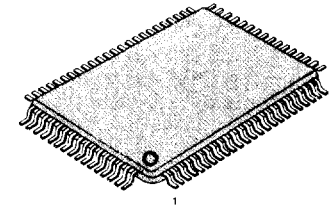
3 3/4-DIGIT 3260-COUNT A/D CONVERTER

The KAD7001 is a low power CMOS dual-slope A/D converter with 3 3/4-digit numeric and 33-segment bar-graph LCD display driver, auto-ranging, and single 3V battery operation.

It is ideal for high performance auto-range DMM applications with 3260 counts full-scale.

The KAD7001 provides many user functions: Manual Range Hold/Data Hold/Auto Power-off/Voltage/Current/Resistance measurement/Diode Test/Continuity Check (Beeper). The built-in high temperature-stable CMOS bandgap reference and a CMOS Op Amp for acto-dc conversion are economical of saving external components. In addtion, the voltage doubler enables a high performance digital multimter to be built with single 3V power supply operation.

80 Q FP



ORDERING INFORMATION

Device	Package	Temperature Range	Resolution
KAD7001CQ	80QFP	0°C ~ 50°C	3 3/4-digit 3260-count

FEATURES

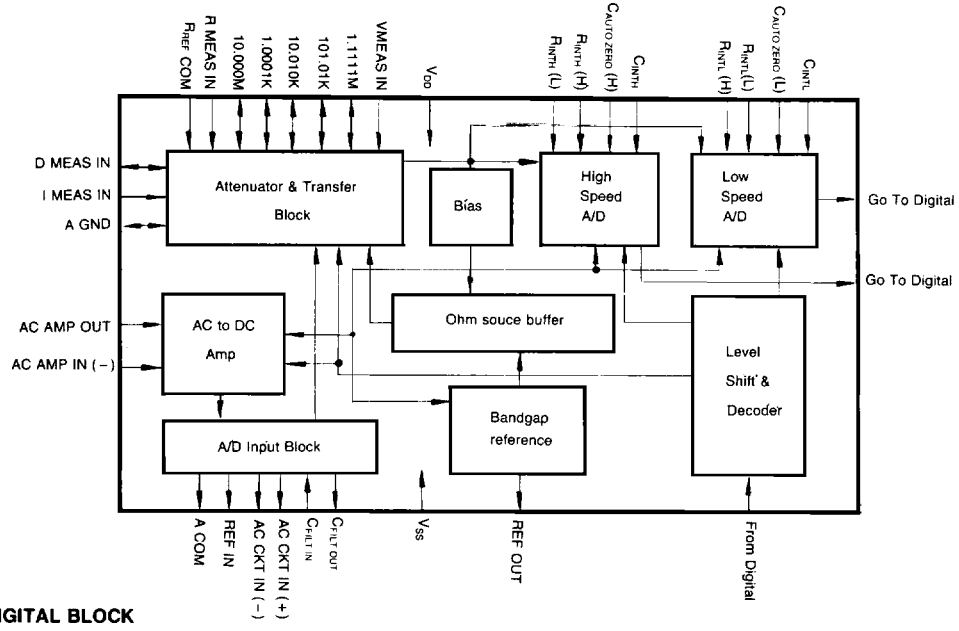
- **Auto Range Function**
  - **-Voltage (DC/AC): 326.0mV (NA for AC), 3.260V, 32.60V, 326.0V, 3260V**
  - **-Resistance: 326.0 Ohm, 3.260K Ohm, 32.60K Ohm, 326.0K Ohm, 3.260M Ohm, 32.60M Ohm**
  - **-Current (DC/AC): 326.0μA, 3260μA, 32.60mA, 326.0mA, 10A**
- **Triplex LCD drive including decimal points, bargraph, and annunciators**
- **Low power consumption: Less than 1.8mW**
- **3V battery operation**
- **Internal voltage doubler, ac-to-dc conversion Op Amp**
- **Range Selection/Display Hold/Auto Power-Off/Diode Test/Continuity Check (Beeper) function**
- **Built-in CMOS bandgap reference**

TYPICAL APPLICATIONS

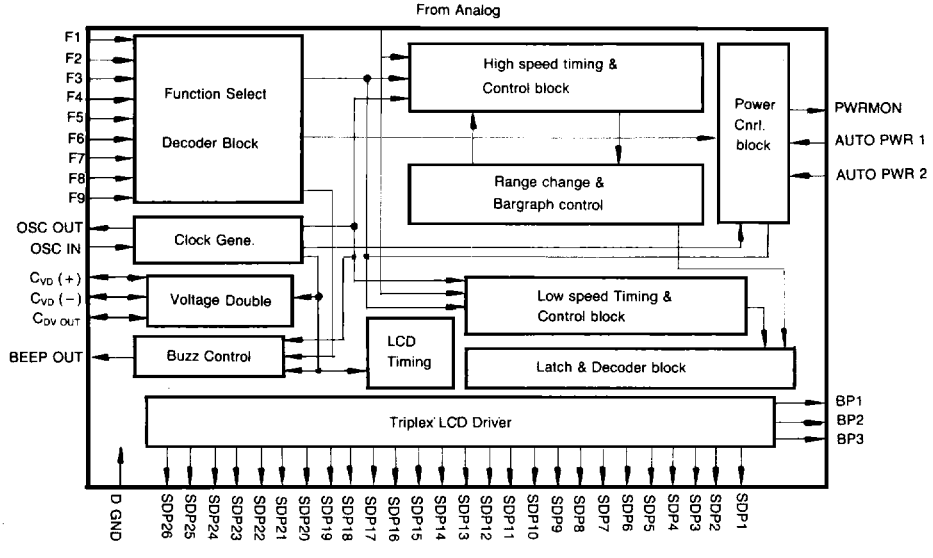
- Hand-held DMM
- Pocket DMM
- Pen-type DMM

BLOCK DIAGRAM

1. ANALOG BLOCK

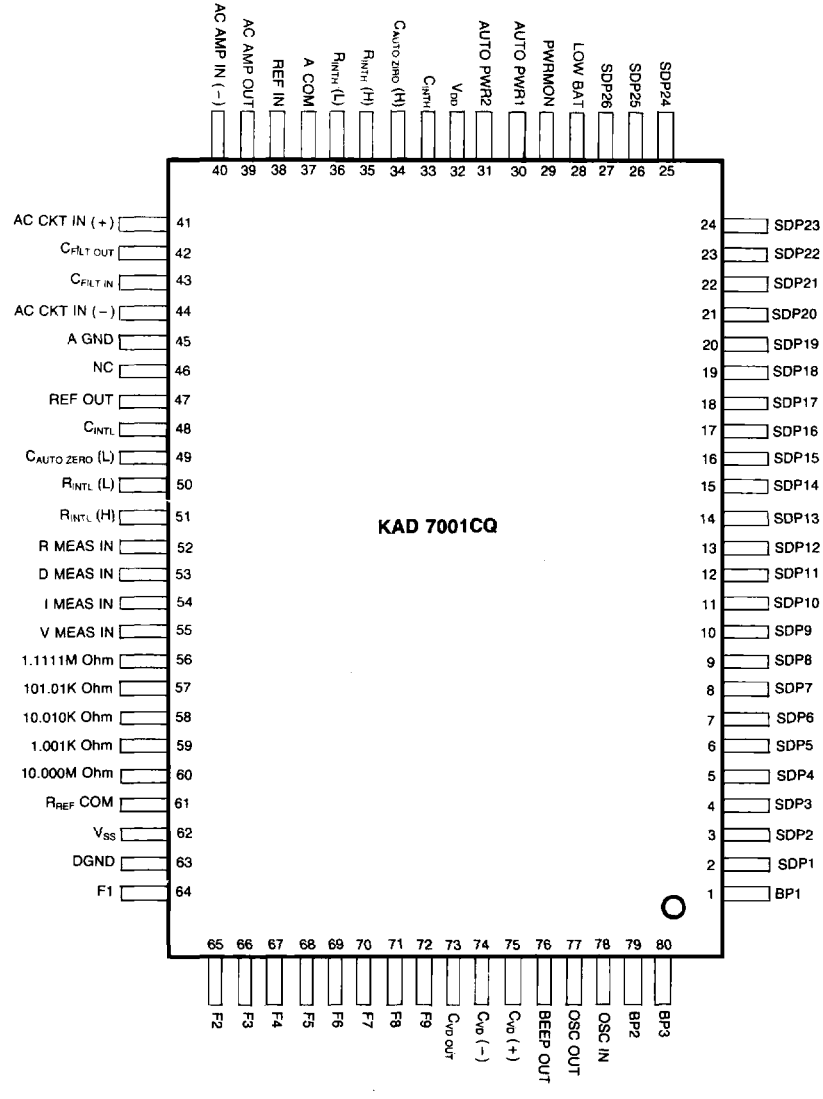


2. DIGITAL BLOCK



PIN CONFIGURATION

Quad Flat Package



Top View

PIN DESCRIPTION

No	Symbol	I/O	Description
1	BP1	O	Backplane 1 of LCD display
2	SDP1	O	Segment display (p31/p32/p33)
3	SDP2	O	Segment display (Ω/V/R-H)
4	SDP3	O	Segment display (K/M/m)
5	SDP4	O	Segment display (⊞/c0/b0)
6	SDP5	O	Segment display (d0/g0/a0)
7	SDP6	O	Segment display (p30/e0/f0)
8	SDP7	O	Segment display (dp1/c1/b1)
9	SDP8	O	Segment display (d1/g1/a1)
10	SDP9	O	Segment display (P29/e1/f1)
11	SDP10	O	Segment display (dp2/c2/b2)
12	SDP11	O	Segment display (d2/g2/a2)
13	SDP12	O	Segment display (p28/e2/f2)
14	SDP13	O	Segment display (dp3/c3/b3)
15	SDP14	O	Segment display (d3/e3/a3, g3)
16	SDP15	O	Segment display (⊣/—/•))
17	SDP16	O	Segment display (AC/D-H/DC)
18	SDP17	O	Segment display (p27/p26/p25)
19	SDP18	O	Segment display (p22/p23/p24)
20	SDP19	O	Segment display (p21/p20/p19)
21	SDP20	O	Segment display (p16/p17/p18)
22	SDP21	O	Segment display (p15/p14/p13)
23	SDP22	O	Segment display (p10/p11/p12)
24	SDP23	O	Segment display (p9/p8/p7)
25	SDP24	O	Segment display (p4/p5/p6)
26	SDP25	O	Segment display (p3/p2/p1)
27	SDP26	O	Segment display (p-/p0)
28	LOW BAT	I	Low battery check voltage input
29	PWRMON	O	Power monitor output
30	AUTO PWR1	I	Auto power ON/OFF selection 1
31	AUTO PWR2	I	Auto power ON/OFF selection 2
32	V_{DD}	I	Supply voltage
33	C_{INTH}	I/O	High-speed A/D integrating capacitor connection
34	$C_{AUTO\ ZERO}$ (H)	I/O	High-speed A/D auto zero capacitor connection
35	R_{INTH} (H)	I/O	High-speed A/D integrating resistor connection (H)
36	R_{INTH} (L)	I/O	High-speed A/D integrating resistor connection (L)
37	A COM	I	Analog circuit reference point. Negative battery supply connetion.
38	REF IN	I	Reference voltage input
39	AC AMP OUT	O	Built-in AC Amp output
40	AC AMP IN (−)	I	Built-in AC Amp negative input

3

PIN DESCRIPTION (Continued)

No	Symbol	I/O	Description
41	AC CKT IN (+)	I	AC measurement positive input
42	$C_{FILT\ OUT}$	0	Output pin for external filter
43	$C_{FILT\ IN}$	I	Input pin for external filter
44	AC CKT IN (−)	I	AC measurement negative input
45	A GND	I	Analog ground
46	NC		No connection. This pin should be open in normal operation
47	REF OUT	0	Built-in bandgap reference voltage output
48	C_{INTL}	I/O	Low-speed A/D integrating capacitor connection
49	$C_{AUTO\ ZERO}$ (L)	I/O	Low-speed A/D auto zero capacitor connection
50	R_{INTL} (L)	I/O	Low-speed A/D integrating resistor connection (L)
51	R_{INTL} (H)	I/O	Low-speed A/D integrating resistor connection (H)
52	R MEAS IN	I	Resistor and diode measurement input
53	D MEAS IN	I/O	Diode and current of high range measurement pin
54	I MEAS IN	I	Input for current measurement
55	V MEAS IN	I	Input for voltage measurement
56	1.1111M Ohm	I/O	Voltage measurement ÷ 10 attenuator (326.0K Ohm range)
57	101.01K Ohm	I/O	Voltage measurement ÷ 100 attenuator (32.60K Ohm range)
58	10.010K Ohm	I/O	Voltage measurement ÷ 1000 attenuator (3.260K Ohm range)
59	1.0001K Ohm	I/O	Voltage measurement ÷ 10000 attenuator (326.0 Ohm range)
60	10.000M Ohm	I/O	Resistance measurement 3.260M Ohm range
61	R_{REF} COM	I	Attenuator resistor common connection
62	V_{SS}	I	Negative supply voltage connection of analog circuit
63	D GND	I	Digital ground
64	F1	I	Function input pin 1
65	F2	I	Function input pin 2
66	F3	I	Function input pin 3
67	F4	I	Function input pin 4
68	F5	I	Function input pin 5
69	F6	I	Function input pin 6
70	F7	I	Function input pin 7
71	F8	I	Function input pin 8
72	F9	I	Function input pin 9
73	$C_{VD\ OUT}$	I/O	Voltage doubler output
74	C_{VD} (−)	I/O	Voltage doubler capacitor connection (−)
75	C_{VD} (+)	I/O	Voltage doubler capacitor connection (+)
76	BEEP OUT	0	Beep frequency output (4096Hz)
77	OSC OUT	0	X-tal connection (32.768KHz)
78	OSC IN	I	X-tal connection
79	BP2	0	Backplane 2 of LCD display
80	BP3	0	Backplane 3 of LCD display

ABSOLUTE MAXIMUM RATINGS (Note 1 & 2)

Characteristis	Symbol	Value	Unit
Supply Voltage (V_{DD} to A COM)	V_{DD}	4	V
Supply Voltage (V_{SS} to A COM)	V_{SS}	-4	V
Digital Input Voltage	DV_{IN}	$-0.3 \sim V_{DD} + 0.3$	V
Analog Input Voltage	AV_{IN}	$V_{SS} - 0.3 \sim V_{DD} + 0.3$	V
EDS Susceptibility (Note 3)	V_{EDS}	$-1600 \sim +2000$	V
Digital Output Current	DI_{OUT}	$-1 \sim +1$	mA
Analog Output Current	AI_{OUT}	$-3 \sim +3$	mA
Beep Output Current	I_{BEEP}	$-1 \sim +1$	mA
LCD Output Current	I_{LCD}	$-0.1 \sim +0.1$	mA
Operating Temperature Range	T_{OPR}	$0 \sim +50$	°C
Storage Temperature Range	T_{STG}	$-40 \sim +125$	°C

Note 1: ABSOLUTE MAXIMUM RATINGS are those values beyond which the life of the device may be impaired permanently. Normal operation is not guaranteed at or above these exttremes.

Note 2: All voltages are measured with respect to the A COM, unless otherwise noted. The separate A GND, D GND, and A COM should always be wired together.

Note 3: 100pF discharged through a 1.5K resistor.

RECOMMENDED OPERATING CONDITIONS

Charactersistics	Symbol	Value			Unit
		Min	Typ	Max	
Supply Voltage	V_{DD}	2.4	3.0	3.6	V
Supply Voltage	V_{SS}	-2.4	-3.0	-3.6	V
Digital Input "L" Voltage	DV_{IL}			0.5	V
Digital Input "H" Voltage	DV_{IH}	$V_{DD} - 0.5$			V
Reference Input Voltage	REF IN		0.32768		V
LCD-On Drive Voltage	V_{LCD-ON}	2.5			V
LCD-Off Drive Voltage	$V_{LCD-OFF}$			1.3	V
Operating Temperature Range	Topr	0		50	°C
Clock Frequency	f		32.768		KHz

ELECTRICAL CHARACTERISTICS

(Converter Specifications: V_{DD} = 3V, REF IN = 0.32768V, f = 32.768KHz, T_A = 25°C, unless otherwise noted.)

Characterisitics		Symbol	Test Conditions	Min	Typ	Max	Unit
Supply Current		I_{DD}	at DCV mode, V_{IN} = OmV with voltage doubler operated			600	μA
Power-off Supply Current		I_{PO}	at Power off (down)		0	4.0	μA
Digital Input "H" Current		I_{IH}	V_{IH} = 3V	−1.0		+1.0	μA
Digital Input "L" Current		I_{IL}	V_{IL} = 0V	−10			μA
Measuring Pin Leakage		I_{LEAK}		−10		+10	pA
Digital Input "H" Voltage		V_{IH}		2.5			V
Digital Input "L" Voltage		V_{IL}				0.5	V
Built-in Reference Voltage Output Range		REF OUT		1.1	1.28	1.4	V
Built-in Reference Voltage Output Voltage Coefficient		ΔREF OUT	V_{DD} = 2.4 ~ 3.6V	−2000		+2000	ppm/V
Battery Check Internal Comparator Off-Set Voltage		V_{BATT}	on pin 47 voltage	−60		+60	mV
LCD-On Drive Voltage		V_{LCD-ON}		2.5			V
LCD-Off Drive Voltage		$V_{LCD-OFF}$				1.3	V
Linearity	DCV Measurement	ERR-DCV		−0.8		+0.08	%/FS
	DCA Measurement	ERR-DCA		−0.15		+0.15	%/FS
	ACV Measurement	ERR-ACV		−0.1		+0.1	%/FS
	ACV Measurement	ERR-ACA		−0.2		+0.2	%/FS
	Resistance Measurement	ERR-R	except 32.6M Ohm	−0.08		+0.08	%/FS
			32.6M Ohm range	−0.5		+0.5	%/FS
	Diode Test	ERR-D	fullscale = 2.0V	−0.2		+0.2	%/FS
	Option Measurement	ERR-OPT		−0.08		+0.08	%/FS
Beep Out Frequency		f_{BEEP}		4095	4096	4097	Hz
Continuity Check Value		R_{CC}		18.3		20.7	Ohm
AC-to-DC Conversion Amp Gain		A_V	input range = −1V ~ 1V	70			dB
O.L Display Count		D O.L		3240		3290	count

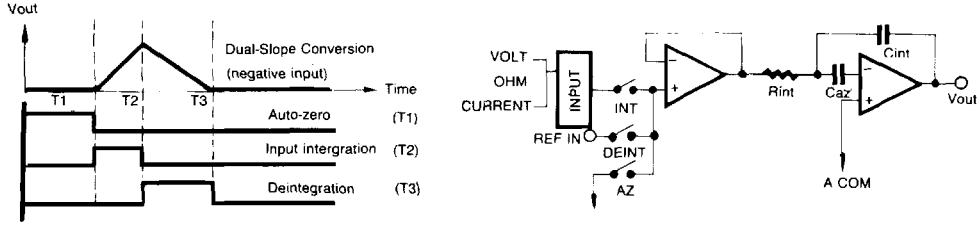
FUNCTIONAL DESCRIPTION

1. KAD7001 Integrating Dual-slope A/D Converter

The KAD7001 consists of a low-speed A/D and a high-speed A/D conversion circuit.

1) Low-speed A/D conversion circuit
When an analog DC input signal under 320mV is applied, the low-speed conversion proceeds like a sequence of AUTO ZERO (A.Z)—> INTEGRATION (INT)—> DEINTEGRATION (DEINT)—>AUTO ZERO.
One conversion takes 519.7ms in the voltage measurement mode.
The counter data of DEINTEGRATION interval is transferred to the LCD and the output value is determined.

2) High-speed A/D conversion circuit
Range selection and bargraph display operate by the high-speed conversion which is like that of low-speed A/D conversion. One conversion takes 80ms in the voltage measurement mode.



Waveform and Block Diagram of Dual-sslope A/D converter (Negative input)

3) Conversion time

Time / Speed	T1	T2	T3	Conversion time (T1 + T2 + T3)
Low-speed A/D	100ms	200ms	219.7ms (109.8ms)*	519.7ms (409.8ms)
High-speed A/D	40ms	20ms	20ms (10ms)	80ms (70ms)

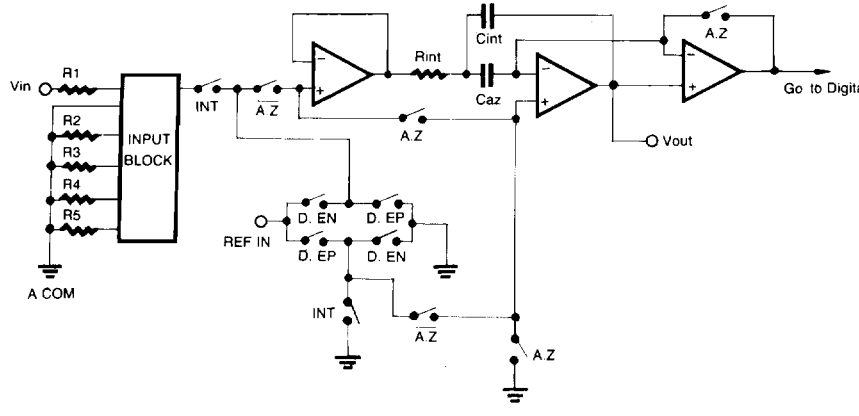
* The value of parenthesis is for current measurement mode.

2. Voltage Measurement

In the voltage measurement mode, input impedance is very high because input signal is applied to the integrator through a internal buffer ampifier.

Ranges are automatically changed by internal switches which select a proper route and attenuate an unknown voltage input to the ratio of 1/1, 1/10, 1/100, 1/1000, 1/10000. 1.1111M ohm, 101.01K ohm, 10.010K ohm, and 1.0001K ohm of attenuator resistors are connected to 10M ohm registor tandemly.

Range	Attenuator (in tandem)	Attenuation Ratio	Resolution
326.0mV (R1)	10M ohm	1	0.1mV
3.260V (R2)	10M & 1.1111M ohm	1/10	1mV
32.60V (R3)	10M & 101.01K ohm	1/100	10mV
326.0V (R4)	10M & 10.01K ohm	1/1000	100mV
3260V (R5)	10M & 1.0001K ohm	1/10000	1V

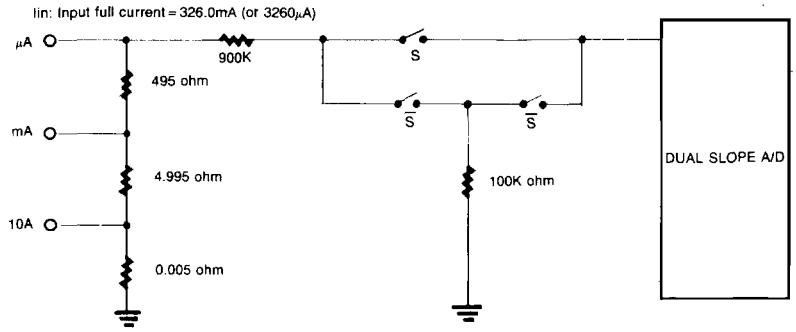


	Counter	Time	Rint	Vout
INT	3277	200.0ms	327K ohm	(Vin•Tint)/(R•Cint)
DEINT	3600	219.7ms	327K ohm	Vout-(Vref•Tdeint)/(R•Cint)

3. Current Measurement

Input terminals consist of μA, mA, and 10A and ranges consist of two auto ranges according to the level of the input.

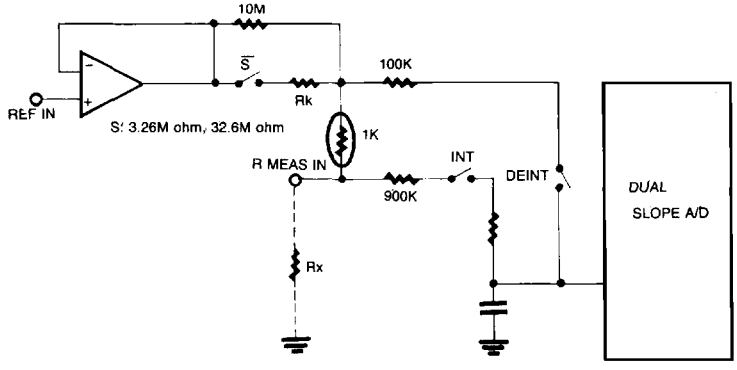
Input Terminal	Range	Internal Switch	Attenuation Ratio	Resolution
μA	326.0 μA	S	1	0.1μA
	3260μA	$\bar{S}$	1/10	1μA
mA	32.60mA	S	1	10μA
	326.0mA	$\bar{S}$	1/10	1μA
10A	10A	S		



	Counter	Time	Rint	Vout
INT	3277	200.0mS	327Kohm	
DEINT	3600	109.8mS	327Kohm	Vout-(Vref·Tdeint/2)/(R·Cint)

4. Resistance, Continuity Measurement

In the resistance measurement mode, each attenuation resistor is connected to a 10M ohm resistor parallelly.

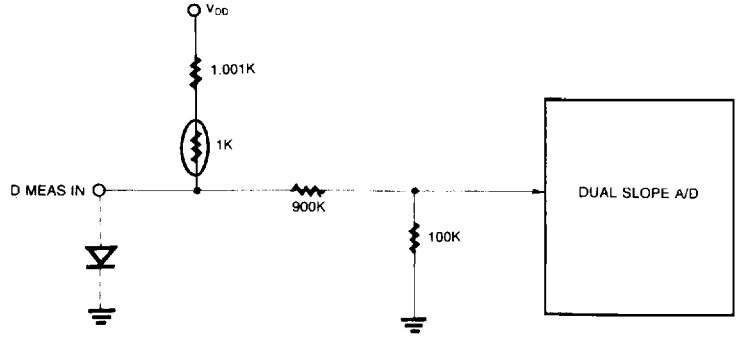


Range	Rk
326.0 ohm (R1)	1.001K ohm
3.260Kohm (R2)	10.010Kohm
32.60Kohm (R3)	101.01Kohm
326.0Kohm (R4)	1.111Mohm
3.260Mohm (R5)	10.00Mohm
32.60Mohm (R32M)	10.00Mohm

Range			Counter	Time	Rint
Resistance	except 32.60Mohm	INT DEINT	3277 3600	200.0mS 129.7mS	327K ohm 1Mohm
	32.60Mohm	INT DEINT	3050 3600	186.0mS 219.7mS	1Mohm 327K ohm
Continuity		same as 326.0 ohm range			

5. Diode Test

In the diode test mode, if a input voltage is over 2.01V (201 counts) then "O.L" is displayed in the LCD and any more measurement is impossible.



FUNCTION AND RANGE TABLE

1. When F5 = 0

No	F2	F1	F4	F3	F9 = 1/F9 = 0	R1, DP1	R2, DP3	R3, DP2	R4, DP1	R5, DP3	R32M, DP2	Remark
1	0	0	0	0	DC/AC VOLT	●	●	●	●	●	X	TPD
2	0	0	0	1	DC/AC VOLT	●	●	●	●	●	X	
3	0	0	1	0	DC/AC VOLT	●	●	●	●	●	X	
4	0	0	1	1	OHM/Continuity	●	●	X	X	X	X	F9 = 0, F8:T
5	0	1	0	0	OPTION only	X	X	X	X	X	X	326m VOLT
6	0	1	0	1	DC VOLT	●	●	●	●	●	X	
7	0	1	1	0	DC VOLT	●	●	●	●	●	X	
8	0	1	1	1	Continuity/Diode	•))	⊣◀					F9 = 1, F7:T
9	1	0	0	0	LCD test	X	X	X	X	X	X	
10	1	0	1	0	DC/AC VOLT	●	●	●	●	●	X	
11	1	0	1	1	OHM	●	●	●	●	●	●	F6 = 1
						●	●	●	●	●	X	F6 = 0
12	1	1	0	0	OPTION	X	X	X	X	X	X	326m VOLT
13	1	1	0	1	DC/AC mA	X	X	●	●	X	X	
14	1	1	1	0	DC/AC μA	X	X	X	●	●	X	
15	1	1	1	1	DC/AC VOLT	●	●	●	●	●	X	

* R1 ~ R5: Range 1 ~ Range 5
* R32M: R32M is 32M ohm range of resistance measurement.
* DP1 ~ DP3: Dot point 1, 2, 3 on the LCD
* F7: Manual Range Hold (to release 'RH', F7 = 0 during over 1sec)
* F8: Data Hold (by toggling)
* F5: Mode can be changed by a toggle switch with F9 (F9 = 1 ⟶ 0) when F5 = 0
  Mode can be changed by a touch switch with F9 (F9 = 1 ⟶ 0 ⟶ 1)
* TPD: Auto power off time (10 minutes)
* F1 ~ F9: Initial state using internal pull up (DC 326.0m V Range) So every function pin (F1 ~ F9) is "1" state unless certain input is given.
* T: Toggle

2. When F5 = 1

No	F2	F1	F4	F3	F9 = 1→0→1	R1 (DP1)	R2 (DP3)	R3 (DP2)	R4 (DP1)	R5 (DP3)	R32 (DP2)	Remark
16	0	0	0	0	DC/AC VOLT	●	●	●	●	●	X	TPD
17	0	0	0	1	DC/AC VOLT	●	●	●	●	●	X	
18	0	0	1	0	DC/AC VOLT	●	●	●	●	●	X	
19	0	0	1	1	OHM	●	●	●	●	●	●	
					CONTINUITY	●	X	X	X	X	X	F9:T
					DIODE	X	●	X	X	X	X	F9:T
20	0	1	1	1	CONTINUITY	●	X	X	X	X	X	
					DIODE	X	●	X	X	X	X	F9:T

3. Auto Power Off Function

Power turned off by 10 minutes unless input value changed within a defined time.

*This function selected as follows.

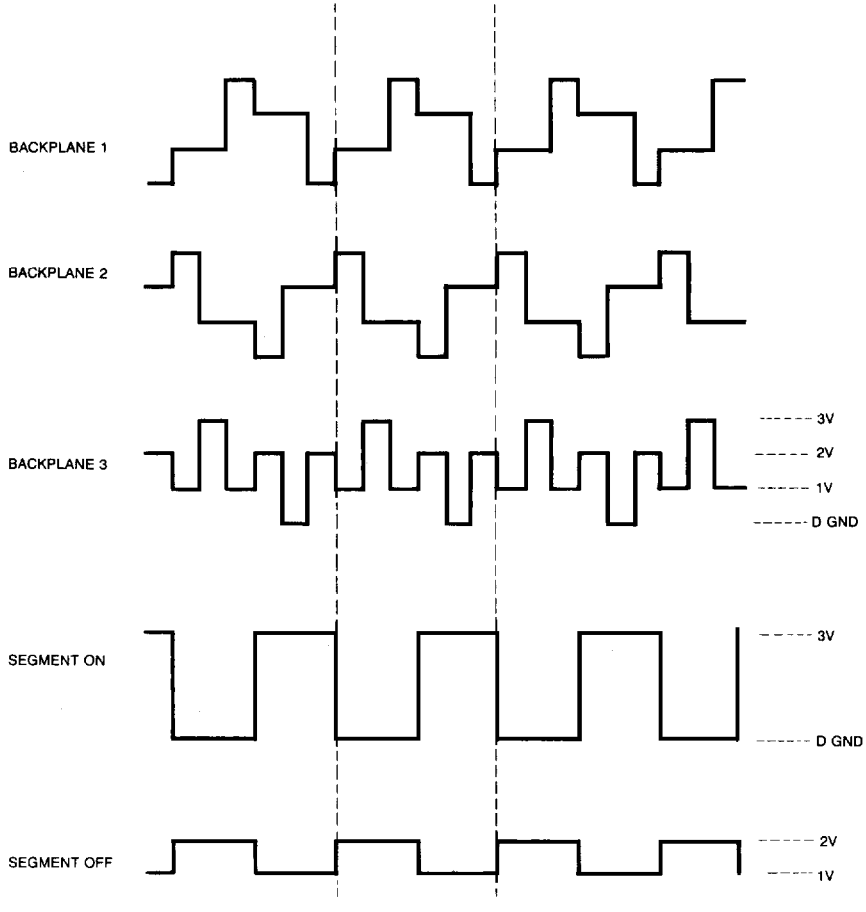
Auto PWR1 (Pin 30) + Auto PWR2 (Pin 31)	0 + 0	1 + 0	0 + 1	1 + 1
POWER	Power On	Auto Power Off	Off	Off

4. Full Display Value according to modes

Mode		R1	R2	R3	R4	R5	R32M
Voltage	DC	326.0mV	3.260V	32.60V	326.0V	3260V	
	AC		3.260V	32.60V	326.0V	3260V	
Current (AC/DC)	mA			32.60mA	326.0mA		
	μA				326.0μA	3260μA	
Resistance (ohm)		326.0	3.260K	32.60K	326.0K	3.260M	32.60M

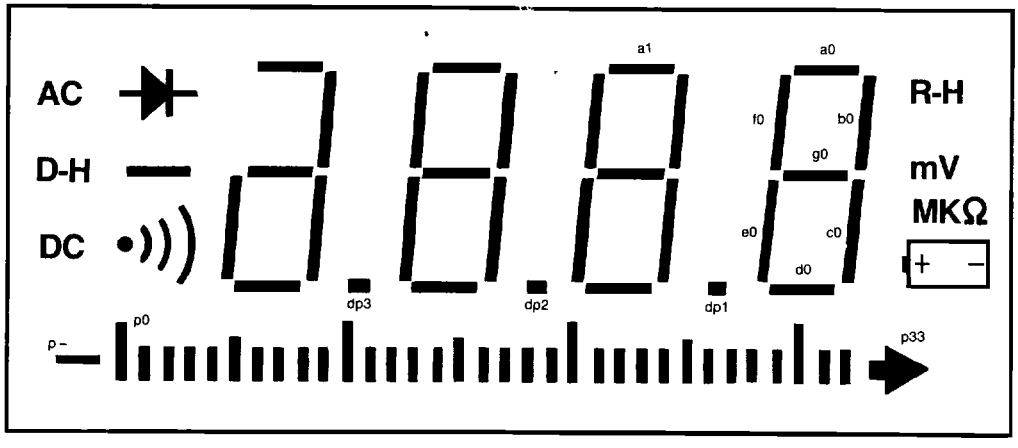
* DP3 of R4 is not displayed under voltage, current mode.

LCD DRIVE WAVEFORM



Triplexed LCD Drive Waveforms*

LCD DISPLAY

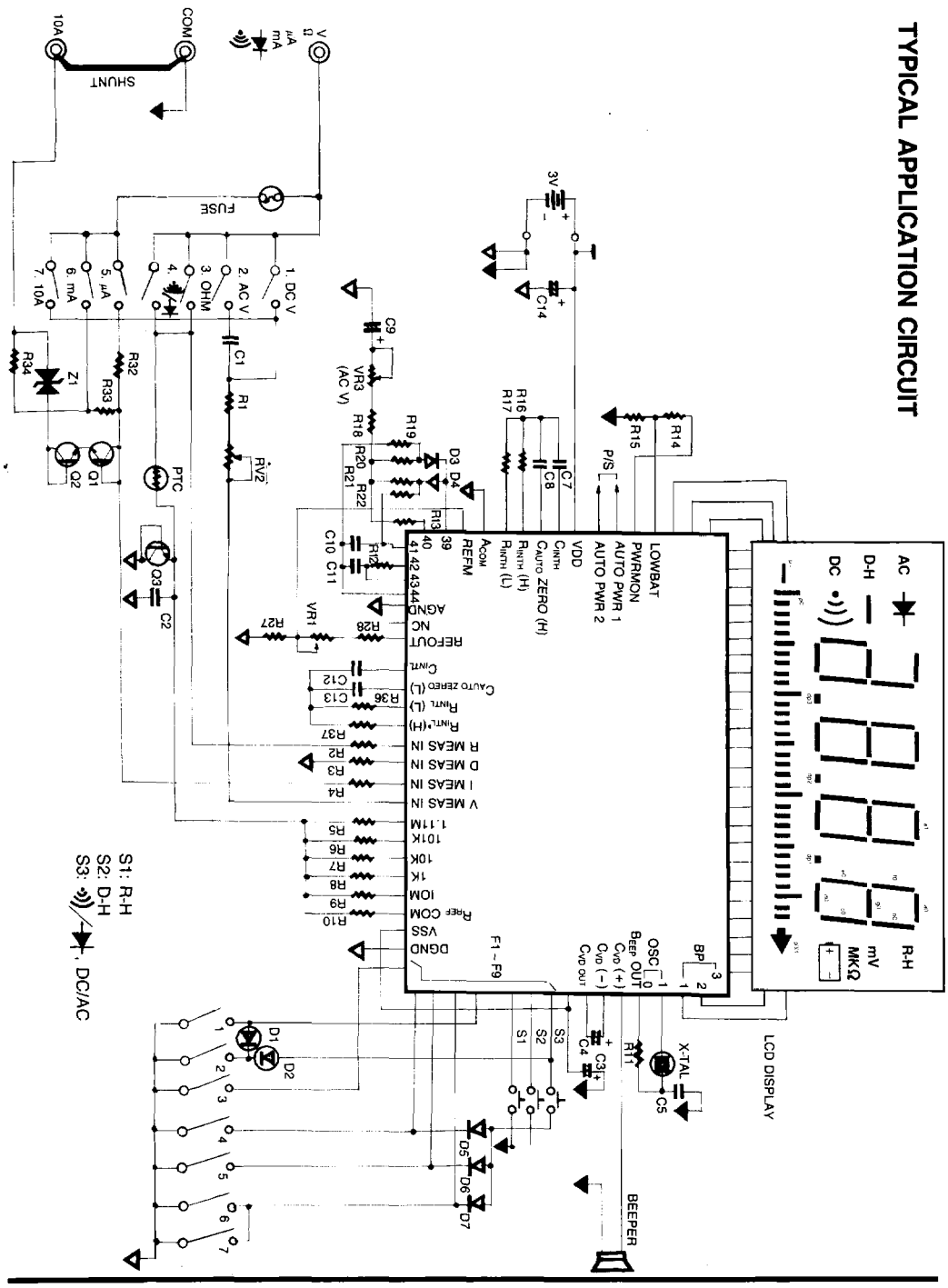


TRIPLEXED LCD DISPLAY FORMAT

BP No \ IC PIN No	2	3	4	5	6	7	8	9	10	11	12	13	14
BP2	79	p31	Ω	K	d0	p30	dp1	d1	p29	dp2	d2	p28	dp3
BP3	80	p32	V	M	c0	g0	e0	c1	g1	e1	c2	g2	e2	c3
BP1	1	p33	R-H	m	b0	a0	f0	b1	a1	f1	b2	a2	f2	b3

BP No \ IC PIN No	15	16	17	18	19	20	21	22	23	24	25	26	27
BP2	79	d3		AC	p27	p22	p21	p16	p15	p10	p9	p4	p3	p-
BP3	80	e3		D-H	p26	p23	p20	p17	p14	p11	p8	p5	p2	p0
BP1	1	a3, g3		DC	p25	p24	p19	p18	p13	p12	p7	p6	p1	

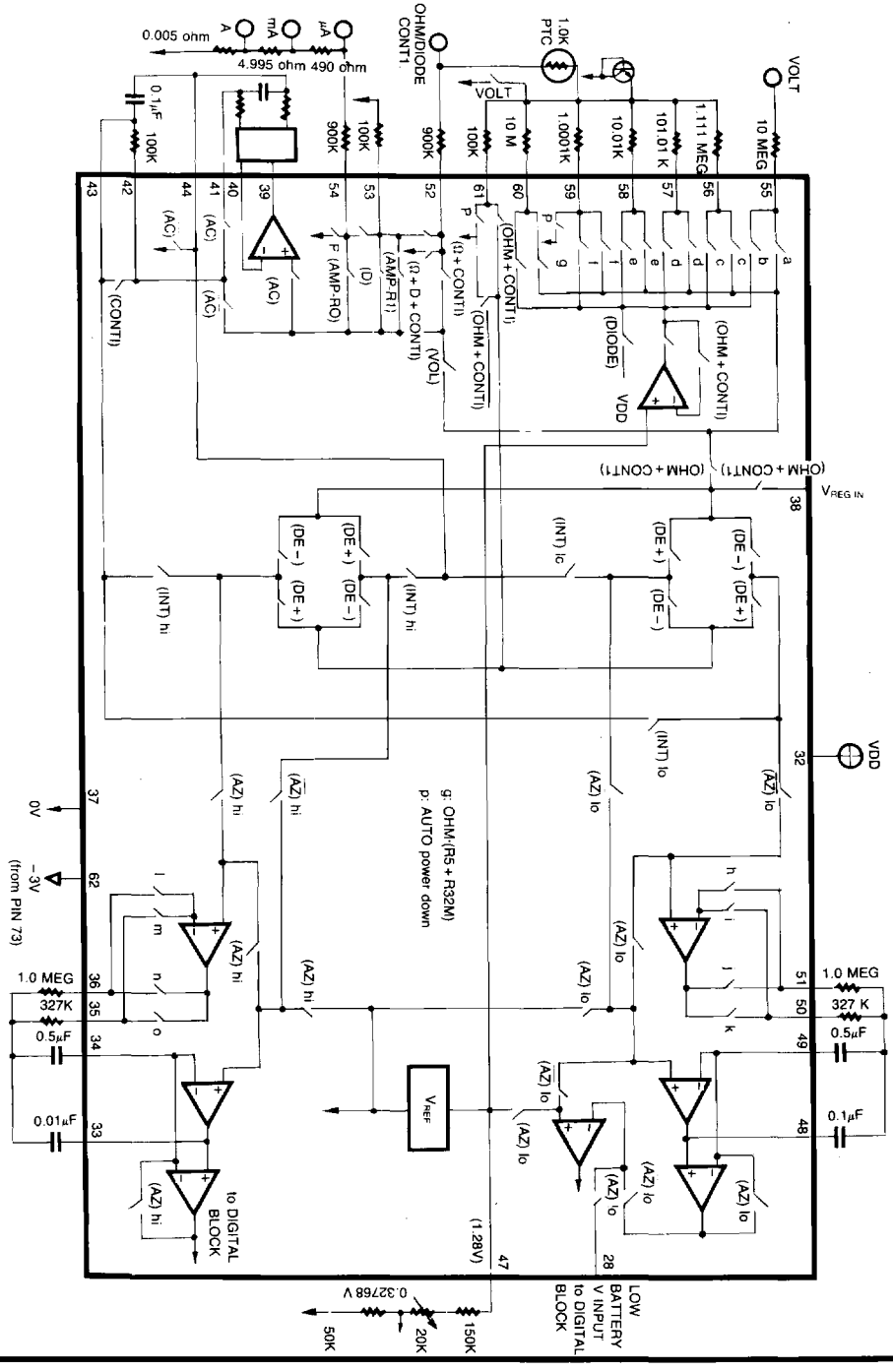
TYPICAL APPLICATION CIRCUIT



COMPONENT VALUE

No	Value	Unit	No	Value	Unit
R1	9900	K Ohm	C8	0.22	μF
R2	909	K Ohm	C9	10	μF
R3	100	K Ohm	C10	0.0068	μF
R4	900	K Ohm	C11	0.1	μF
R5	101.01	K Ohm	C12	0.15	μF
R6	101.01	K Ohm	C13	1	μF
R7	10.01	K Ohm	C14	10	μF
R8	1.001	K Ohm			
R9	10	M Ohm			
R10	100	K Ohm	VR1	20	K Ohm
R11	470	K Ohm	VR2	200	K Ohm
R12	0.1	M Ohm	VR3	500	Ohm
R13	100	K Ohm			
R14	160	K Ohm			
R15	150	K Ohm	D1	1N4148	
R16	324	K Ohm	D2	1N4148	
R17	1	M Ohm	D3	1N4148	
R18	8.2	K Ohm	D4	1N4148	
R19	100	K Ohm	D5	1N4148	
R20	10	K Ohm	D6	1N4148	
R21	10	K Ohm	D7	1N4148	
R22	100	K Ohm			
R27	50	K Ohm			
R28	150	K Ohm	Q1	C2500	
R32	39	Ohm	Q2	C2500	
R33	495	Ohm	Q3	C945	
R34	4.995	Ohm			
R36	324	K Ohm	X-Tal	32768	Hz
R37	990	K Ohm			
			Z1	ZENAMIC 220	
C1	0.022	μF			
C2	0.022	μF			
C3	10	μF			
C4	10	μF			
C5	10	pF			
C7	0.015	μF			

INTERNAL SWITCH DIAGRAM



TEST CIRCUIT