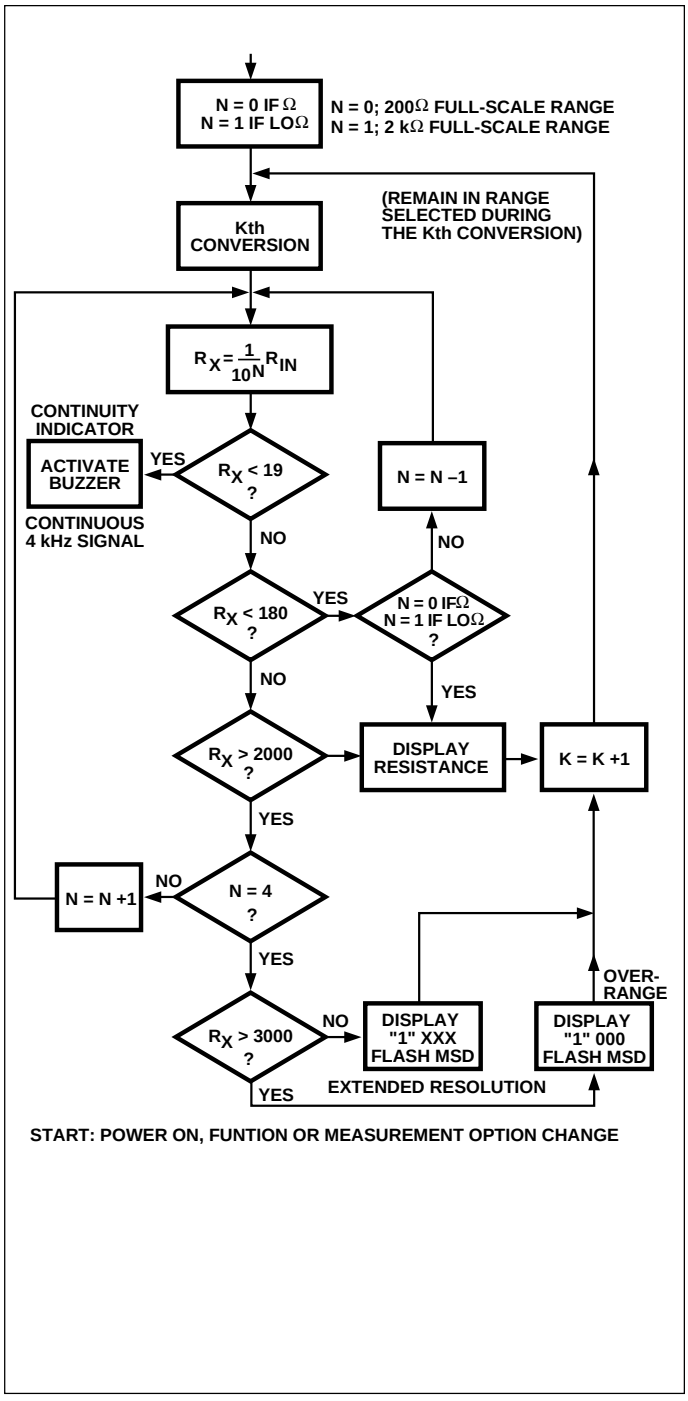


Figure 10. Auto-Range Operation; Resistance Measurement

Out-of-range input conditions are displayed by a blinking MSD with the three LSDs set to "000," and by the fully extended bar-graph.

The extended resolution feature operates only on the 200kΩ and 2000V full-scale ranges during auto-range operation. A blinking "1" most significant digit is interpreted as the digit 2. The three LSDs display data normally.

TC818A

Low-Battery Detection Circuit

The TC818A contains a low-battery detector. When the 9V battery supply has been depleted to a 7V nominal value, the LCD low-battery annunciator is activated.

The low-battery detector is shown in Figure 11. The low-battery annunciator is guaranteed to remain OFF with the battery supply greater than 7V. The annunciator is guaranteed to be ON before the supply battery has reached 6.3V.

Triplex Liquid Crystal Display (LCD) Drive

The TC818A directly drives a triplexed LCD using 1/3 bias drive. All numeric data, decimal point, polarity, and function annunciator drive signals are developed by the TC818A.

The LCDs must be driven with an AC signal having a zero DC component, for long display life. The liquid crystal polarization is a function of the RMS voltage appearing across the backplane and segment driver. The peak drive signal applied to the LCD is:

$V_{CC} - V_{DISP}$

For example, if V_{DISP} is set at a potential 3V below V_{CC}, the peak drive signal is:

$V_P = V_{CC} - V_{DISP} = 3V$

An "OFF" LCD segment has an RMS voltage of $V_P/3$ across it or 1V. An "ON" segment has a 0.63 V_P signal across it or 1.92V for $V_{CC} - V_{DISP} = 3V$.

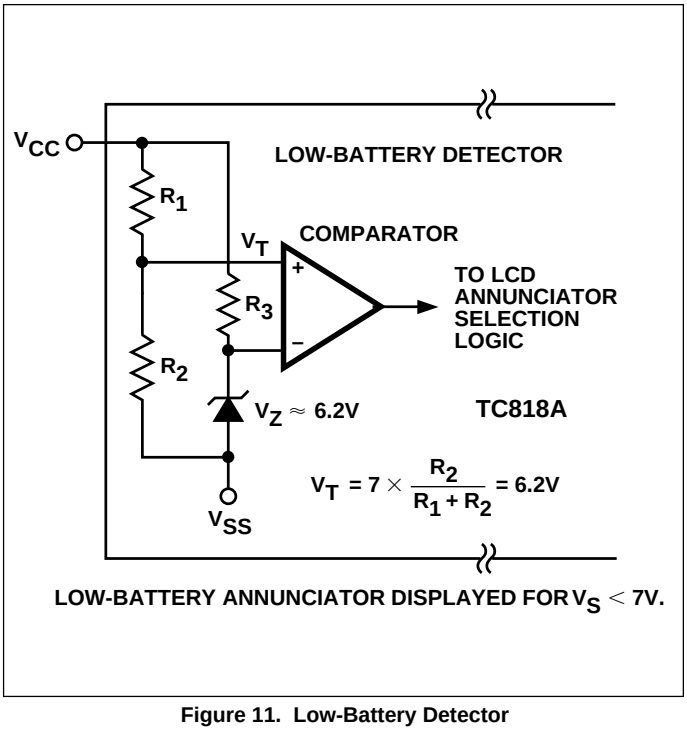


Figure 11. Low-Battery Detector

Since the V_{DISP} pin is available, the user may adjust the "ON" and "OFF" LCD levels for various manufacturer's displays by changing V_P signal across it or 1.92V for $V_{CC} - V_{DISP} = 3V$.

"OFF" segments may become visible at high LCD operating temperatures. A voltage with a –5 to –20 mV/°C temperature coefficient can be applied to V_{DISP} to accommodate the liquid crystal temperature operating characteristics, if necessary.

The TC818A internally generates two intermediate LCD drive potentials (V_H and V_L) from resistive dividers (Figure 12) between V_{CC} and V_{DISP}. The ladder impedance is approximately 150kΩ. This drive method is commonly known as 1/3 bias. With V_{DISP} connected to digital ground, $V_P \approx 5V$.

The intermediate levels are needed so that drive signals giving RMS "ON" and "OFF" levels can be generated. Figure 13 shows a typical drive signal and the resulting waveforms for "ON" and "OFF" RMS voltage levels across a selected numeric LCD element.

Liquid Crystal Displays (LCDs)

Most users design their own custom LCD. However, for prototyping purposes, a standard display is available from Varitronix, Ltd. The prototype display configuration is shown in Figure 14.

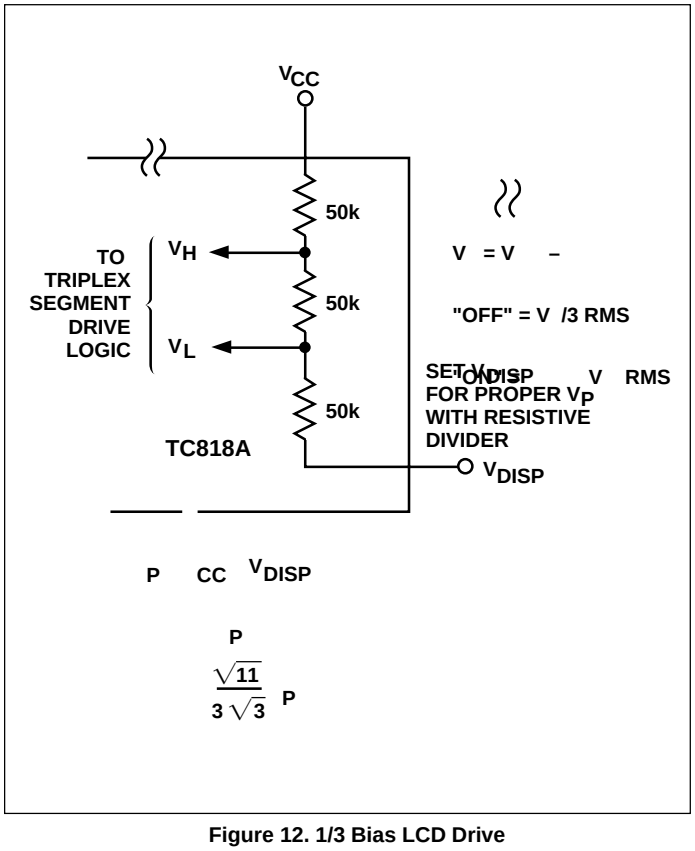


Figure 12. 1/3 Bias LCD Drive

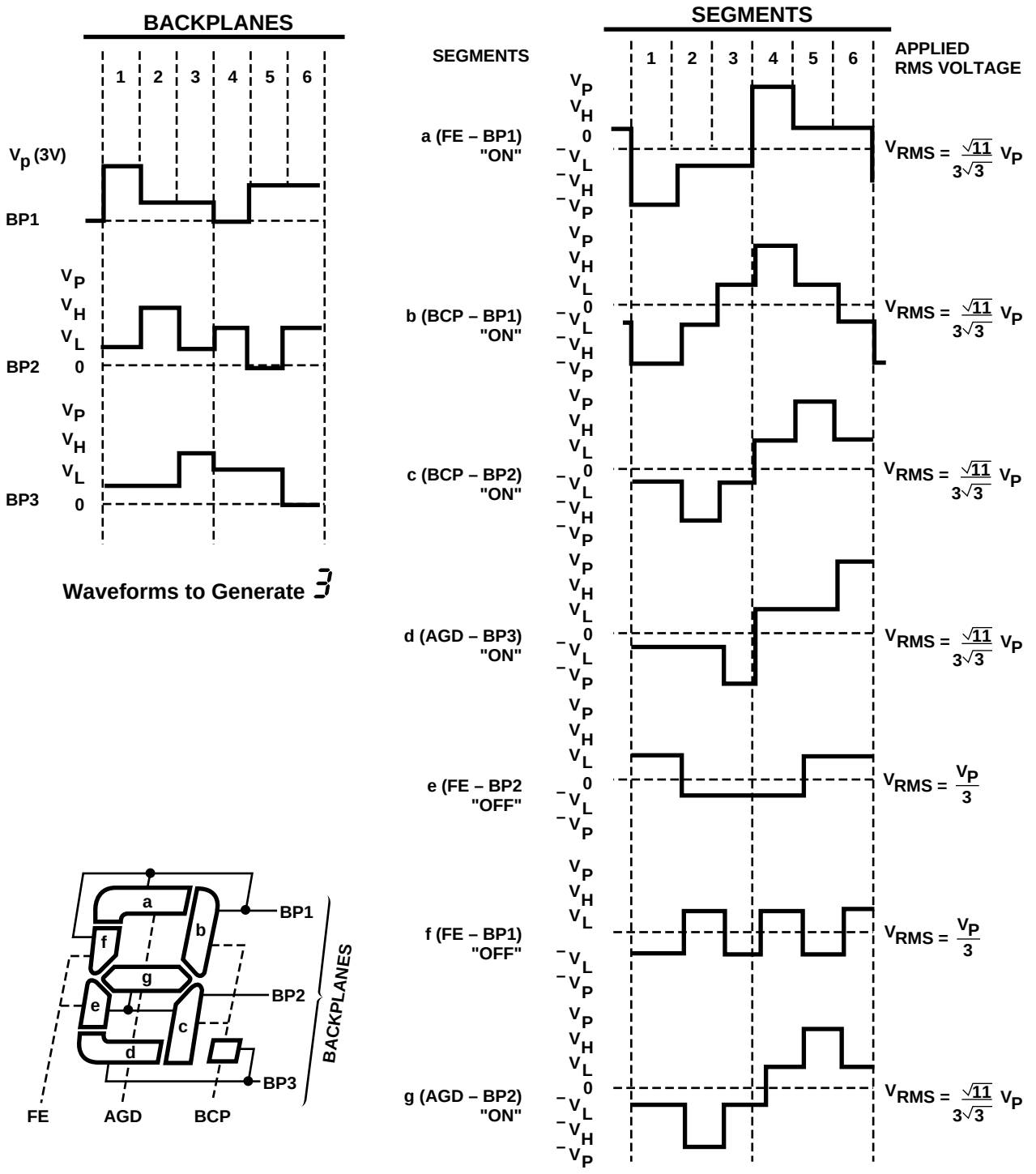


Figure 13. Triplex LCD Drive Waveforms

TC818A

- Varitronix Ltd.
  9/F Liven House, 61-63, King Yip Street
  Kwun Tjong, Hong Kong
  Tel: 3-410286
  Telex: 36643 VTRAX HX
  FAX: 852-3-439555

  Part No. VIM-328-DP

- USA Office:
  VL Electronics Inc.
  3171 Los Feliz Blvd, #303
  Los Angeles, CA 0039
  Tel: (213) 738-8700

External Crystal

The TC818A is designed to operate with a 32,768Hz crystal. This frequency is internally divided by two to give a 61.04µsec clock period. One conversion takes 8000 clock periods or 488.3mecs (≈2 conversions/second). Integration time is 1638.5 clock periods or 100msec.

The 32kHz quartz crystal is readily available and inexpensive. The 32kHz crystal is commonly used in digital clocks and counters.

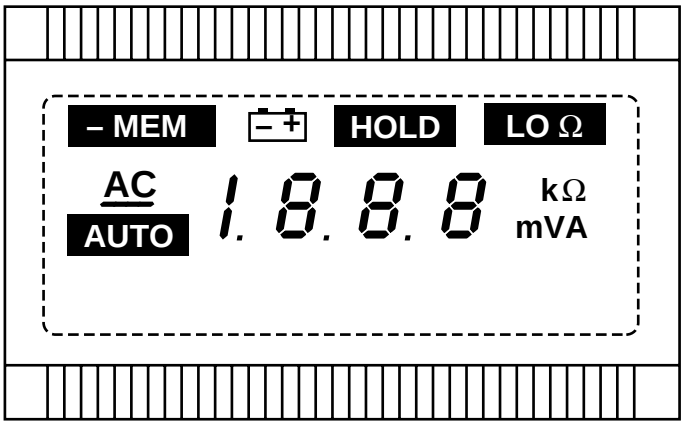
Several crystal sources exist. A partial listing is:

- Statek Corporation
  512 N. Main
  Orange, CA 92668
  (714) 639-7810
  TWX: 910-593-1355
  Telex: 67-8394

- Daiwa Sinku Corporation
  1389, Shinzaike – AZA-Kono
  Hirakacho, Kakogawa Hyogo, Japan
  Tel: 0794-26-3211

- International Piezo LTD
  24-26 Sze Shan Street
  Yau Ton, Hong Kong
  TLX: 35454 XTAL HZ
  Tel: 3-3501151

Contact manufacturer for full specifications.



PAD	BP1	BP2	BP3	PAD	BP1	BP2	BP3
1	—	—	SCALE	19	—	—	BP3
2	X0	X1	X2	20	—	BP2	—
3	X5	X4	X3	21	BP1	—	—
4	X6	X7	X8	22	—	LOW	A
5	X11	X10	X9	23	—	W	V
6	X12	X13	X14	24	HOLD	k	m
7	X17	X16	X15	25	4B	4C	—
8	X18	X19	X20	26	4A	4G	4D
9	X23	X22	X21	27	4F	4E	—
10	X24	X25	X26	28	3B	3C	3P
11	X29	X28	X27	29	3A	3G	3D
12	X30	X31	X32	30	3F	3E	—
13	X35	X34	X33	31	2B	2C	2P
14	X36	X37	X38	32	2A	2G	2D
15	—	X40	X39	33	2A	2G	2D
16	BP1	—	—	34	1B	1C	1P
17	—	BP2	—	35	Z	–MEM	—
18	—	—	BP3	36	AC	y	AUTO

Figure 14. Typical LCD Configuration, TC818A Triplex

"Buzzer" Drive Signal

The BUZ output (pin 4) will drive a piezoelectric audio transducer. The signal is activated to indicate an input overrange condition for current and voltage measurements or continuity during resistance measurements.

During a resistance measurement, a reading less than 19 on any full-scale range causes a continuous 4 kHz signal to be output. This is used as a continuity indication.

A voltage or current input measurement overrange is indicated by a noncontinuous 4kHz signal at the BUZ output. The LCD most significant digit also flashes and the three least significant digits are set to display zero. The buzzer drive signal for overrange is shown in Figure 15. The BUZ output is active for any reading over 2000 counts in both manual and auto-range operation. The buzzer is activated during an extended resolution measurement.

The BUZ signal swings from V_{CC} (pin 28) to DGND (pin 58). The signal is at V_{CC} when not active.

The BUZ output is also activated for 15 ms whenever a range change is made in auto-range or manual operation. Changing the type of measurement (voltage, current, or resistance), or measurement option (AC/DC, Ω/LOΩ), also activates the buzzer output for 15msec. A range change during a current measurement will not activate the buzzer output.

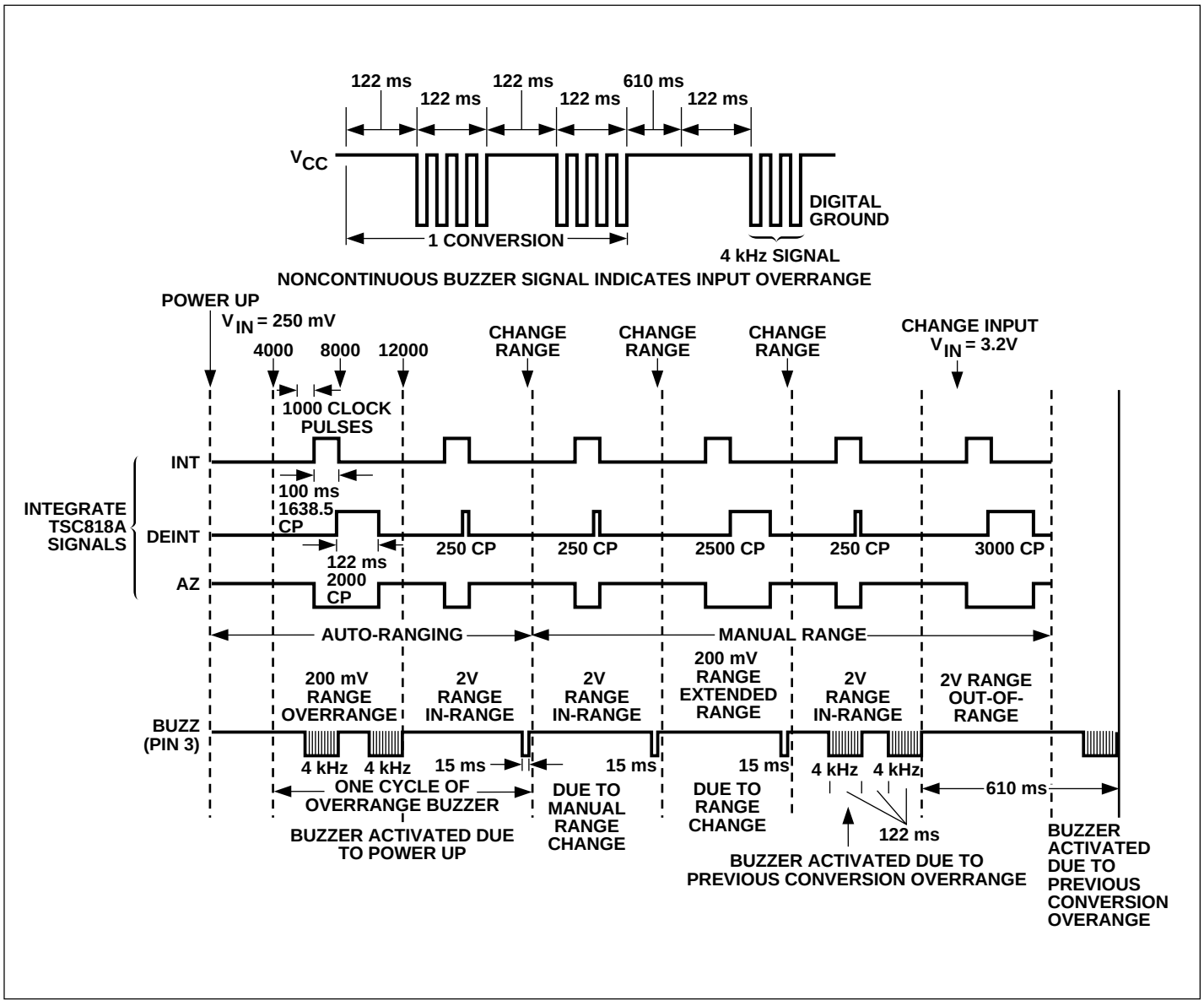


Figure 15. TC818A Timing Waveform for Buzzer Output

Vendors for piezoelectric audio transducers are:

- Gulton Industries
  Piezo Products Division
  212 Durham Avenue
  Metuchen, New Jersey 08840
  (201) 548-2800
  Typical P/Ns: 102-95NS, 101-FB-00
- Taiyo Yuden (USA) Inc.
  Arlington Center
  714 West Algonquin Road
  Arlington Heights, Illinois 60005
  Typical P/Ns: CB27BB, CB20BB, CB355BB

Display Decimal Point Selection

The TC818A provides a decimal point LCD drive signal. The decimal point position is a function of the selected full-scale range, as shown in Table V.

Table V. Decimal Point Selection

	1 * 9 * 9 * 9		
Full-Scale Range	**DP3**	**DP2**	**DP1**
2000V, 2000 kΩ	OFF	OFF	OFF
200V, 200 kΩ	OFF	OFF	ON
20V, 20 kΩ	OFF	ON	OFF
2V, 2 kΩ	ON	OFF	OFF
200V, 200Ω	OFF	OFF	ON
200 mV, 200Ω	OFF	OFF	ON
20 mA	OFF	ON	OFF
200 mA	OFF	OFF	ON

AC-to-DC Converter Operational Amplifier

The TC818A contains an on-chip operational amplifier that may be connected as a rectifier for AC-to-DC voltage and current measurements. Typical operational amplifier characteristics are:

- Slew Rate: 1 V/µsec
- Unity-Gain Bandwidth: 0.4MHz
- Open-Loop Gain: 44dB
- Output Voltage Swing (Load = 10 kΩ) ±1.5V (Referenced to Analog Common)

When the AC measurement option is selected, the input buffer receives an input signal through switch S14 rather than switch S11 (see Figure 1). With external circuits, the AC operating mode can be used to perform other types of functions within the constraints of the internal operational amplifier. External circuits that perform true RMS conversion or a peak hold function are typical examples.

Component Selection

Integration Resistor Selection

The TC818A automatically selects one of two external integration resistors. RVIBUF (pin 55) is selected for voltage and current measurement. RΩBUF (pin 54) is selected for resistance measurements.

RVIBUF Selection (Pin 55)

In auto-range operation, the TC818A operates with a 200mV maximum full-scale potential at V_I (pin 44). Resistive dividers at VR2 (pin 41), VR3 (pin 40), VR4 (pin 43), and VR5 (pin 42) are automatically switched to maintain the 200mV full-scale potential.

In manual mode, the extended operating mode is activated giving a 300mV full-scale potential at V_I (pin 44).

The integrator output swing should be maximized, but saturations must be avoided. The integrator will swing within 0.45V of V_{CC} (pin 28) and 0.5V of V_{SS} (pin 57) without saturating. A ±2V swing is suggested. The value of RVIBUF is easily calculated, assuming a worst-case extended resolution input signal:

$$RVIBUF = \frac{V_{MAX}\ (t_I)}{V_{INT}\ (C_I)} \approx 150k\Omega$$

where:

V_{INT} = Integrator swing = ±2V
t_I = Integration time = 100 msec
C_I = Integration capacitor = 0.1µF
V_{MAX} = Maximum input at V_I = 300mV

RWBUF Selection (Pin 51)

In ratiometric resistance measurements, the signal at R_X (pin 50) is always positive with respect to analog common. The integrator swings negative.

The worst-case integrator swing is for the 200Ω range with the manual, extended resolution option.

The input voltage, V_X (pin 50) is easily calculated (Figure 16):

$$R\Omega BUF = \frac{(V_{CC} - V_{ANCOM})\ R_X}{(R_X + R_S + R_1 + R_S)} = 0.63V$$

where:

V_{ANCOM} = Potential at analog common ≈ 2.7V
R_S = 220Ω
R_I = 163.85Ω
R_X = 300Ω
R_S = Internal switch 33 resistance ≈ 600Ω

For a 3.1V integrator swing, the value of RΩBUF is easily calculated:

$$R\Omega BUF = \frac{(V_X\ Max)\ (t_I)}{C_I\ (V_{INT})} \approx 220k\Omega$$

where:

V_{INT} = Integrator swing = 3.1V
t_I = Integration time = 100msec
C_I = Integration capacitor = 0.1µF
R_X Max = 300Ω
V_X Max = 700mV

With a low battery voltage of 6.6V, analog common will be approximately 3.6V above the negative supply terminal. With the integrator swinging down from analog common toward the negative supply, a 3.1V swing will set the integrator output to 0.5V above the negative supply.

Capacitors — C_{INT}, C_{AZ} and C_{REF}

The integration capacitor, C_{INT}, must have low dielectric absorption. A 0.1µF polypropylene capacitor is suggested. The auto-zero capacitor, C_{AZ}, and reference capacitor, C_{REF}, should be selected for low leakage and dielectric absorption. Polystyrene capacitors are good choices.

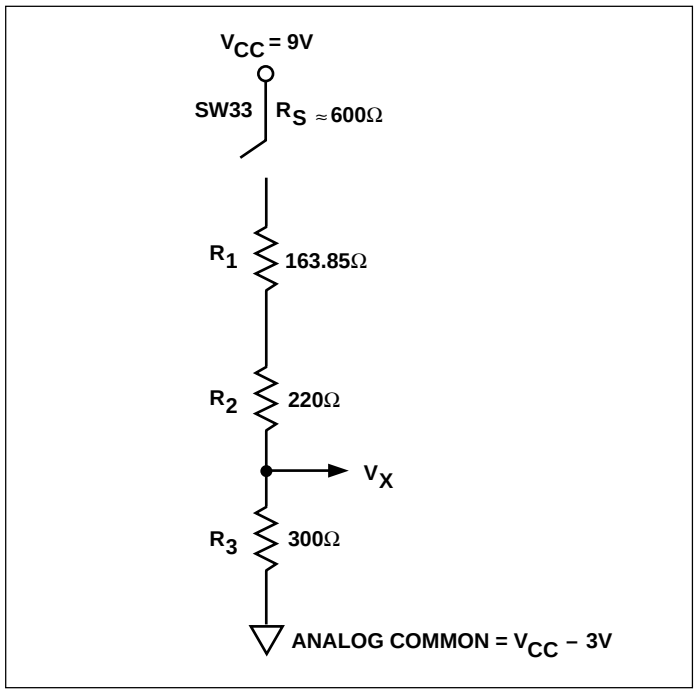


Figure 16. RΩBUF Calculation (200Ω Manual Operation)

Reference Voltage Adjustment

The TC818A contains a low temperature drift internal voltage reference. The analog common potential (pin 29) is established by this reference. Maximum drift is a low 75ppm/°C. Analog common is designed to be approximately 2.6V below V_{CC} (pin 28). A resistive divider (R18/R19, Functional Diagram) sets the TC818A reference input voltage (REFHI, pin 34) to approximately 163.85mV.

With an input voltage near full scale on the 200mV range, R19 is adjusted for the proper reading.

Display Hold Feature

The LCD will not be updated when $\overline{HOLD}$ (pin 60) is connected to GND (pin 58). Conversions are made, but the display is not updated. A $\overline{HOLD}$ mode LCD annunciator is activated when $\overline{HOLD}$ is low.

The LCD $\overline{HOLD}$ annunciator is activated through the triplex LCD driver signal at pin 13.

Flat Package Socket

Sockets suitable for prototype work are available. A USA source is:

- Nepenthe Distribution
  2471 East Bayshore, Suite 520
  Palo Alto, CA 94303
  (415) 856-9332
  TWX: 910-373-2060
  "CBQ" Socket, Part No. IC51-064-042

Resistive Ladder Networks

Resistor attenuator networks for voltage and resistance measurements are available from:

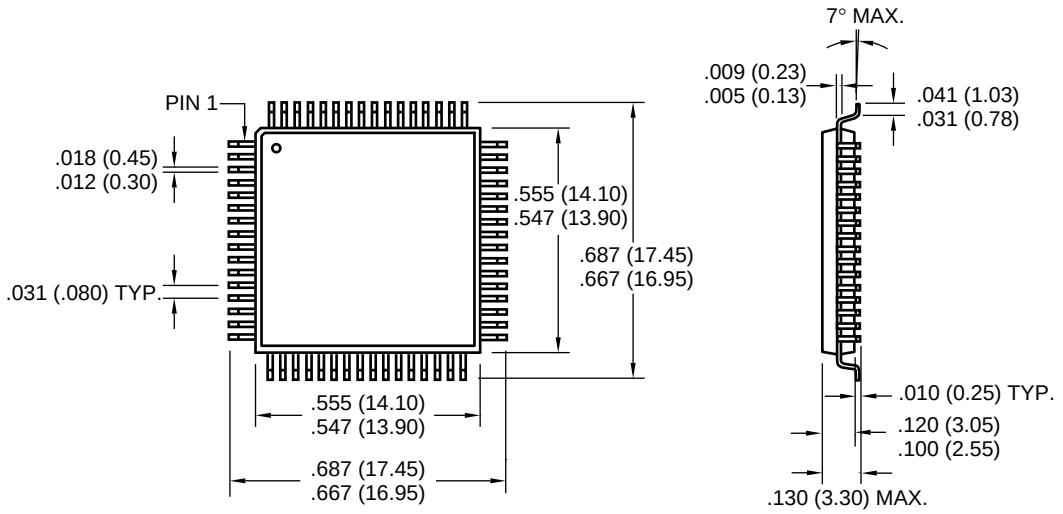
- Caddock Electronics
  1717 Chicago Avenue
  Riverside, CA 92507
  Tel: (714) 788-1700
  TWX: 910-332-6108

Attenuator Accuracy	Attenuator Type	Caddock Part Number
0.1%Voltage	1776-C441	
0.25%Voltage	1776-C44	
0.25%Resistance	T1794-204-1	

TC818A

PACKAGE DIMENSIONS

64-Pin Plastic Quad Package



Dimensions: inches (mm)

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