TC815

3-1/2 Digit Auto-Ranging A/D Converter with Triplex LCD Drive and Display Hold Function

Features

- 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 Mode: 1/3000
- Memory Mode for Relative Measurements:
  - ±5% F.S.
- Internal AC to DC Conversion Op Amp
- Triplex LCD Drive for Decimal Points, Digits and Annunciators
- Continuity Detection and Piezoelectric Transducer Driver
- Compact Surface Mounted 64-pin Plastic Flat Package
- Low Drift Internal Reference: 75ppm/°C
- 9V Battery Operation: 10mW
- Low Battery Detection and LCD Annunciator

Device Selection Table

Part Number	Package	Operating Temperature Range
TC815CBU	64-Pin PQFP	0°C to +70°C

General Description

The TC815 is a 3-1/2 digit integrating analog-to-digital converter with triplex LCD display drive and automatic ranging. A display hold function is on-chip. Input voltage/ohm attenuators ranging from 1 to 1/10,000 are automatically selected. Five full scale ranges are provided. The CMOS TC815 contains all the logic and analog switches needed to manufacture an auto-ranging instrument for ohms and voltage measurements. User selected 20mA and 200mA current ranges are available. Full scale range and decimal point LCD annunciators are automatically set in auto-range operation. Auto-range operation is available during ohms (high and low power ohms) and voltage (AC and DC) measurements, eliminating expensive range switches in hand-held DMM designs. The auto-range feature may be bypassed allowing decimal point selection and input attenuator selection control through a single line input. Expensive rotary switches are not required.

During Manual mode operation, resolution is extended to 3000 counts full scale. The extended range operation is indicated by a flashing 1 MSD. The extended resolution is also available during 200kΩ and 2000V full scale auto-range operation.

The Memory mode subtracts a reading, up to ±5% of full scale from subsequent measurements. Typical applications involve probe resistance compensation for resistance measurements, tolerance measurements, and tare weight measurements.

The TC815 includes an AC to DC converter for AC measurements. Only external diodes/resistors/capacitors are required.

A complete LCD annunciator set describes the TC815 meter function and measurement range during ohms, voltage and current operation. AC measurements are indicated as well as auto-range operation. A low battery detection circuit also sets the low battery display annunciator. The triplex LCD display drive levels may be set and temperature compensation applied via the V_{DISP} pin. With HOLD low, the display is not updated. A HOLD mode LCD annunciator is activated.
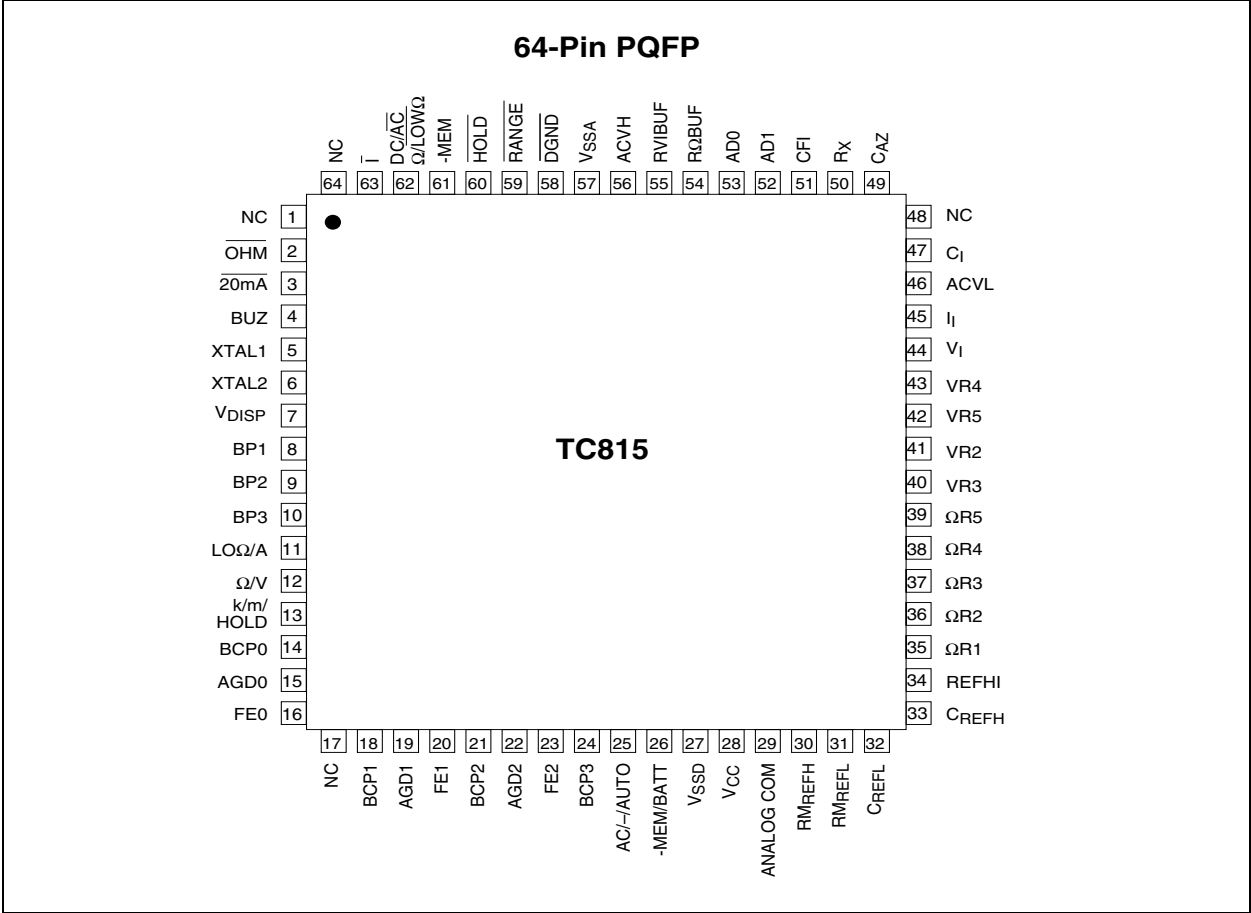
The "low ohms" measurement option allows in-circuit resistance measurements by preventing semiconductor junctions from being forward biased.
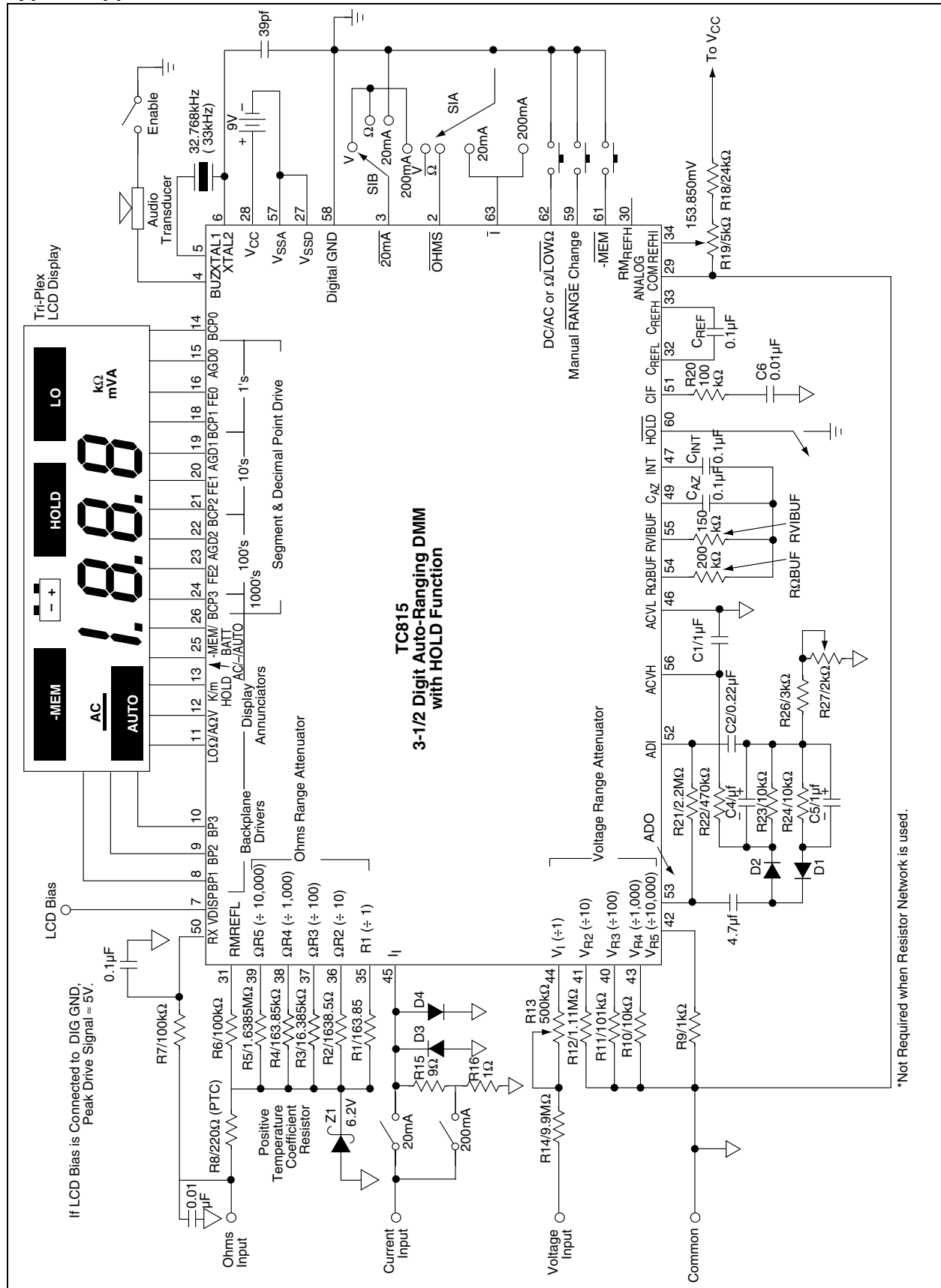
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A continuity buzzer output is activated with inputs less than 1% of full scale. An overrange input signal also enables the buzzer, except during resistance measurements, and flashes the MSD display.

Featuring single 9V battery operation, 10mW power consumption, a precision internal voltage reference (75ppm/°C max TC) and a compact surface mounted 64-pin quad flat package, the TC815 is ideal for portable instruments.

Package Type

64-Pin PQFP

Left side pins (top to bottom):
Pin	Name
1	NC
2	$\overline{OHM}$
3	$\overline{20mA}$
4	BUZ
5	XTAL1
6	XTAL2
7	V_{DISP}
8	BP1
9	BP2
10	BP3
11	LOΩ/A
12	Ω/V
13	k/m/HOLD
14	BCP0
15	AGD0
16	FE0

Top pins (left to right):
Pin	Name
64	NC
63	$\overline{I}$
62	DC/$\overline{AC}$
61	Ω/$\overline{LOWΩ}$
61	-MEM
60	HOLD
59	RANGE
58	DGND
57	V_{SSA}
56	ACVH
55	RVIBUF
54	RΩBUF
53	AD0
52	AD1
51	CFI
50	Rx
49	CAZ

Right side pins (top to bottom):
Pin	Name
48	NC
47	C_I
46	ACVL
45	I_I
44	V_I
43	VR4
42	VR5
41	VR2
40	VR3
39	ΩR5
38	ΩR4
37	ΩR3
36	ΩR2
35	ΩR1
34	REFHI
33	C_{REFH}

Bottom pins (left to right):
Pin	Name
17	NC
18	BCP1
19	AGD1
20	FE1
21	BCP2
22	AGD2
23	FE2
24	BCP3
25	AC/-AUTO
26	-MEM/BATT
27	V_{SSD}
28	V_{CC}
29	ANALOG COM
30	RM_{REFH}
31	RM_{REFL}
32	C_{REFL}

Typical Application and Test Circuit

**TC815
3-1/2 Digit Auto-Ranging DMM
with HOLD Function**

*Not Required when Resistor Network is used.

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1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings*

Supply Voltage (V+ to V–) 15V
Analog Input Voltage (Either Input) .... V+ to V-
Reference Input Voltage................................. V+ to V-
Voltage at Pin 45 .... GND ±0.7V
Power Dissipation ($T_A \leq 70°C$)
   64-Pin Plastic Flat Package 1.14W
Operating Temperature Range:
   Commercial Package (C) .... 0°C to +70°C
Storage Temperature Range .... -65°C to +150°C

*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 operation sections of the specifications is not implied. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability.

TC815 ELECTRICAL SPECIFICATIONS

Electrical Characteristics: V_A = 9V, T_A = +25°C, unless otherwise specified (see Typical Application and Test Circuit Figure).						
Symbol	Parameter	Min	Typ	Max	Unit	Test Conditions
	Zero Input Reading Input Resistor	-0000	0000	+0000	Digital Reading	200mV Range w/o 10MΩ Input
		-0001	—	+0001	Digital Reading	200mV Range w/10MΩ Input
		-0000	0000	+0000	Digital Reading	20mA and 200mA Range
RE	Rollover Error	—	—	±1 Count		200mV Range w/o 10MΩ Input Resistor
		—	—	±3		200mV Range w/10MΩ Input
		—	—	±1		20mA and 200mA Range
NL	Linearity Error	—	—	±1	Count	Best Case Straight Line
I_{IN}	Input Leakage Current	—	—	10	pA	
E_N	Input Noise	—	20	—	μV_{p-p}	BW = 0.1 to 10Hz
	AC Frequency Error	—	±1	—	%	40Hz to 500Hz
		—	±5	—	%	40Hz to 200Hz
	Open Circuit Voltage	—	570	660	mV	Excludes 200Ω Range for OHM Measurements
	Open Circuit Voltage	—	285	350	mV	Excludes 200Ω Range for LO OHM Measurement
V_{COM}	Analog Common Voltage	2.5	2.6	3.3	V	$(V^+ - V_{COM})$
V_{CTC}	Common Voltage Temperature Coefficient	—	—	50	ppm/°C	
	Display Multiplex Rate	—	100	—	Hz	
V_{IL}	Low Logic Input	—	—	1	V	$\overline{20mA}$, $\overline{AC}$, I, $\overline{LOW\ \Omega}$, $\overline{HOLD}$ Range, -MEM, OHMs (Relative to DGND Pin 58)
	Logic 1 Pull-up Current	—	25	—	μA	$\overline{20mA}$, $\overline{AC}$, I, $\overline{LOW\ \Omega}$, $\overline{HOLD}$ Range, -MEM, OHMs (Relative to DGND Pin 58)
	Buzzer Drive Frequency	—	4	—	kHz	
	Low Battery Flag Voltage	6.3	6.6	7.0	V	V_{CC} to V_{SSA}
	Operating Supply Current	—	0.8	1.5	mA	

2.0   PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 2-1.

TABLE 2-1:   PIN FUNCTION TABLE

Pin Number (64-Pin Plastic) Quad Flat Package	Symbol	Description
1	NC	Logic Input. "0" (Digital Ground) for resistance measurement.
2	$\overline{OHM}$	Logic Input. "0" (Digital Ground) for 20mA full scale current measurement.
3	$\overline{20mA}$	Audio frequency, 4kHz, output for continuity indication during resistance measurement.
4	BUZ	Audio frequency, 4kHz, output for continuity indication during resistance measurement. A non-continuous 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_{DD} - 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 ("milliamps" and "millivolts") and HOLD mode.
14	BCP0 (One's 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.
17	NC	No connection.
18	BCP1	LCD segment drive for "b," "c" segments and decimal point of 2nd LSD.
19	AGD1	LCD segment drive for "a," "g," "d" segments of 2nd LSD (Ten's digit).
20	FE1	LCD segment drive for "f" and "e" segments of 2nd LSD.
21	BCP2	LCD segment drive for "b," "c" segments and decimal point of 3rd LSD (Hundred's digit).
22	AGD2	LCD segment drive for "a," "g," "d" segments of 3rd LSD.
23	FE2	LCD segment drive for "b," "c" segments and decimal point of 3rd LSD.
24	BCP3	LCD segment drive for "b," "c" segments and decimal point of MSD (Thousand's digit).
25	AC/-/AUTO	LCD annunciator drive signal for AC measurements, polarity, and auto-range operation.
26	-MEM/BATT	LCD annunciator drive signal for low battery indication and Memory (Relative Measurement) mode.
27	V_{SSD}	Negative battery supply connection for internal digital circuits. Connect to negative terminal of battery.
28	V_{CC}	Positive battery supply connection.
29	ANALOG COM	Analog circuit ground reference point. Nominally 2.6V below V_{CC}.
30	RM_{REFH}	Ratiometric (Resistance measurement) reference high voltage.
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.

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TABLE 2-1: **PIN FUNCTION TABLE (CONTINUED)**

Pin Number (64-Pin Plastic) Quad Flat Package	Symbol	Description
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 range.
38	ΩR4	Standard resistor connection for 200kΩ full scale range.
39	ΩR5	Standard resistor connection for 2000kΩ full scale range.
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 ÷ 1 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. (Low dielectric absorption. Polypropylene dielectrics suggested.)
48	NC	No connection.
49	C_{AZ}	Auto-zero capacitor connection; nominally 0.1µf.
50	R_X	Unknown resistance input.
51	CFI	Input filter connection.
52	AD1	Negative input of internal AC to DC operational amplifier.
53	AD0	Output of internal AC to DC operational amplifier.
54	RΩBUF	Active buffer output for resistance measurement. Integration resistor connection. Integrator resistor nominally 220kΩ.
55	RVIBUF	Active buffer output for voltage and current measurement. Integration resistor connection. Integration resistor nominally 150kΩ.
56	ACVH	Positive output of AC to DC converter.
57	V_{SSA}	Negative supply connection for analog circuits. Connect to negative terminal of 9V battery.
58	$\overline{DGND}$	Internal logic digital ground. The logic "0" level. Nominally 4.7V below V_{CC}.
59	$\overline{RANGE}$	Input to set manual operation and change ranges.
60	$\overline{HOLD}$	Input to hold display. Connect to DIG GND.
61	-MEM	Input to enter Memory Measurement mode for relative measurements. The two LSD's are stored and subtracted from future measurements.
62	DS/$\overline{AC}$ Ω/$\overline{LOW\Omega}$	Input that selects AC or DC option during voltage/current measurements. For resistance measurements, Ω/$\overline{LOW\Omega}$, the ohms or low power (voltage) ohms option can be selected.
63	$\overline{I}$	Input to select current measurement. Set to logic "0" (Digital ground) for current measurement
64	NC	No connection.

3.0   DETAILED DESCRIPTION

3.1   Resistance, Voltage, Current Measurement Selection

The TC815 is designed to measure voltage, current, and resistance. Auto-ranging is available for resistance and voltage measurements. The $\overline{\text{OHMS}}$ (Pin 2) and $\bar{\text{I}}$ (Pin 63) input controls are normally pulled internally to V_{CC}. By tying these pins to Digital Ground (Pin 58), the TC815 is configured internally to measure resistance, voltage, or current. The required signal combinations are shown in Table 3-1.

TABLE 3-1:   MEASUREMENT SELECTION LOGIC

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

Note 1: 0 = Digital Ground
2: 1 = Floating or Tied to V_{CC}
3: $\overline{\text{OHM}}$ and $\bar{\text{I}}$ are normally pulled internally high to V_{CC} (Pin 28). This is considered a logic "1."
4: Logic "0" is the potential at digital ground (Pin 58).

3.2   Resistance Measurements (Ohms and Low Power Ohms)

The TC815 can be configured to reliably measure in-circuit resistances shunted by semiconductor junctions. The TC815 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 $\Omega/\overline{\text{LOW}\Omega}$ (Pin 62) input selects the Low Power Ohms Measurement mode. For low power ohms measurements, $\Omega/\overline{\text{LOW}\Omega}$ (Pin 62) is momentarily brought low to digital ground potential. The TC815 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 display annunciator, $\overline{\text{LOW}\Omega}$, will be activated. On power-up, the Low Power Ohms mode is not active.

If the Manual mode has been selected, toggling $\Omega/\overline{\text{LOW}\Omega}$ will reset the TC815 back to the 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 100Ω full scale range. Open circuit voltage on this range is below 2.8V. The standard resistance values are listed in Table 3-2.

R8, a positive temperature coefficient resistor, and the 6.2V zener Z1 in Figure 3-1, provide input voltage protection during ohms measurements.

TABLE 3-2:   OHMS RANGE LADDER NETWORK

Full Scale Range	Standard Resistance	Low Power Ohms Mode
200Ω	163.85 Ω (R1)	NO
2000Ω	1638.5 kΩ (R2)	YES
20kΩ	16,385Ω (R3)	YES
200kΩ	16385Ω (R4)	YES
2,000kΩ	1,638,500Ω (R5)	YES

3.3   Ratiometric Resistance Measurements

The TC815 measures resistance ratiometrically. Accuracy is set by the external standard resistors connected to Pin 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 3-1 shows a detailed block diagram of the TC815 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 3-2 shows the conversion accuracy relies on the accuracy of the external standard resistors only.

Normally the required accuracy of the standard resistances will be dictated by the accuracy specifications of the users end product. Table 3-3 gives the equivalent ohms per count for various full scale ranges to allow users to judge the required resistor for accuracy.

TABLE 3-3:   REFERENCE RESISTORS

Full Scale Range	Reference Resistor	Ω/Count
200k	163.85	0.1
2k	1638.5	1
20k	16385	10
200k	163850	100
2M	1638500	1000

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FIGURE 3-1: **RATIOMETRIC RESISTANCE MEASUREMENT FUNCTIONAL DIAGRAM**
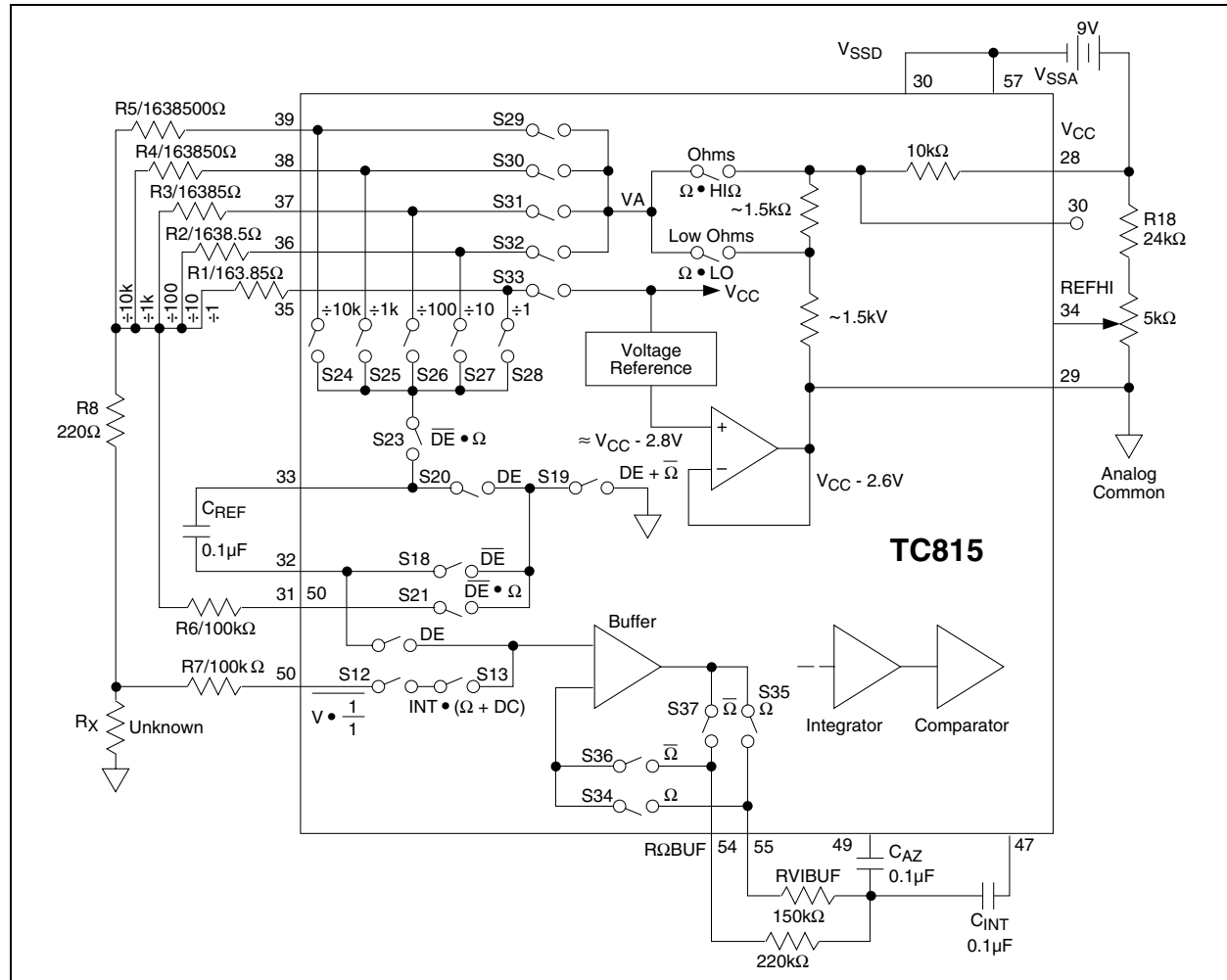
**FIGURE 3-2:** **RESISTANCE MEASUREMENT ACCURACY SET BY EXTERNAL STANDARD RESISTOR**

Example: 200kΩ Full Scale Measurement

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

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

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

$$\therefore \quad \frac{V_X}{(R_I C_I)} \times T_I = \frac{V_X}{(R_I C_I)} T_{DE}$$

Where:
R_I = Integrating Resistor, T_I = Integrate Time
C_I = Integrating Capacitor, T_{DE} = Deintegrate Time

(d) $R_X = 163.85 \dfrac{(T_{DE})}{T_I}$

Independent of R_I, C_I or Internal Voltage Reference
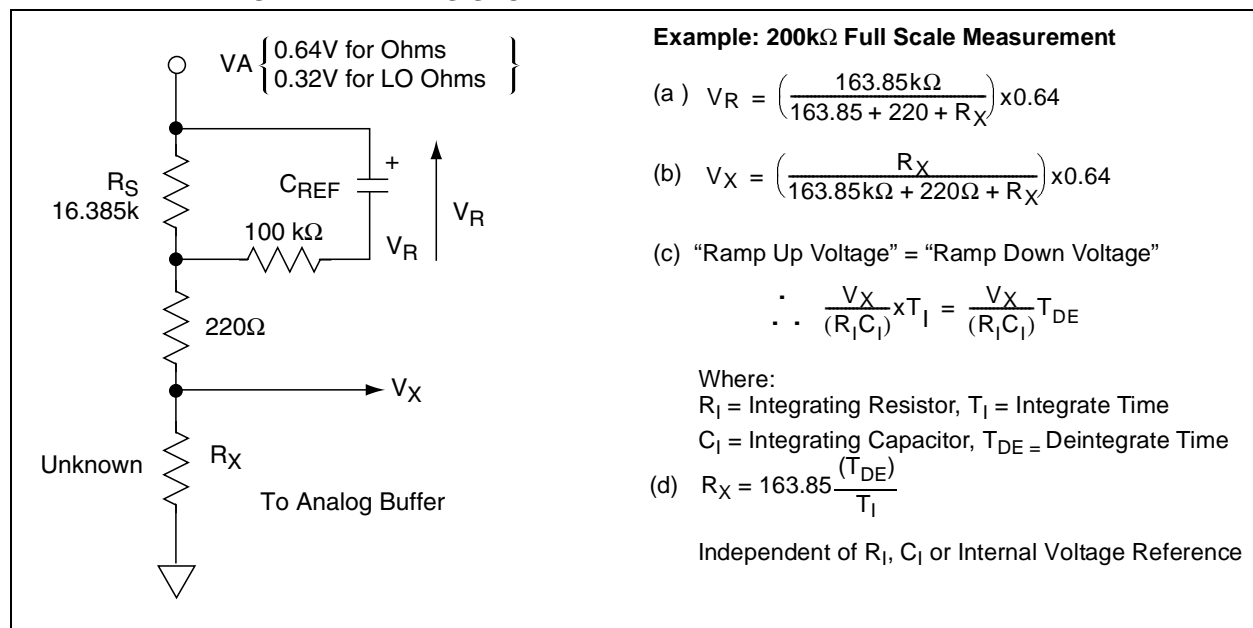
3.4 Voltage Measurement

Resistive dividers are automatically changed to provide in range readings for 200mV to 2000V full scale readings (Figure 3-3). 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 V_I (Pin 44) for full scale voltages from 200mV to 2000V.

For applications which 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.

FIGURE 3-3: TC815 ANALOG SECTION
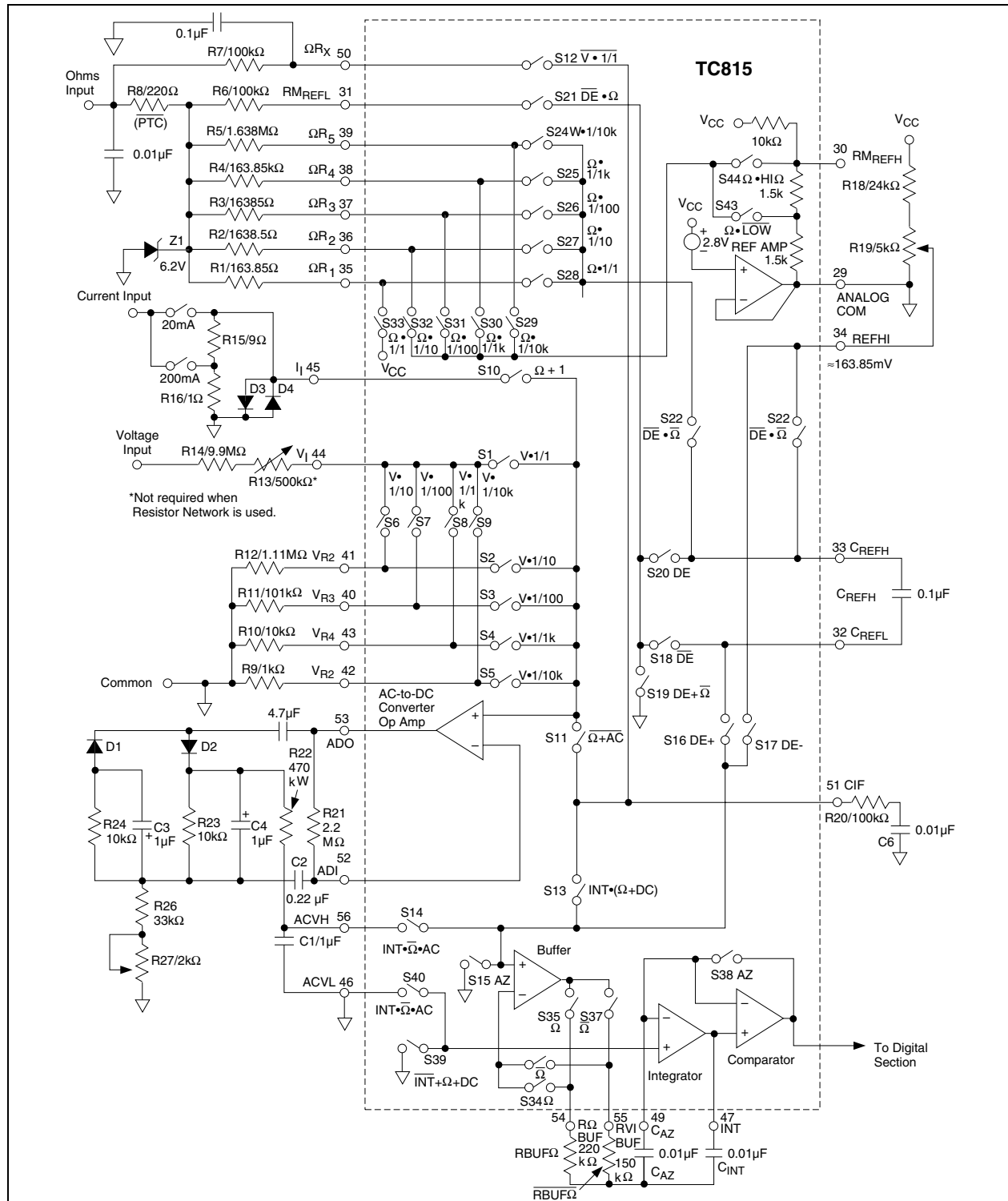
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3.5 Current Measurement

The TC815 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 $\overline{20mA}$ 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 I_I input (Pin 45). For $\overline{20mA}$ measurements a 10Ω resistor is used. The 200mA range needs a 1Ω resistor; full scale is 200mV.

PC board trace resistance between analog common and R16 (see Figure 2-1) must be minimized. In the 200mA range, for example, a 0.05 trace resistance will cause a 5% current to voltage conversion error at I_I (Pin 45).

The extended resolution measurement option operates during current measurements. To minimize rollover error the potential difference between ANALOG COM (Pin 29) and system common must be minimized.

3.6 Measurement Options (AC to DC Measurements)

In voltage and current measurements, the TC815 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 TC815 enters the DC Measurement mode. For AC measurements (current or voltage), $\overline{AC}/DC$ (Pin 62) is momentarily brought low to digital ground potential; the TC815 sets-up for AC measurements and the AC liquid crystal display annunciator activates. Toggling $\overline{AC}/DC$ low again will return the TC815 to DC operation.

If the Manual Operating mode has been selected, toggling $\overline{AC}/DC$ will reset the TC815 back to the Auto-Range mode. In Manual mode operation, AC or DC operation should be selected first and then the desired range selected.

The minimum AC voltage full scale voltage range is 2V. The DC full scale minimum voltage is 200mV. AC current measurements are available on the 20mA and 100mA full scale current ranges.

4.0   CONVERSION TIMING

The TC815 analog-to-digital converter uses the conventional dual slope integrating conversion technique with an added phase that automatically eliminates zero offset errors. The TC815 gives a zero reading with a zero volt input.

The TC815 is designed to operate with a 32.768kHz crystal. The 32kHz crystal is low cost and readily available; it serves as a time-base oscillator crystal in many digital clocks. (See External Crystal Sources.)

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

The integration time is fixed at 1638.5 clock periods or 100msec. This gives rejection of 50/60Hz AC line noise.

The maximum reference de-integrate time, representing a full scale analog input, is 3000 clock periods or 183.1msec during manual extended resolution operation. The 3000 counts are available in Manual mode, extended resolution operation only. In Auto-Ranging mode, the maximum de-integrate 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 De-integrate mode, the auto-zero phase is entered. Figure 4-1 shows the basic TC815 timing relationships.

FIGURE 4-1:   BASIC TC815 CONVERSION TIMING

External Crystal = 32.768kHz
Internal Clock Period = T_P = 2/32.768 = 61.04µsec

Total Conversion Time = T_{CONV} = 8000 (T_P)
= 488.3mec ≈ 2 Conv/Sec.

Integration Time = T_I = 1638.5 (T_P) = 100.0msec.

Maximum Reference De-integration Time =
T_{DE} = 3000 (T_P) = 183.1msec
(Manual Extended Resolution)

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)

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5.0 MANUAL RANGE SELECTION

The TC815 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 TC815 power-up circuit selects auto-range operation initially. Once the manual range option is entered, range changes are made by momentarily grounding the $\overline{\text{RANGE}}$ control input. The TC815 remains in the Manual Range mode until the measurement function (voltage or resistance), or measurement option ($\overline{\text{AC}}$/DC, $\Omega/\overline{\text{LO}}\Omega$) changes. This causes the TC815 to return to auto-ranging operation.

The "Auto" LCD annunciator driver is active only in the Auto-Range mode. Table 5-1 shows typical operation, where the manual range selection option is used. Also shown is the extended resolution display format.

Also see Figure 5-1 through Figure 5-3.

TABLE 5-1: MANUAL RANGE OPERATION

Input	DC Volts 23.5V		AC Volts 18.2V		Ohm 18.2kΩ		LO Ohm 2.35MΩ	
	Range	Display	Range	Range	Display	Range	Range	Display
Power-on Auto-Range Operation	200mV	"1"00.0V	2V	"1"000V	200Ω	"1"00.0Ω	2kΩ	"1".000kΩ
	2V	1.000V	20V	18.20V	2kΩ	"1".000kΩ	10kΩ	"1".0.00kΩ
	20V	"1"0.00V	—	—	20kΩ	18.20Ω	200kΩ	"1".00.0kΩ
	200V	23.5V	—	—	—	—	2000kΩ	"1"350kΩ

Manual Operation

Input	DC Volts 23.5V		AC Volts 18.2V		Ohm 18.2kΩ		LO Ohm 2.35MΩ	
# of Range Changes (See Note 4) ⎤_⎡	Range	Display	Range	Range	Display	Range	Range	Display
1	200V	23.5V	20V	18.20V	20kΩ	18.20V	2000kΩ	"1"350kΩ
2	200mV	"1"00.0V	2V	"1".000V	200Ω	"1"00.0ΩkΩ	2kΩ	"1".000kΩ
3	2V	1.000V	20V	18.20V	2kΩ	"1"000kΩ	20kΩ	"1"0.00kΩ
4	20V	"1"3.50V	20V	18.2V	20kΩ	18.20kΩ	200kΩ	"1"00.0kΩ
5	200V	23.5V	600V	19V	200kΩ	18.2kΩ	2000kΩ	"1"350kΩ
6	1000V	24V	2V	"1".000V	2000kΩ	19kΩ	2kΩ	"1".000kΩ
7	200mV	"1"00.0mV	20V	18.20V	200kΩ	"1"00.0Ω	20kΩ	"1"0.00kΩ
8	2V	"1".000V	200V	18.2V	2kΩ	"1".000kΩ	200kΩ	"1"00.0kΩ

Note 1: A flashing MSD is shown as a "1". A flashing MSD indicates the TC815 is over-ranging if all other digits are zero.

2: The first manual range selected is the last range in the Auto-Ranging mode.

3: A flashing MSD with a non-zero display indicates the TC815 has entered the Extended Resolution Operating mode. An additional 1000 counts of resolution is available. This extended operation is available only in manual operation for voltage, resistance and current measurements.

4: ⎤_⎡ = Momentary ground connection.

FIGURE 5-1: MANUAL RANGE SELECTION: RESISTANCE MEASUREMENTS

*Mode also operates when Auto-Ranging Operation is selected and 2MΩ < R_X < 2.999MΩ
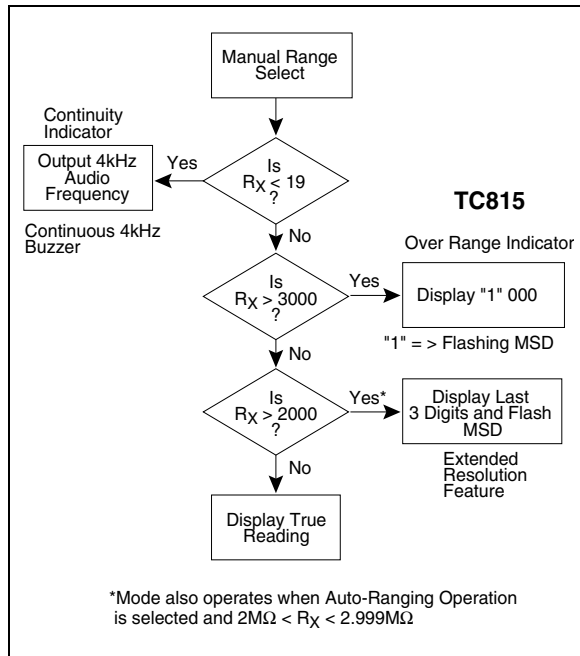
For resistance measurements, the buzzer signal does not indicate an overrange condition. The buzzer is used to indicate continuity. Continuity is defined as a resistance reading less than 19 counts.

FIGURE 5-2: MANUAL RANGE SELECTION: CURRENT MEASUREMENTS
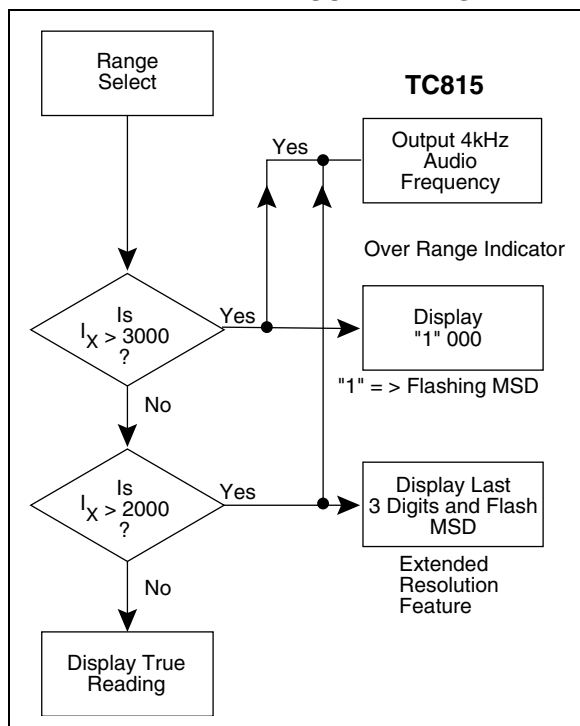
FIGURE 5-3: MANUAL RANGE SELECTION: VOLTAGE MEASUREMENTS
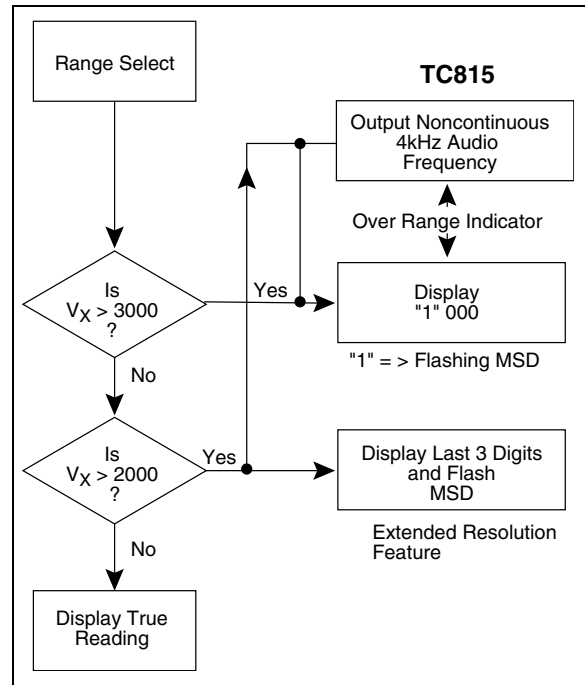
5.1 Extended Resolution Manual Operation

The TC815 extends resolution by 50% when operated in the Manual Range Select mode for current, voltage, and resistance measurements. Resolution increases to 3000 counts from 2000 counts. The extended resolution feature operates only on 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.

An input overrange condition causes the most significant digit to blink and sets the three least significant digits 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 operation.

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6.0   -MEM OPERATING MODE

Bringing -MEM (Pin 61) momentarily low configures the TC815 "-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. The following examples clarify operation:

EXAMPLE 6-1:   IN AUTO-RANGING

R_I (N) = 18.21kΩ (20kΩ Range) = > Display 18.21kΩ

$\overline{MEM}$ ⌐_⌐ = > Store 0.21kΩ

R_I (N+1) = 19.87kΩ (20kΩ Range)
        = > Display 19.87 - 0.21 = 19.66kΩ

R_I (N+2) = 22.65kΩ (200kΩ Range)
        = > Display 22.7kΩ and $\overline{MEM}$ disappears

EXAMPLE 6-2:   IN FIXED RANGE
(200.0Ω FULL SCALE)

R_I (N) = 18.21kΩ = > Display 18.2kΩ

$\overline{MEM}$ ⌐_⌐ = > 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 = 2.4Ω*

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

EXAMPLE 6-3:   IN FIXED RANGE

V_I (N) = 0.51V = > Display 0.51V

$\overline{MEM}$ ⌐_⌐ = > 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 TC815 "-MEM" mode is not active. Once the "-MEM" is entered, bringing $\overline{MEM}$ low again, it returns the TC815 to normal operation.

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

In the 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 when lead length resistance would cause measurement errors.

7.0   AUTOMATIC RANGE SELECTION OPERATION

When power is first applied, the TC815 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 ($\overline{AD}$/DC, $\Omega/\overline{LO}\Omega$).

The automatic voltage range selection begins on the most sensitive scale first: 200mV for DC or 2.000V for AC measurements. The voltage range selection flow chart is given in Figure 7-1.

Internal input protection diodes to V_{DD} (Pin 28) and V_{SSA} (Pin 57) clamp the input voltage. The external 10MΩ input resistance (see Figure 7-1, R14 and R13) 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 over range 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 piezo electric acoustic transducer. An out of range input signal causes the 4kHz signal to be on 122msec, off for 122 msec, on for 122msec and off for 610msec (see Figure 11-1).

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

The resistance automatic range selection procedure is shown in Figure 7-2. The 200Ω range is the first range selected unless the TC815 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 over range input does not activate the buzzer.

Out of range input conditions are displayed by a blinking most significant digit with the three least significant digits set to "000."

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

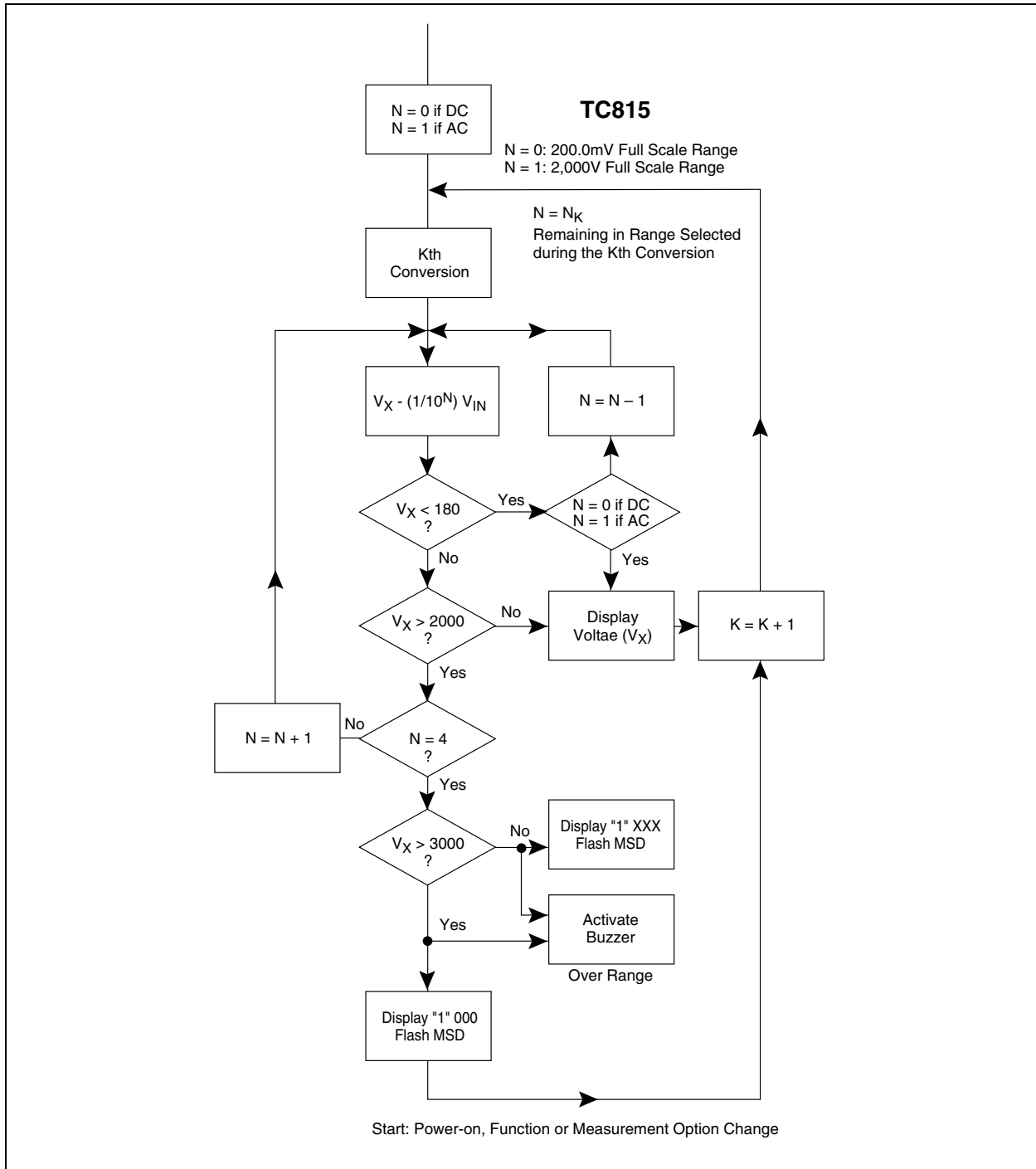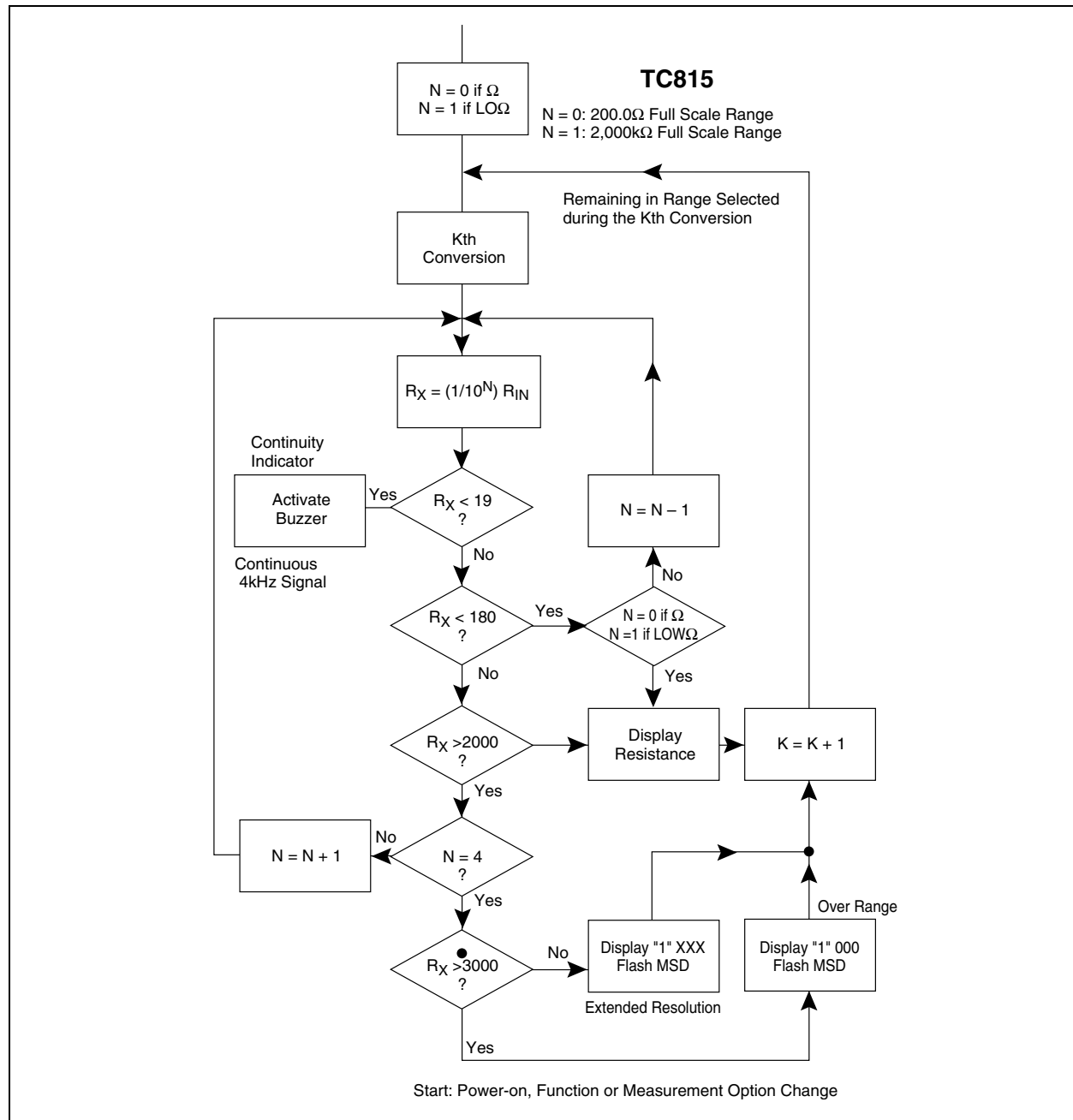**FIGURE 7-1:   AUTO-RANGE OPERATION: VOLTAGE MEASUREMENT**

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N = 0: 200.0mV Full Scale Range
N = 1: 2,000V Full Scale Range

N = 0 if DC
N = 1 if AC

$N = N_K$
Remaining in Range Selected
during the Kth Conversion

Kth
Conversion

$V_X - (1/10^N) V_{IN}$

N = N − 1

$V_X < 180$?   Yes   N = 0 if DC / N = 1 if AC

No

$V_X > 2000$?   No   Display Voltae (V_X)   K = K + 1

Yes

N = N + 1   No   N = 4 ?

Yes

$V_X > 3000$?   No   Display "1" XXX Flash MSD

Yes   Activate Buzzer

Over Range

Display "1" 000 Flash MSD

Start: Power-on, Function or Measurement Option Change

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FIGURE 7-2: **AUTO-RANGE OPERATION: RESISTANCE MEASUREMENT**

FIGURE 7-2: AUTO-RANGE OPERATION: RESISTANCE MEASUREMENT

TC815

N = 0 if Ω
N = 1 if LOΩ

N = 0: 200.0Ω Full Scale Range
N = 1: 2,000kΩ Full Scale Range

Remaining in Range Selected during the Kth Conversion

Kth Conversion

$R_X = (1/10^N) R_{IN}$

Continuity Indicator

Activate Buzzer

Continuous 4kHz Signal

$R_X < 19$?

N = N − 1

$R_X < 180$?

N = 0 if Ω
N = 1 if LOWΩ

$R_X > 2000$?

Display Resistance

K = K + 1

N = N + 1

N = 4 ?

Over Range

$R_X > 3000$?

Display "1" XXX Flash MSD

Display "1" 000 Flash MSD

Extended Resolution

Start: Power-on, Function or Measurement Option Change

8.0 LOW BATTERY DETECTION CIRCUIT

The TC815 contains a low battery detector. When the 9V battery supply has been depleted to a 7V nominal value, the LCD display low battery annunciator is activated.

The low battery detector is shown in Figure 8-1. The low battery annunciator remains OFF with the battery supply greater than 0.7V. The annunciator is ON before the supply battery has reached 6.3V.

FIGURE 8-1: LOW BATTERY DETECTOR
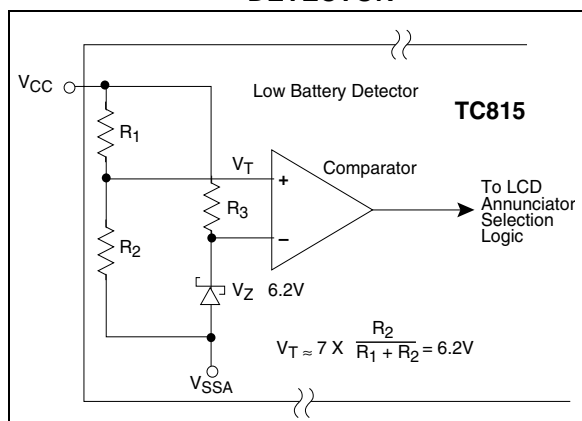
9.0 TRIPLEX LIQUID CRYSTAL DRIVE

The TC815 directly drives a triplexed liquid crystal display (LCD) using 1/3 bias drive (see Figure 9-1). All data, decimal point, polarity and function annunciator drive signals are developed by the TC815. A direct connection to a triplex LCD display is possible without external drive electronics. Standard and custom LCD displays are readily available from LCD manufacturers.

The LCDs must be driven with an AC signal having 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}.

If V_{DISP}, for example, 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 Vp/3 across it or 1 volt. An "ON" segment has a 0.63Vp signal across it or 1.92V for $V_{CC} - V_{DISP} = 3V$.

Since the V_{DISP} pin is available, the user may adjust the "ON" and "OFF" LCD levels for various manufacturer's displays by changing Vp. The liquid crystal threshold voltage moves down with temperature.

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

The TC815 internally generates two intermediate LCD drive potentials (V_H and V_L) from a resistive divider (Figure 9-1), between V_{CC} (Pin 28) and V_{DISP} (Pin 7). The ladder impedance is approximately 150kΩ. This drive method is commonly known as 1/3 bias. With V_{DISP} connected to digital ground $V_P \approx 5.0V$.

The intermediate levels are needed so that drive signals giving RMS "ON" and "OFF" levels can be generated. Figure 9-2 shows a typical drive signal and the resulting wave forms for "ON" and "OFF." RMS voltage levels across a selected LCD element. Also, see Figure 9-3 and Table 9-1.

FIGURE 9-1: 1/3 BIAS LCD DRIVE
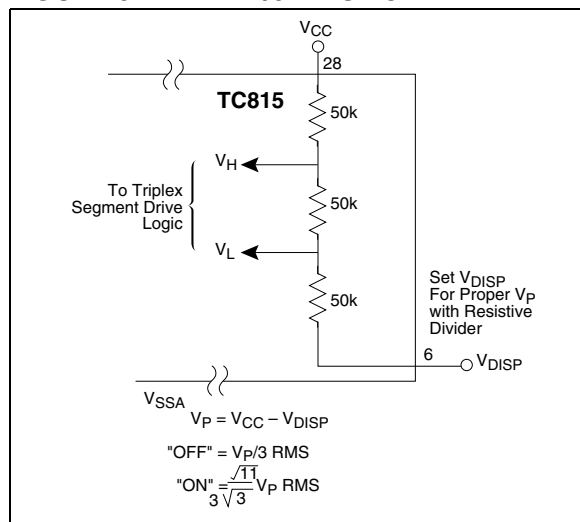
9.1 LCD Displays

Although most users will design their own custom LCD display, several manufacturers offer standard displays for the TC815. Figure 9-3 shows a typical display available from Varitronix.

1. Varitronix Ltd.
   4/F Liven House, 61-63, King Yip Street
   Kwun Tong, Hong Kong
   Tel: (852)2389-4317
   Part No.: VIM 310-1 Pin Connector
               VIM 310-2 Elastomer Connector

   USA OFFICE:
   VL Electronics/Varitronix
   3250 Wilshire Blvd. Suite 1901
   Los Angeles, CA 90010
   Tel: (213) 738-8700

2. Adamant Kogyo Co., LTD
   16-7, Shinden, 1-Chome, Adachi-Ku,
   Tokyo, 123, Japan
   Tel: Tokyo 919-1171

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FIGURE 9-2: **TRIPLEX LCD DRIVE WAVEFORMS**
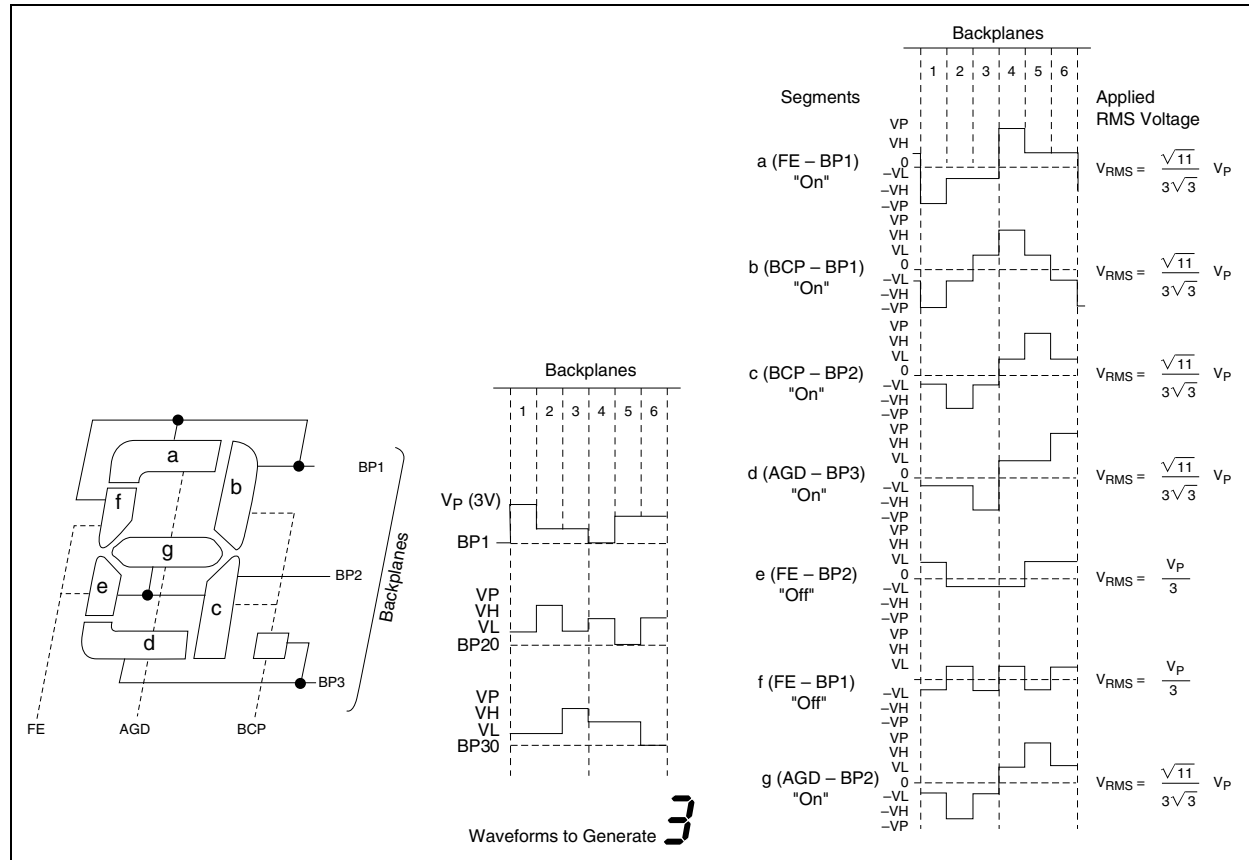
FIGURE 9-3: **TYPICAL LCD DISPLAY CONFIGURATION TC815 TRIPLEX**
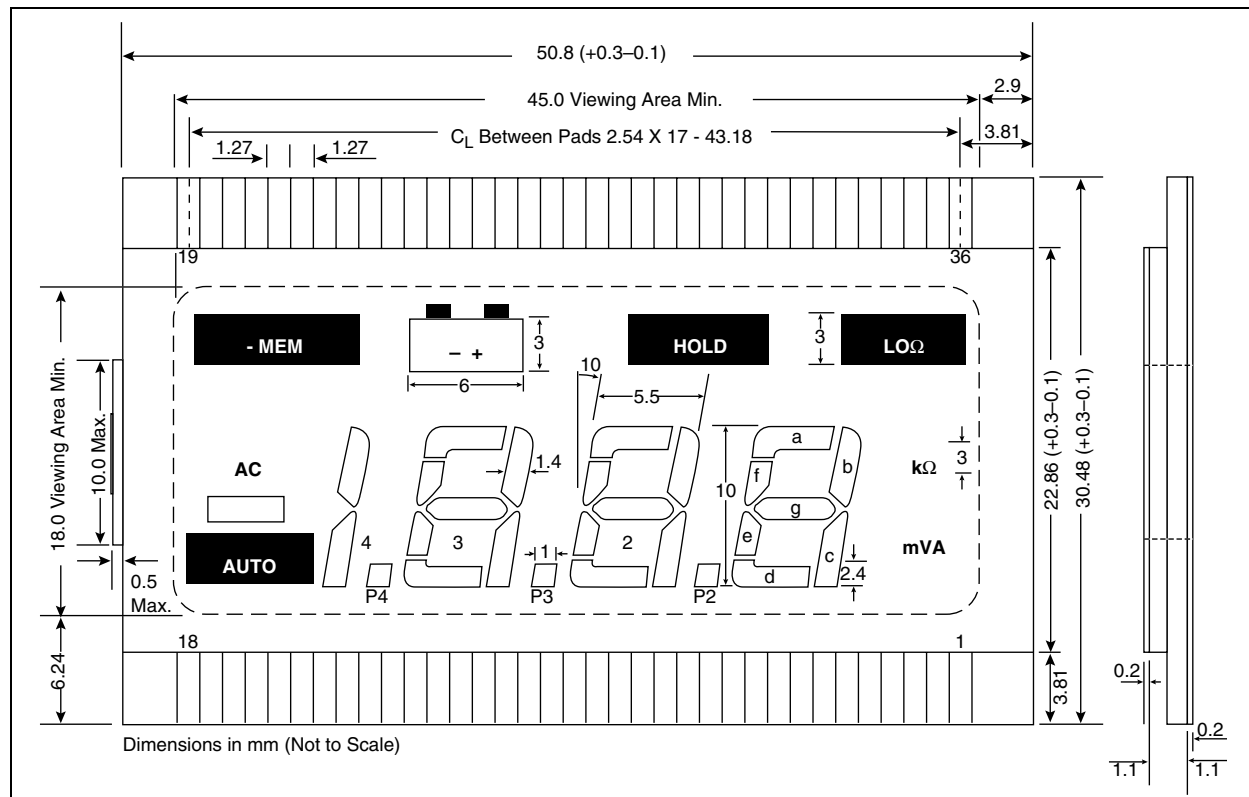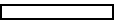
TABLE 9-1:

PAD	BP1	BP2	BP3	PAD	COM1	COM2	COM3
1	BP1	/	/	19	/	/	/
2	/	BP2	/	20	/	/	/
3	/	/	BP3	21	/	/	/
4	/	LOΩ	A	22	/	/	/
5	/	W	V	23	/	/	/
6	HOLD	k	m	24	/	/	/
7	b1	c1	/	25	/	/	/
8	a1	g1	d1	26	/	/	/
9	f1	e1	/	27	/	/	/
10	b2	c2	P2	28	/	/	/
11	a2	g2	d2	29	/	/	/
12	f2	e2	/	30	/	/	/
13	b3	c3	P3	31	/	/	/
14	a3	g3	d3	32	/	/	/
15	f3	e3	/	33	/	/	/
16	b4	c4	P4	34	/	/	/
17	AC	⊏＿＿＿＿⊐	Auto	35	/	/	/
18	⊏⊓⊓⊐	–MEM	/	36	/	/	/

10.0 EXTERNAL CRYSTAL

The TC815 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 488.3 msec ($\approx$ 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

- Fox Electronics
  5570 Enterprise Parkway
  Fort Myers, FL 33905
  (941) 693-0099

Contact manufacturer for full specifications.

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11.0 "BUZZER" DRIVE SIGNAL

The TC815 BUZ output (Pin 4) will drive a piezo electric 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 4kHz 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 display MSD also flashes and the three least significant digits are set to display zero.

The buzzer drive signal for over range is shown in Figure 11-1 The buzzer 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 Digital Ground (Pin 58). The signal is at V_{CC} when not active.

The BUZ output is also activated for 15msec 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, $\Omega/\overline{LO}\Omega$) will also activate the buzzer output for 15msec. A range change during a current measurement will not activate the buzzer output.

FIGURE 11-1:   TC815 WAVEFORM FOR BUZZER OUTPUT
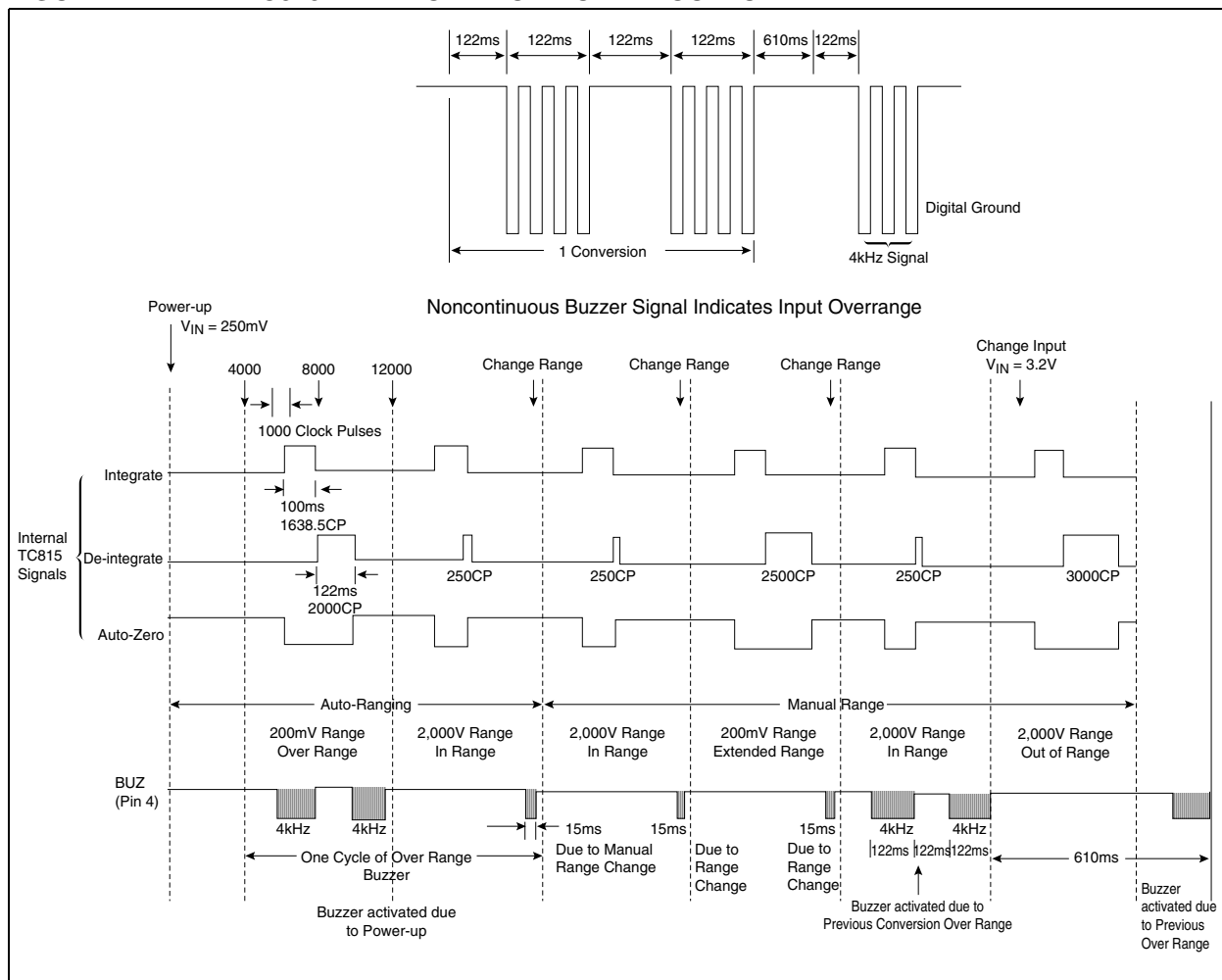
Vendors for piezo electric audio transducers are:

- 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

11.1 Display Decimal Point Selection

The TC815 provides a decimal point LCD drive signal. The decimal point position is a function of the selected full scale range, as shown in Table 11-1.

TABLE 11-1:   DECIMAL POINT SELECTION

	1 * 9	* 9	* 9
Full Scale Range	DP3	DP2	DP1
2000V, 2000kΩ	OFF	OFF	OFF
200V, 200.0kΩ	OFF	OFF	ON
20V, 20.00kΩ	OFF	ON	OFF
2V, 2.000kΩ	ON	OFF	OFF
200V, 200.0Ω	OFF	OFF	OFF
200mV, 200.0Ω	OFF	OFF	ON
20mA	OFF	ON	OFF
200mA	OFF	OFF	ON

11.2 AC-to-DC Converter Operational Amplifier

The TC815 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 = 10kΩ) ± 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. 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.

11.3 Component Selection

11.3.1 INTEGRATION RESISTOR SELECTION

The TC815 automatically selects one of two external integration resistors. RVBUF (pin 55) is selected for voltage and current measurement. RΩBUF (Pin 54) is selected for resistance measurements.

11.3.2 RVIBUF SELECTION (PIN 55)

In auto-range operation, the TC815 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 200V 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:

V_{INT} =   Integrator swing = ±2V

t_I =   Integration time = 100msec

C_I =   Integration capacitor = 0.1µF

V_{MAX} =   Maximum input at V_I = 300mV

EQUATION 11-1:

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

11.3.3 RΩBUF SELECTION (PIN 54)

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 (see Figure 11-2):

V_{ANCOM} = Potential at Analog Common ≈ 2.7V

R_8 =   220Ω

R_I =   163.85Ω

R_X =   300Ω

R_S =   Internal switch 33 resistance ≈ 600Ω

EQUATION 11-2:

$$R\Omega BUF = \frac{V_{CC} - (V_{ANCOM})R_X}{(R_X + R_S + R_1 + R_8)} = 0.63V$$

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

V_{INT} = Integrator swing = 3.1V

t_I = Integration time = 100msec

C_I = Integration capacitor = 0.1µF

R_{XMAX} = 300Ω

$V_{X\ MAX}$ = 700mV

EQUATION 11-3:

$$R\Omega BUF = \frac{V_{XMAX}(T_I)}{C_I(V_{INT})} = 200k\Omega$$

FIGURE 11-2:   RΩ CALCULATION (200Ω MANUAL OPERATION)
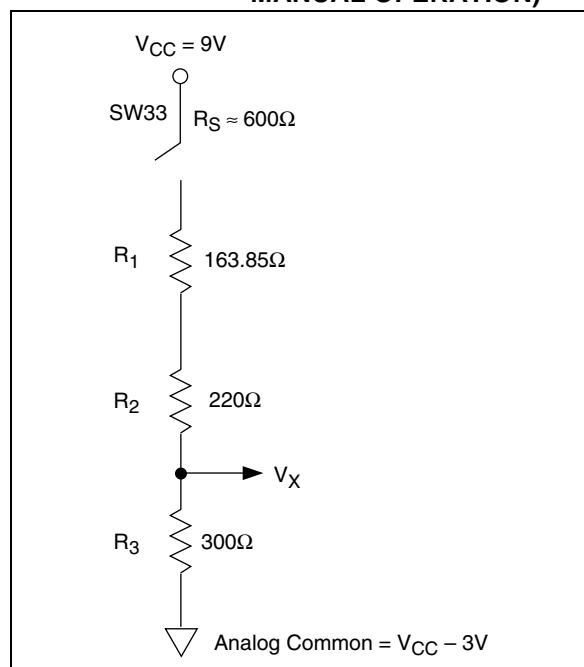
With a low battery voltage of 6.6V, analog common will be approximately 3.6V above the negative supply terminal. With the integrator swinging down from analog common toward the negative supply, a 3.1V swing will set the integrator output to 0.5V above the negative supply.

11.4   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.

11.5   Reference Voltage Adjustment

The TC815 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 TC815 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.

11.6   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.

11.7   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

11.8   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

TABLE 11-2:   RESISTIVE LADDER NETWORKS

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

12.0   PACKAGING INFORMATION

12.1   Package Marking Information

Package marking data not available at this time.

12.2   Taping Form

Component Taping Orientation for 64-Pin PQFP Devices

User Direction of Feed

PIN 1

W

P

Standard Reel Component Orientation
for TR Suffix Device
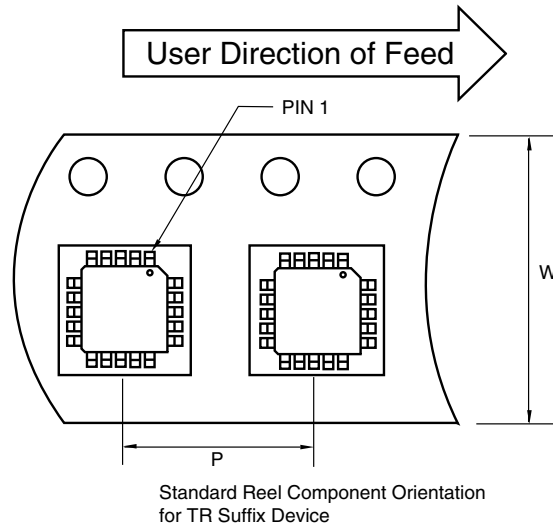
Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
64-Pin PQFP	32 mm	24 mm	250	13 in

Note: Drawing does not represent total number of pins.

12.3   Package Dimensions

64-Pin PQFP

7° MAX.

PIN 1

.018 (0.45)
.012 (0.30)

.031 (0.80) TYP.

.555 (14.10)
.547 (13.90)

.687 (17.45)
.667 (16.95)

.555 (14.10)
.547 (13.90)

.687 (17.45)
.667 (16.95)

.009 (0.23)
.005 (0.13)

.041 (1.03)
.031 (0.78)

.010 (0.25) TYP.

.120 (3.05)
.100 (2.55)

.130 (3.30) MAX.
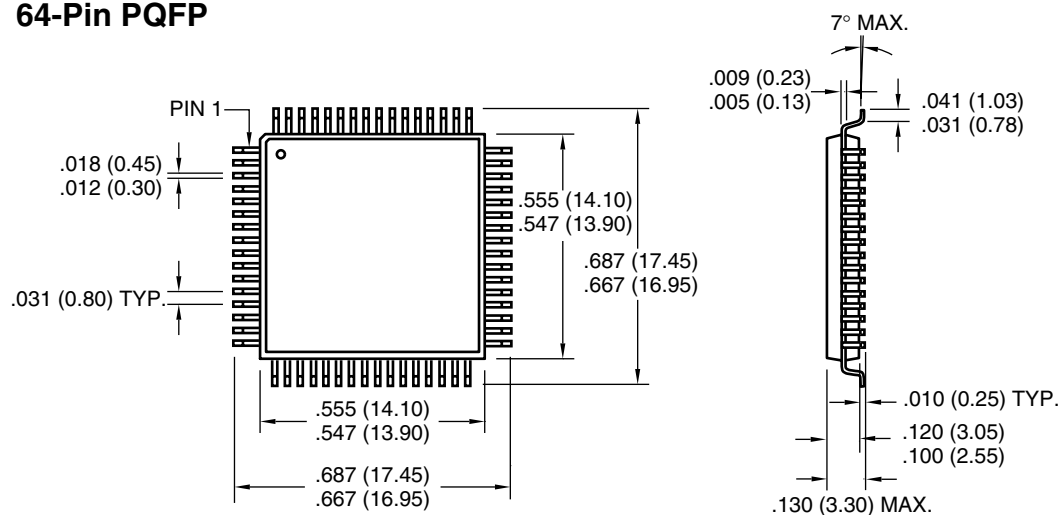
Dimensions: mm (inches)

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SALES AND SUPPORT

Data Sheets
Products supported by a preliminary Data Sheet may have an errata sheet describing minor operational differences and recommended workarounds. To determine if an errata sheet exists for a particular device, please contact one of the following:

1. Your local Microchip sales office
2. The Microchip Corporate Literature Center U.S. FAX: (480) 792-7277
3. The Microchip Worldwide Site (www.microchip.com)

Please specify which device, revision of silicon and Data Sheet (include Literature #) you are using.

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