MICROCHIP

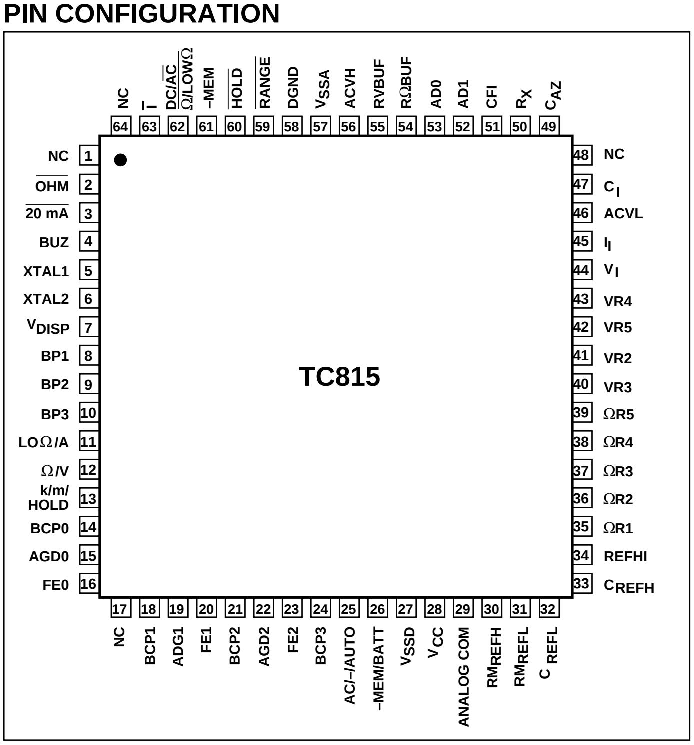
TC815

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**

PIN CONFIGURATION



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.

ORDERING INFORMATION

Part No.	Package	Operating Temp. Range
TC815CBU	64-Pin PQFP Formed Leads	0°C to +70°C

The "low ohms" measurement option allows in circuit resistance measurements by preventing semiconductor junctions from being forward biased.

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 (75 ppm/°C max TC) and a compact surface mounted 64-pin quad flat package, the TC815 is ideal for portable instruments.

ABSOLUTE MAXIMUM RATINGS*

Supply Voltage (V^+ to V^-) 15V
Analog Input Voltage .... V^+ to V^-
Reference Input Voltage .... V^+ to V^-
Voltage at Pin 45 .... GND ±0.7V
Power Dissipation ($T_A \leq 70°C$)
Plastic Flat Package 1.14mW
Operating Temperature
"C" Devices .... 0°C to +70°C
Storage Temperature .... –65°C to +160°C
Lead Temperature (Soldering, 10 sec.) .... +300°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 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, unless otherwise specified, Figure 1 Test Circuit.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
	Zero Input Reading Input Resistor	200mV Range w/o 10MΩ	–0000	0000	+0000	Digital Reading
		200mV Range w/10MΩ Input	–0001	—	+0001	
		20mA and 200mA Range	–0000	0000	+0000	
RE	Rollover Error	200mV Range w/o 10MΩ Input Resistor	—	—	±1 Count	
		200mV Range w/10MΩ Input	—	—	±3	
		20mA and 200mA Range	—	—	±1	
NL	Linearity Error	Best Case Straight Line	—	—	±1	Count
IIN	Input Leakage Current		—	—	10	pA
E_N	Input Noice	BW = 0.1 to 10 Hz	—	20	—	μV_{p-p}
	AC Frequency Response	±1% Error	—	40 to 500	—	Hz
		±5% Error	—	40 to 2000	—	
	Open Circuit Voltage	Excludes 200Ω Range for OHM Measurements	—	570	660	mV
	Open Circuit Voltage	Excludes 200Ω Range for LO OHM Measurement	—	285	350	mV
V_{COM}	Analog Common Voltage	($V^+ - V_{COM}$)	2.5	2.6	3.3	V
V_{CTC}	Common Voltage Temperature Coefficient		—	—	50	ppm/°C
	Display Multiplex Rate		—	100	—	Hz
V_{IL}	Low Logic Input	$\overline{20mA}$, $\overline{AC}$, $\overline{I}$, $\overline{Low\ \Omega}$, $\overline{HOLD}$ $\overline{Range}$, $-\overline{MEM}$, $\overline{OHMs}$ (Relative to DGND Pin 58)	—	—	1	V
	Logic 1 Pull Up Current	$\overline{20mA}$, $\overline{AC}$, $\overline{I}$, $\overline{Low\ \Omega}$, $\overline{HOLD}$ $\overline{Range}$, $-\overline{MEM}$, $\overline{OHMs}$ (Relative to DGND Pin 58)	—	25	—	µA
	Buzzer Drive Frequency		—	4	—	kHz
	Low Battery Flag Voltage	V_{CC} to V_{SSA}	6.3	6.6	7.0	V
	Operating Supply Current		—	0.8	1.5	mA

PIN DESCRIPTIONS

Pin No. (64-Pin Plastic) Quad Flat Package	Symbol	Description
1	NC	
2	$\overline{\text{OHM}}$	Logic Input. “0” (Digital Ground) for resistance measurement.
3	$\overline{\text{20mA}}$	Logic Input. “0” (Digital Ground) for 20mA full-scale current measurement.
4	BUZ	Audio frequency, 4 kHz, output for continuity indication during resistance measurement. A non-continuous 4 kHz signal is output to indicate an input overrange during voltage or current measurements.
5	XTAL1	32.768 kHz Crystal Connection
6	XTAL2	32.768 kHz Crystal Connection
7	V_{DISP}	Sets peak LCD drive signal: VP - VDD-VDISP. VDISP 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	Lo Ω/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.
17	NC	
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 (Hundreds 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} 0.1 µf.
33	C_{REFH}	Reference capacitor positive terminal C_{REF} 0.1 µf.
34	R_{EFHI}	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 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.

PIN DESCRIPTIONS (Cont.)

Pin No. (64-Pin Plastic) Quad Flat Package	Symbol	Description
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	
49	CAZ	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. 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	$\overline{\text{DGND}}$	Internal logic digital ground. 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 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	DC/$\overline{\text{AC}}$	Input that selects AC or DC option during voltage/current measurements. For resistance measurements, $\overline{\Omega\ /\text{LOW}\Omega}$ the ohms or low power (voltage) ohms option can be selected.
63	$\overline{\text{I}}$	Input to select current measurement. Set to logic “0” (Digital ground) for current measurement.
64	NC	

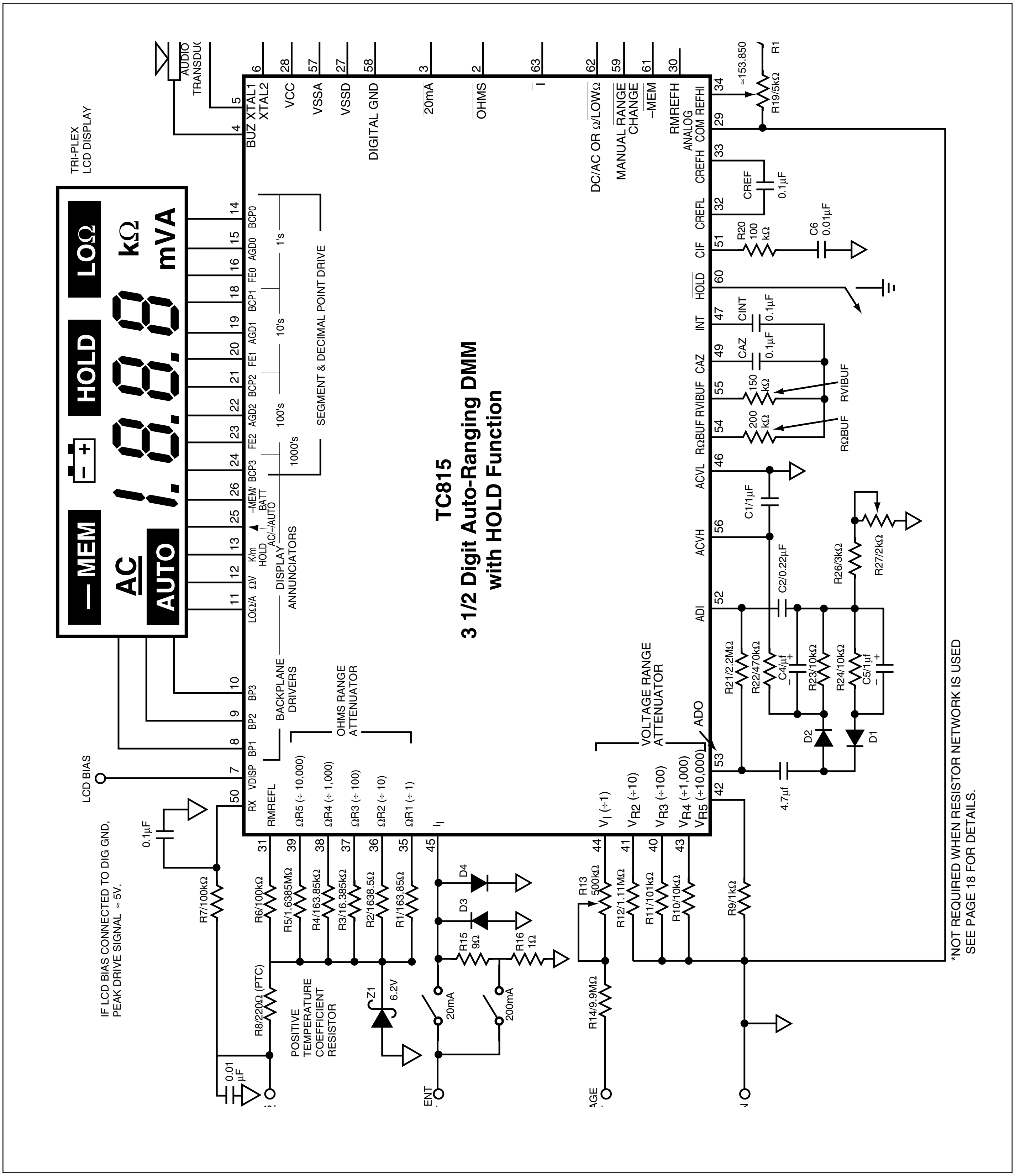


Figure 1: Typical Application and Test Circuit

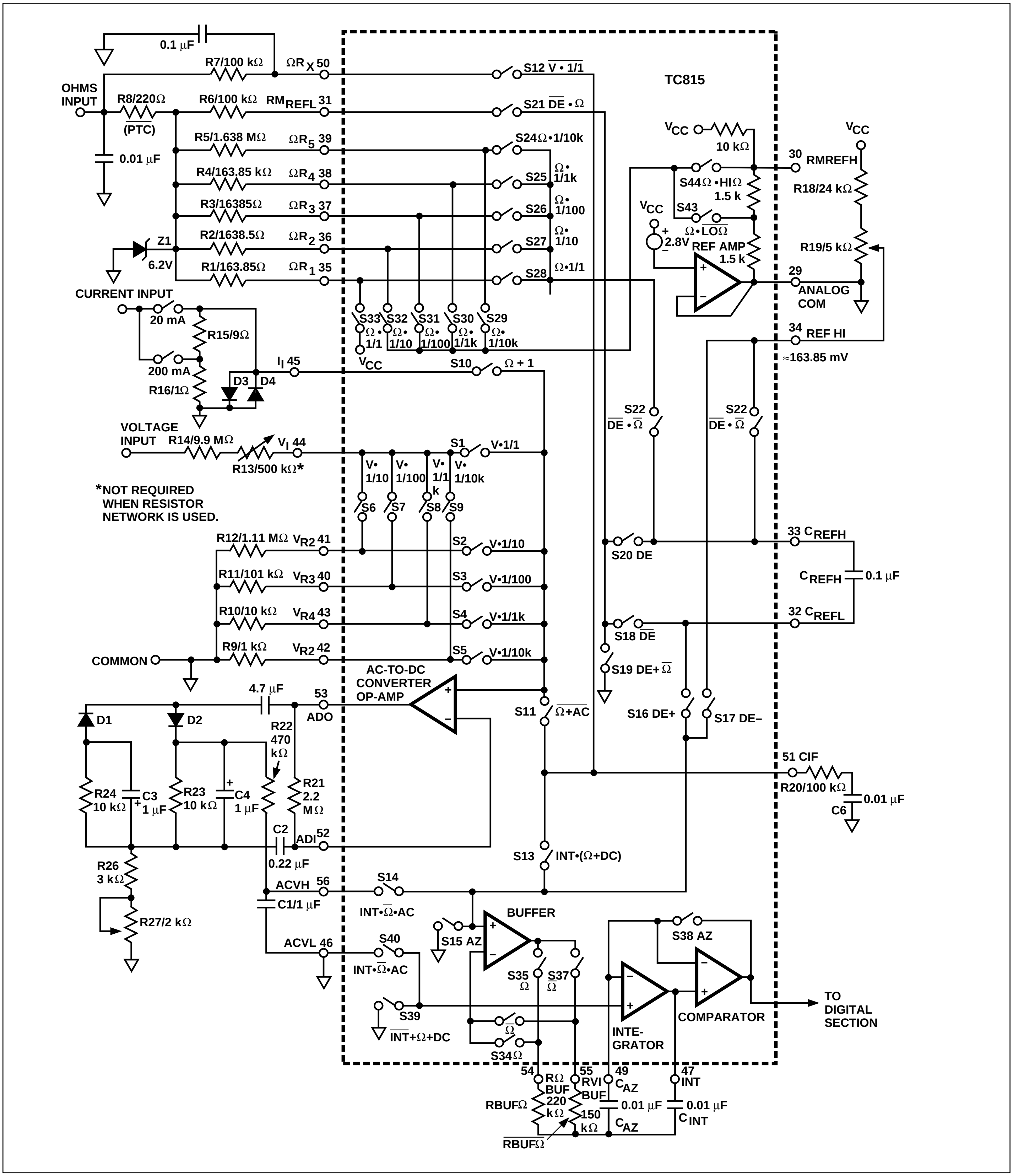


Figure 2: TC815 Analog Section

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 $\overline{\text{I}}$ (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 1.

Table 1. TC815 Measurement Selection Logic

Function Select Pin		
OHM (Pin 2)	**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. $\overline{\text{OHM}}$ & $\overline{\text{I}}$ 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 & 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 $\overline{\Omega\text{/LOW}\Omega}$ (Pin 62) input selects the low power ohms measurement mode. For low power ohms measurements $\overline{\Omega\text{/LOW}\Omega}$ (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 $\overline{\Omega\text{/LOW}\Omega}$ 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 2.

Table 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	16,385 Ω (R3)	YES
200kΩ	16385 Ω (R4)	YES
2,000kΩ	1,638,500 Ω (R5)	YES

N/A = Not available.

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

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 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–RX. Figure 4 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 gives the equivalent ohms per count for various full-scale ranges to allow users to judge the required resistor for accuracy.

Table 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

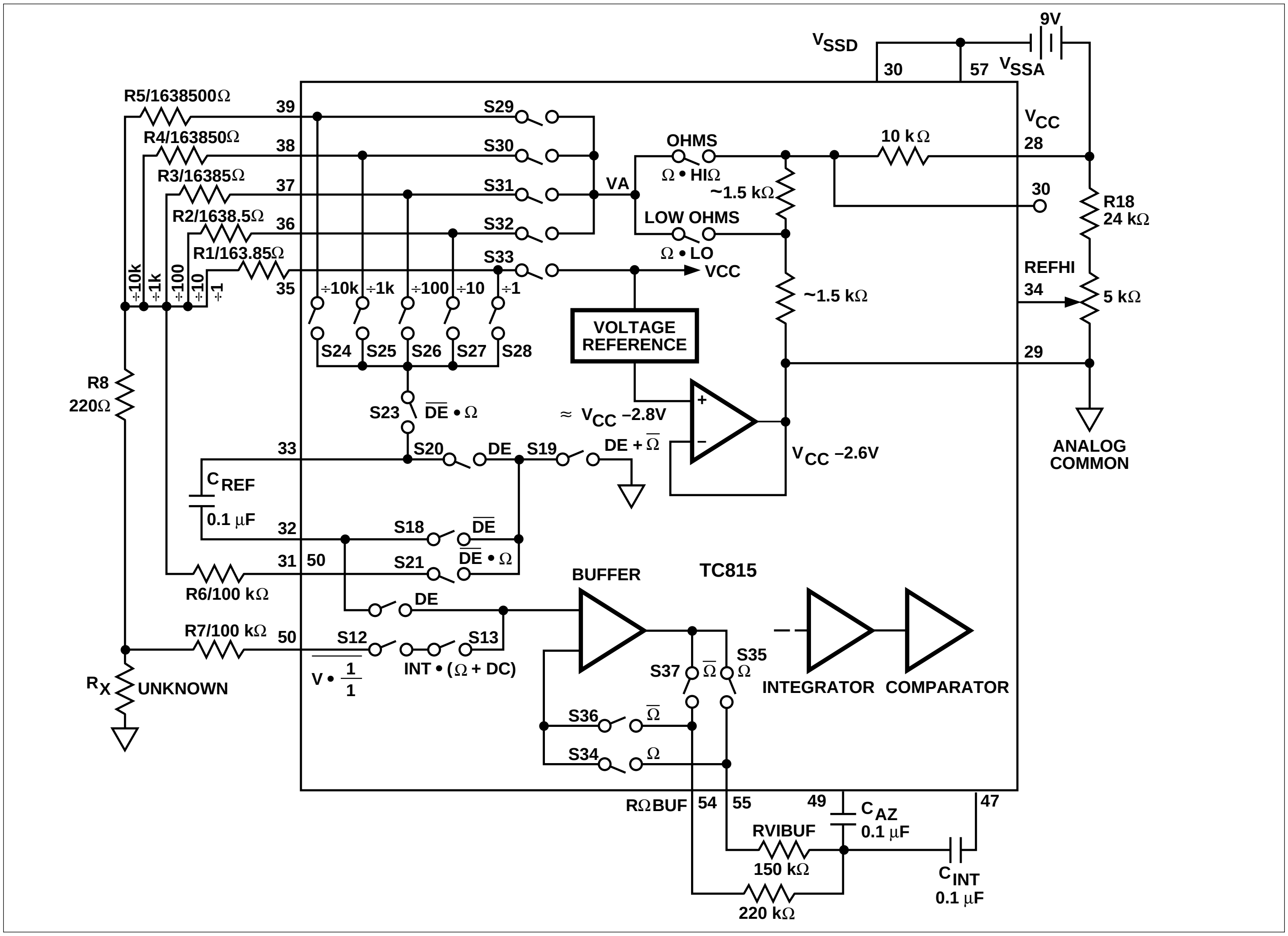


Figure 3: Ratiometric Resistance Measurement Functional Diagram

VOLTAGE MEASUREMENT

Resistive dividers are automatically changed to provide in range readings for 200mV to 2000V full-scale readings (Figure 2). 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.

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 $\overline{\text{I}}$ input (Pin 63) low at digital ground potential. The $\overline{\text{OHM}}$ input (Pin 2) is left floating or tied to the positive supply.

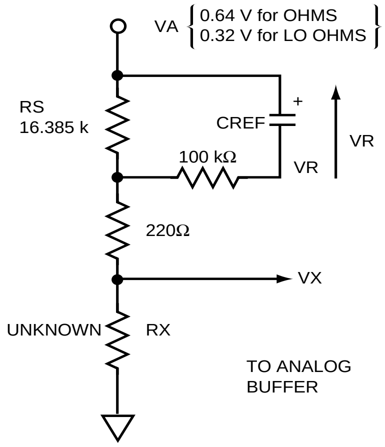
Two ranges are possible. The $\overline{\text{20mA}}$ full-scale range is selected by connecting the $\overline{\text{20mA}}$ input (Pin 3) to digital ground. If left floating the 200mA full-scale range is selected.

External current to voltage conversion resistors are used at the I_I input (Pin 45). For $\overline{\text{20mA}}$ 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 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 COMMON (Pin 29) and system common must be minimized.



Example: 200kΩ Full-Scale Measurement

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

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

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

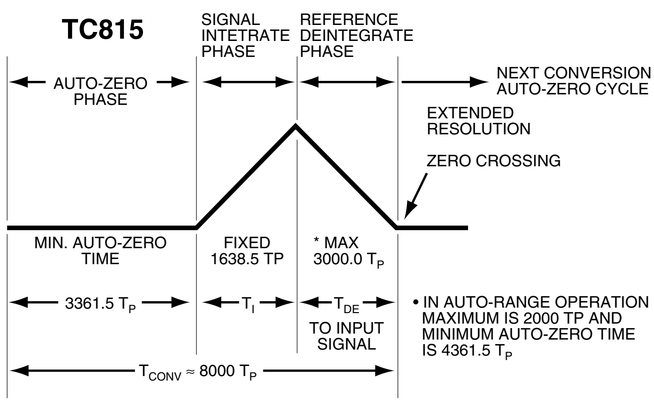
$$\therefore \frac{VX}{R_I C_I} \times T_I = \frac{VR}{R_I C_I} \quad T_{DE}$$

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

(d) $$RX = 163.85 \left(\frac{T_{DE}}{T_I}\right)$$

Independent of R_I, C_I or Internal Voltage Reference

Figure 4. Resistance Measurement Accuracy Set by External Standard Resistor



External Crystal = 32.768kHz
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) = 100.0msec

Maximum Reference Deintegrate Time =
T_{DE} = 3000 (T_P) = 183.1 ms (Manual, Extended Resolution)
= 2000 (T_P) = 122.1msec (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 TC815 Conversion Timing

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 AC/DC low again will return the TC815 to DC operation.

If the manual operating mode has been selected toggling 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.

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 32.768 kHz 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 deintegrate 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 deintegrate 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 TC815 timing relationships.

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 (AC/DC, Ω/LOΩ) 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 4 shows typical operation where the manual range selection option is used. Also shown is the extended resolution display format.

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.

Table 4. Manual Range Operation

		DC VOLTS		AC VOLTS		OHM		LO OHM	
INPUT		**23.5V**		**18.2V**		**18.2KΩ**		**2.35MΩ**	
		RANGE	**DISPLAY**	**RANGE**	**DISPLAY**	**RANGE**	**DISPLAY**	**RANGE**	**DISPLAY**
POWER-ON AUTO-RANGE OPERATION		200mV	"1"00.0mV	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	18.20kΩ	200kΩ	"1"00.0kΩ
		200V	23.5V					2000kΩ	"1"350kΩ
	# of RANGE CHANGES								
		RANGE	**DISPLAY**	**RANGE**	**DISPLAY**	**RANGE**	**DISPLAY**	**RANGE**	**DISPLAY**
MANUAL OPERATION	1	200V	23.5V	20V	18.20V	20kΩ	18.20kΩ	2000kΩ	"1"350kΩ
	2	200mV	"1"00.0V	2V	"1".000V	200Ω	"1"00.0 ΩkΩ	2kΩ	"1".000kΩ
	3	2V	1.000V	20V	18.20V	2kΩ	"1".000kΩ	20kΩ	"1"0.00kΩ
	4	20V	"1"3.50V	200V	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	200Ω	"1"00.0 Ω	20kΩ	"1"0.00 kΩ
	8	2V	"1".000V	200V	18.2V	2kΩ	"1".000kΩ	200kΩ	"1"00.0kΩ

Notes:
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.

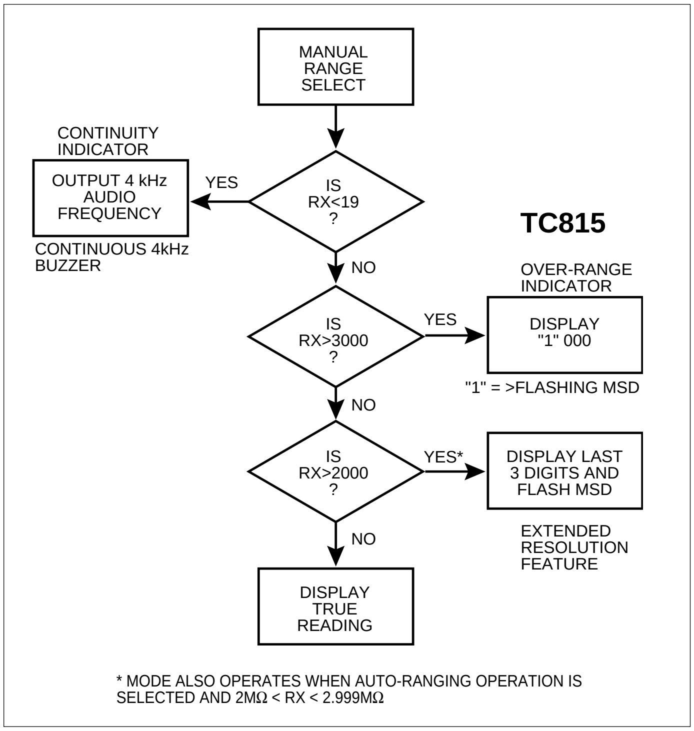


Figure 6. Manual Range Selection; Resistance Measurements

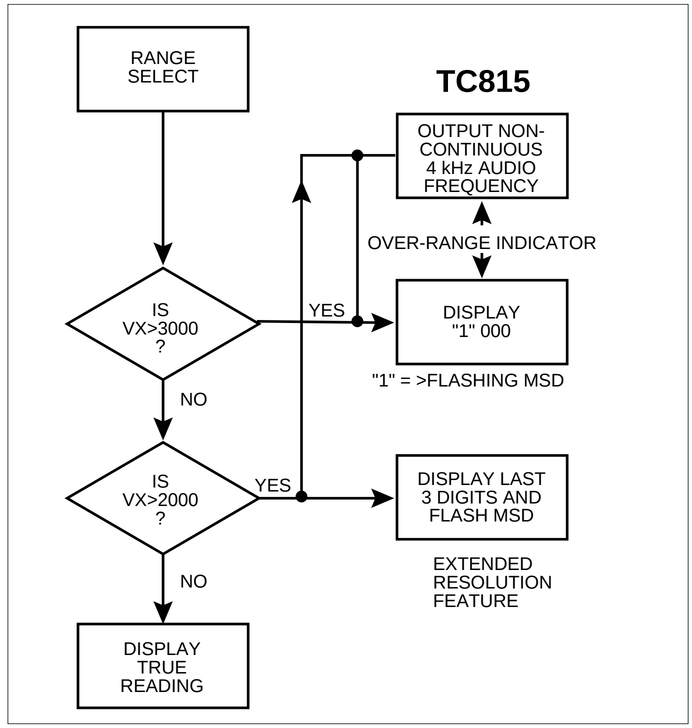


Figure 8. Manual Range Selection; Voltage Measurements

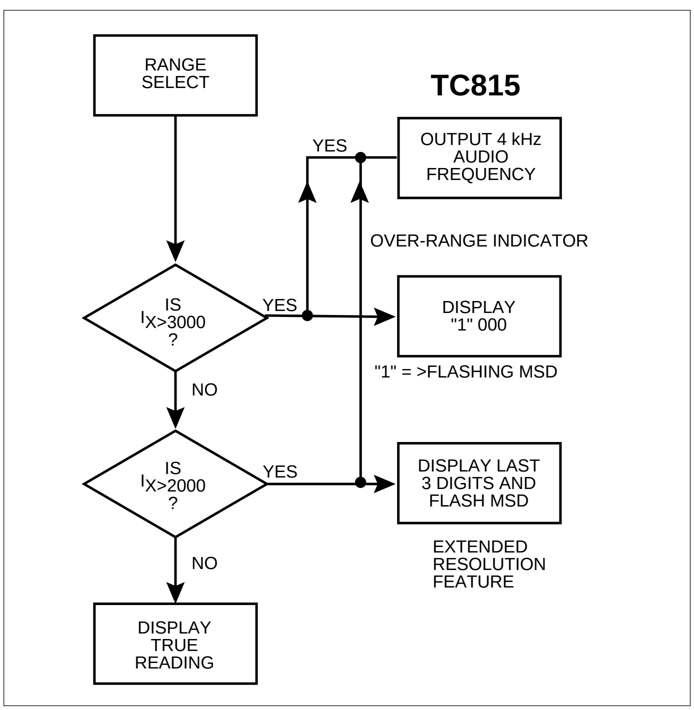


Figure 7. Manual Range Selection; Current Measurements

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 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.

A few examples clarify operation:

Example 1: In Auto-Ranging

Ri (N) = 18.21 kΩ (20 kΩ Range) = > Display 18.21 kΩ
$\overline{\text{MEM}}$ = > Store 0.21 kΩ
Ri (N+1) = 19.87 kΩ (20 kΩ Range)
= > Display 19.87 – 0.21 = 19.66 kΩ
Ri (N+2) = 22.65 kΩ (200 kΩ Range)
= > Display 22.7 kΩ & $\overline{\text{MEM}}$ Disappears

Example 2: In Fixed Range 200.0Ω Full-Scale

Ri (N) = 18.2 Ω = > Display 18.2 Ω
$\overline{\text{MEM}}$ = > Store 8.2 Ω
Ri (N+1) = 36.7 Ω
= > Display 36.7 – 8.2 = 28.5Ω
Ri (N+2) = 5.8 Ω
= > 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

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

$\overline{\text{MEM}}$ ⌐⌙⌐ = > Store 0.51 V

Vi (N+1) = 3.68V

= > Display 3.68 – 0.51 = 3.17V

Vi (N+2) = 0.23V

= > Display 0.23 – 0.51 = –0.28V

Vi (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 $\overline{\text{MEM}}$ low again it returns the TC815 to normal operation.

The "—MEM" mode is also cancelled whenever the measurement type (resistance, voltage, current $\overline{\text{AC}}$/DC, $\Omega/\overline{\text{LO }\Omega}$) 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.

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 ($\overline{\text{AD}}$/DC, $\Omega/\overline{\text{LO }\Omega}$).

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 9.

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 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 overrange voltage input condition is flagged whenever the internal count exceeds 2000 by activating the buzzer output (Pin 4). This 4 kHz signal can directly drive a piezo electric acoustic transducer. An out of range input signal causes the 4 kHz signal to be on 122msec, off for 122 ms, on for 122msec and off for 610msec (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 automatic range selection procedure is shown in Figure 10. 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 4 kHz signal is output at BUZ (Pin 4). An

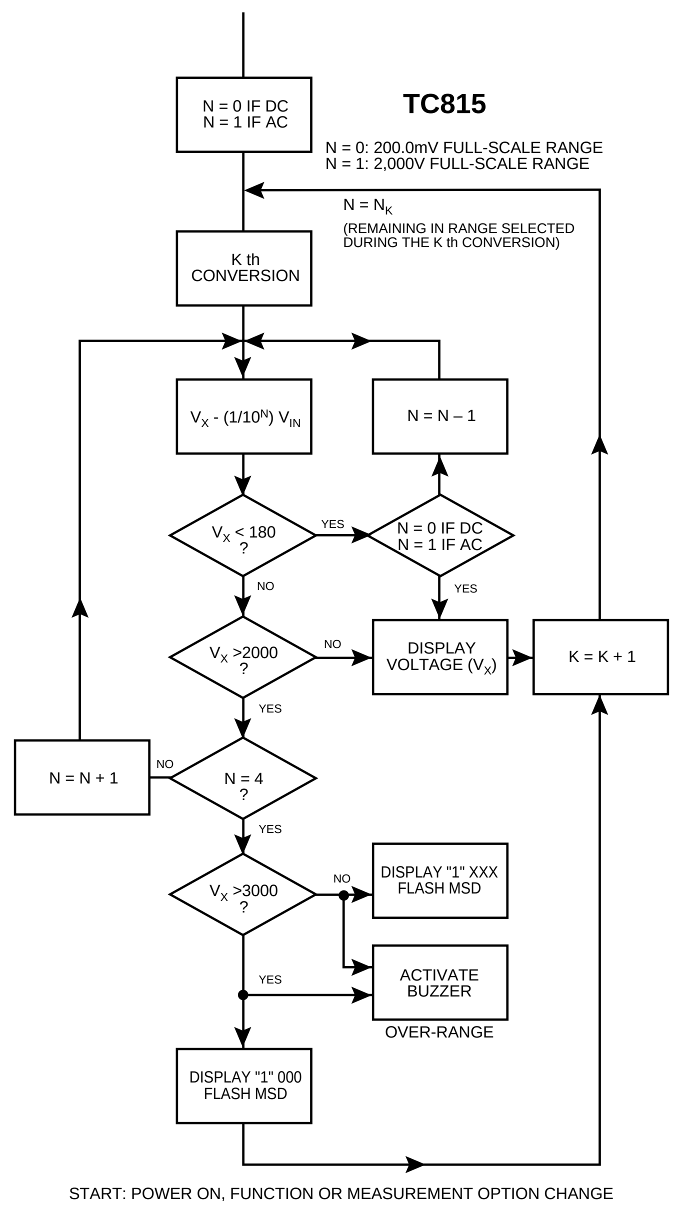


Figure 9. Auto-Range Operation; Voltage Measurement

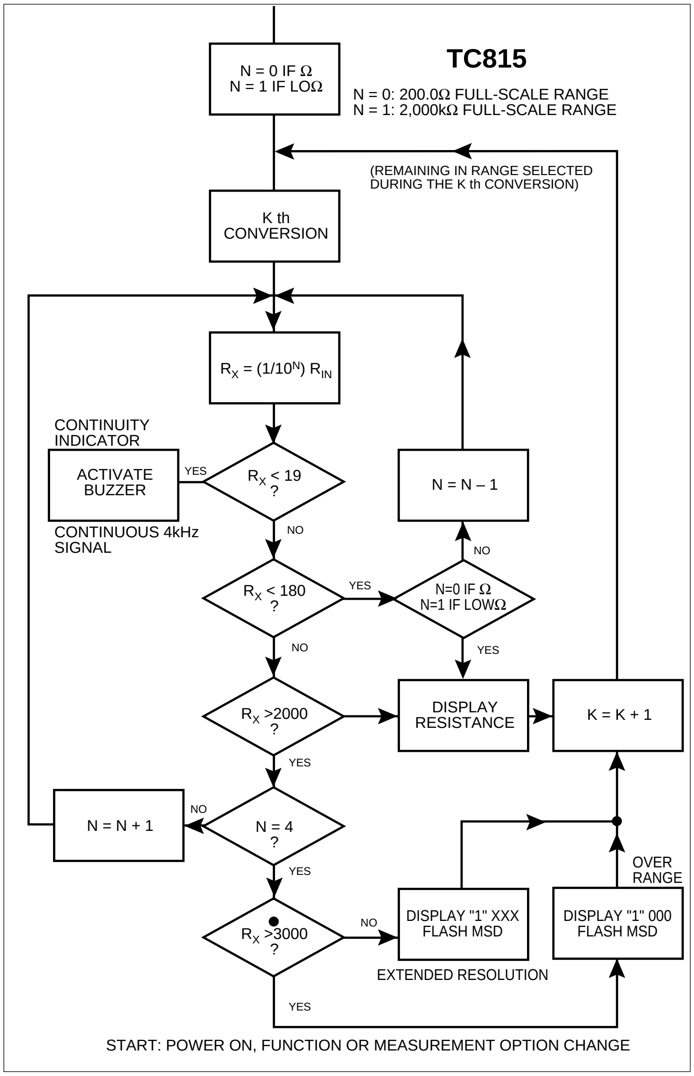


Figure 10. Auto-Range Operation; Resistance Measurement

overrange 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.

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 11. The low battery annunciator is guaranteed to remain OFF with the battery supply greater than 0.7V. The annunciator is guaranteed to be ON before the supply battery has reached 6.3V.

TRIPLEX LIQUID CRYSTAL DRIVE

The TC815 directly drives a triplexed liquid crystal display (LCD) using 1/3 bias drive. 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: $V_{CC} – V_{DISP}$.

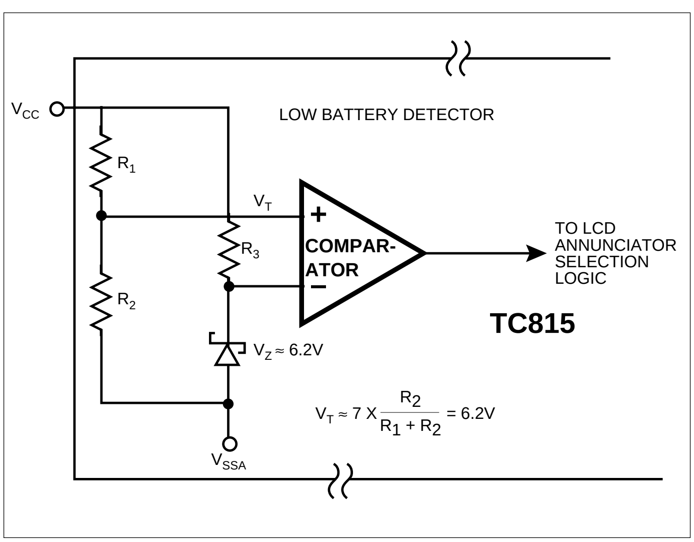


Figure 11. Low Battery Detector

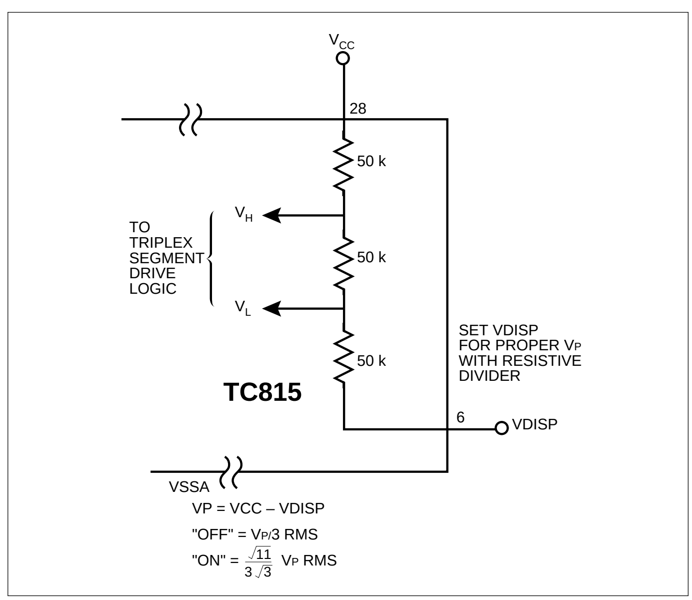


Figure 12. 1/3 Bias LCD Drive

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

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

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 & V_L) from a resistive divider (Figure 12) 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≈5.0V.

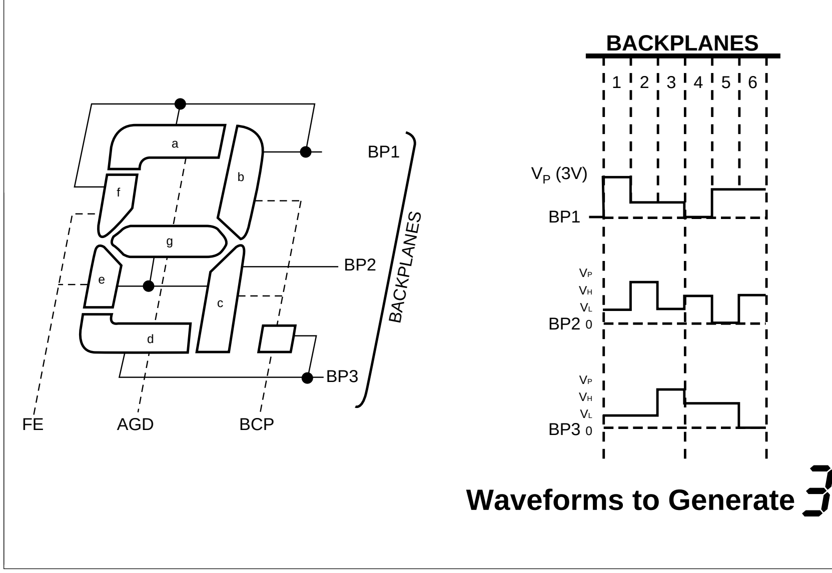
The intermediate levels are needed so that drive signals giving RMS "ON" and "OFF" levels can be generated. Figure 13 shows a typical drive signal and the resulting wave forms for "ON" and "OFF." RMS voltage levels across a selected LCD element.

LCD DISPLAYS

Although most users will design their own custom LCD display, several manufacturers offer standard displays for the TC815. Figure 14 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



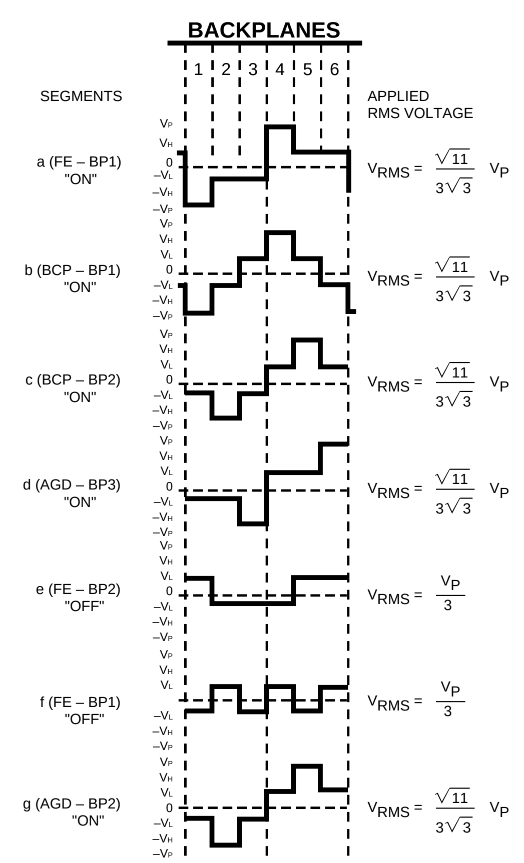


Figure 13. Triplex LCD Drive Waveforms

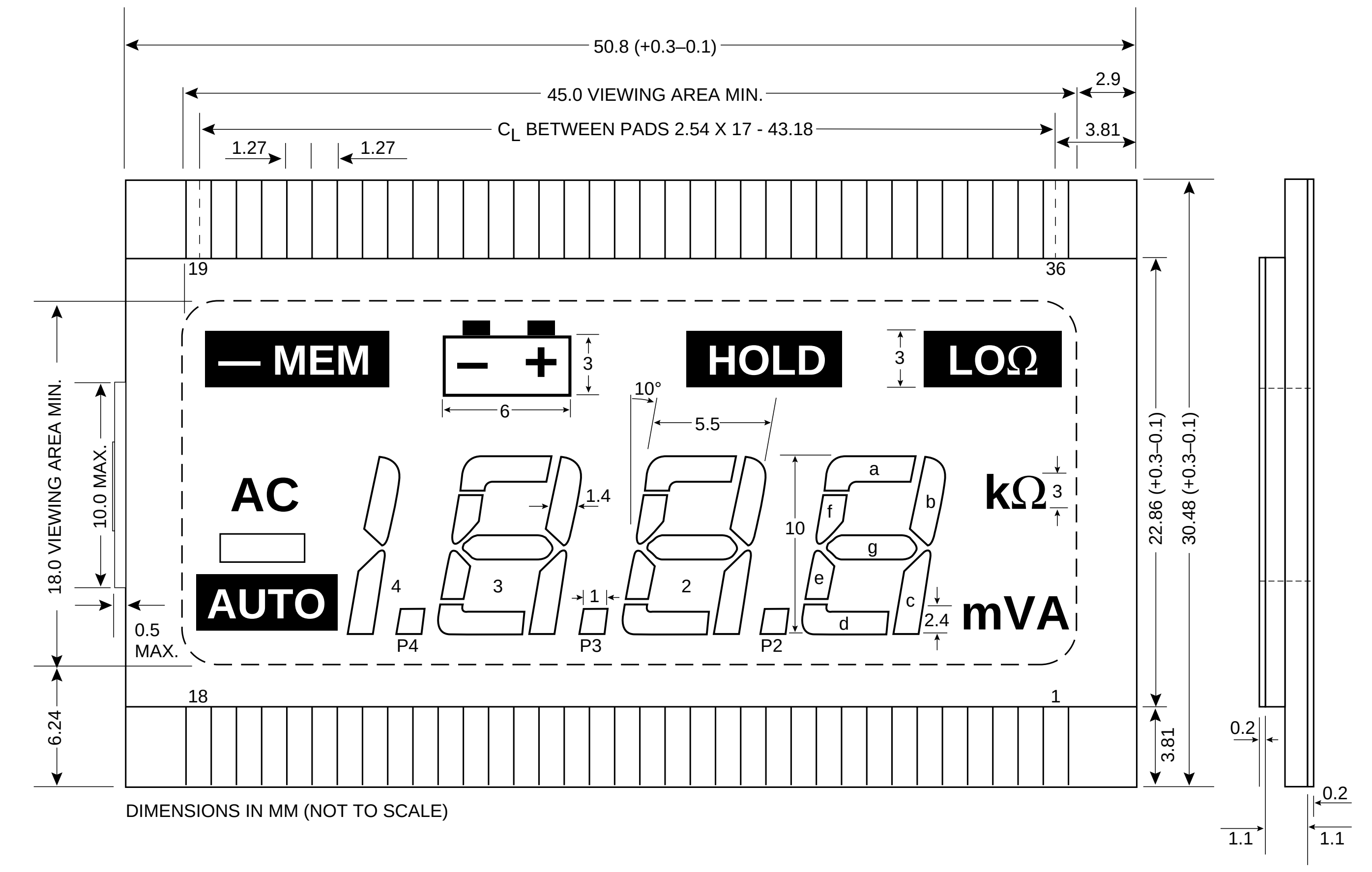
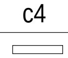
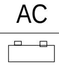
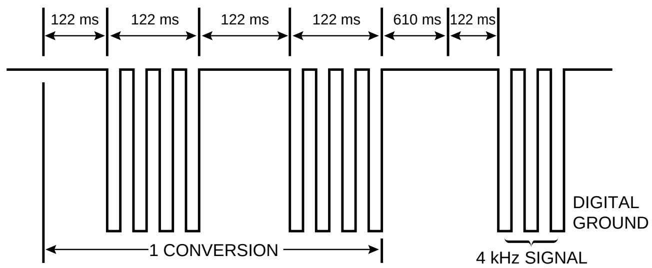


Figure 14. Typical LCD Display Configuration TC815 Triplex

PAD	BP1	BP2	BP3	PAD	COM1	COM2	COM3
1	BP1	/	/	19	/	/	/
2	/	BP2	/	20	/	/	/
3	/	/	BP3	21	/	/	/
4	/	LOΩ	A	22	/	/	/
5	/	Ω	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	/	/	/



Non-Continuous Buzzer Signal Indicates Input Overrange

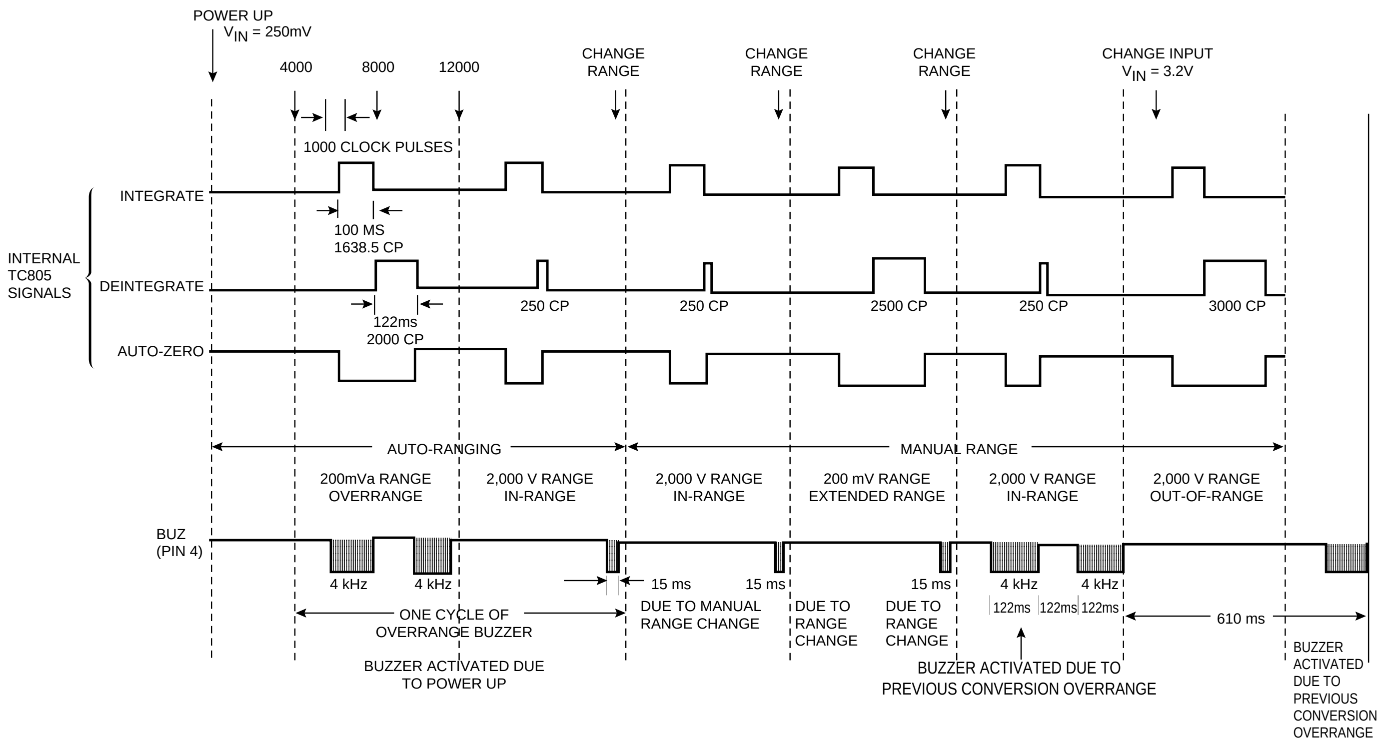


Figure 15. TC815 Timing Waveform for Buzzer Output

EXTERNAL CRYSTAL

The TC815 is designed to operate with a 32,768 Hz 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 (≈ 2 conversions/second). Integration time is 1638.5 clock periods or 100msec.

The 32kHz quartz crystal is readily available and inexpensive. The 32 kHz 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 HX
  Tel: 3-3501151

Contact manufacturer for full specifications.

"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 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 display MSD 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 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, Ω/LOΩ) will also activate the buzzer output for 15msec. A range change during a current measurement will not activate the 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

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 5.

Table 5. Decimal Point Selection

Full-Scale Range	1 * 9 DP3	* 9 DP2	* 9 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

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: 0.4 MHz
- 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 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.

RVBUF Selection (Pin 55)

In auto-range operation, the TC815 operates with a 200 mV 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 200VV full-scale potential.

In manual mode, the extended operating mode is activated giving a 300 mV 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 RVBUF 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

$$\text{RVBUF} = \frac{V_{MAX}(T_I)}{V_{INT}\,(C_I)} \approx 150\text{k}\Omega$$

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 (Figure 16):

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

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

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_X Max = 300Ω
V_X Max = 700mV

$$\text{R}\Omega\text{BUF} = \frac{(V_X\ \text{MAX})\ (T_I)}{C_I\ (V_{INT})} \approx 220\text{k}\Omega$$

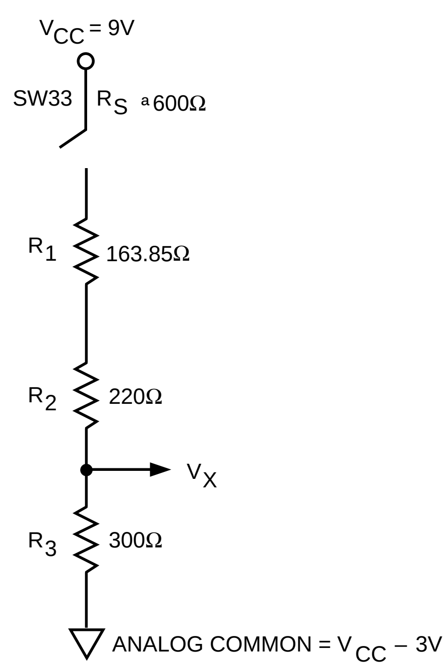


Figure 16. RΩBUF Calculation (200 Ω Manual Operation)

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.

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.

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 75 ppm/°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.

Display Hold Feature

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

The LCD $\overline{\text{HOLD}}$ 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

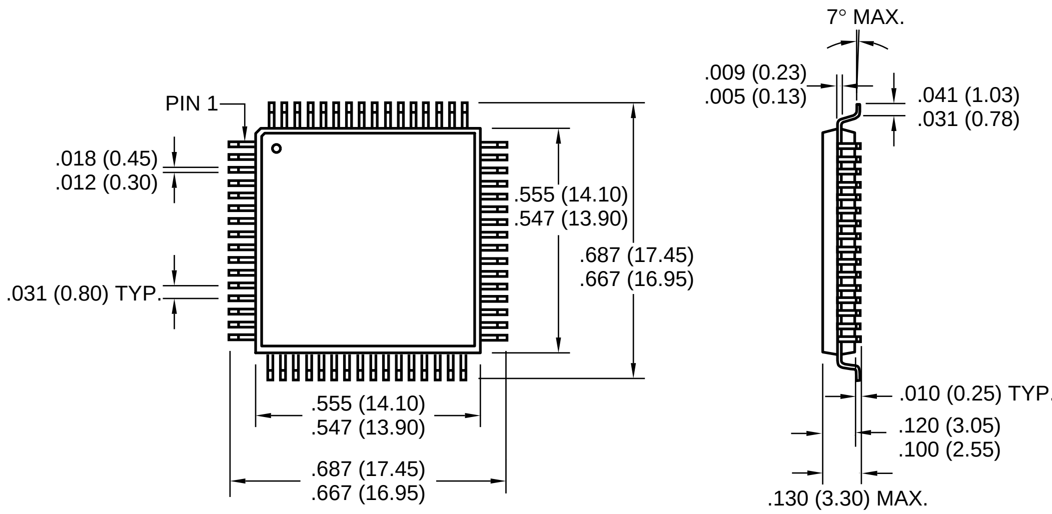
Resistor attenuator networks for voltage and resistance measurements are available from:

- 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

PACKAGE DIMENSIONS

64 -Pin PQFP



Dimensions: mm (inches)

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