ES51971
3400 AUTO DMM

Features

- Full automatic measurement
  - Voltage measurement
  - Current measurement
  - Resistor measurement
- 3400 count display
- Range change function
- Data hold function
- Diode measurement
- Continuity check
- External reference voltage
- Serial data output (RS232 format)
- Auto power off and re-power on
- Low battery detect (3V and 9V)
- Internal RC oscillator or external crystal oscillator
- 3V DC power supply
- 100 pin flat package

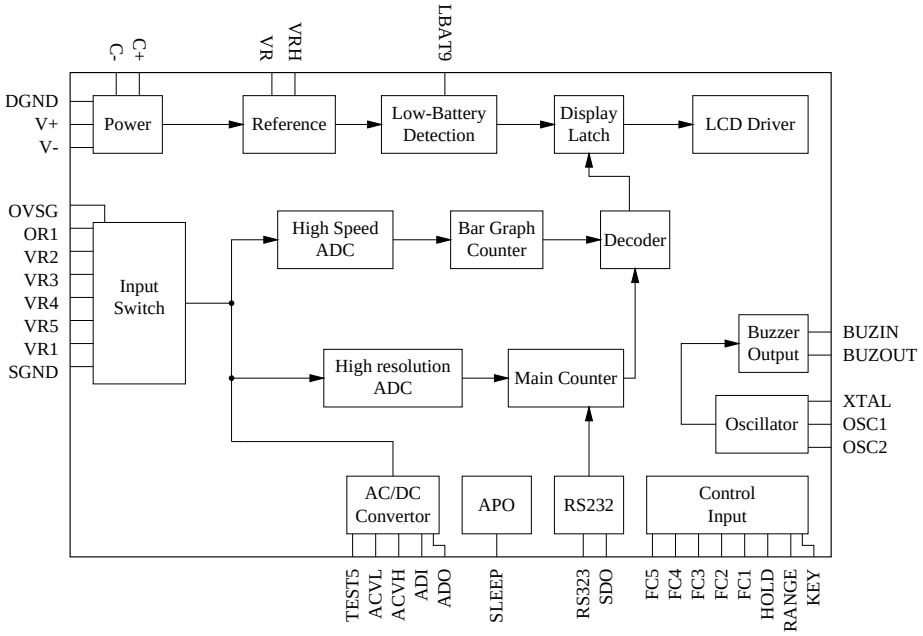
Description

ES51971 is an integrated analog-to-digital converter (ADC) with 3400 counts and bar graph LCD display, automatic range selection, and 3V DC power supply. Automatic range selection is provided for voltage (AC/DC) measurement, resistor measurement, and current measurement. Expensive and bulky mechanical range switches are not required. Other features include data holding, diode measurement, continuity checking, low battery detection, auto power off, re-power on, and RS232 data output.

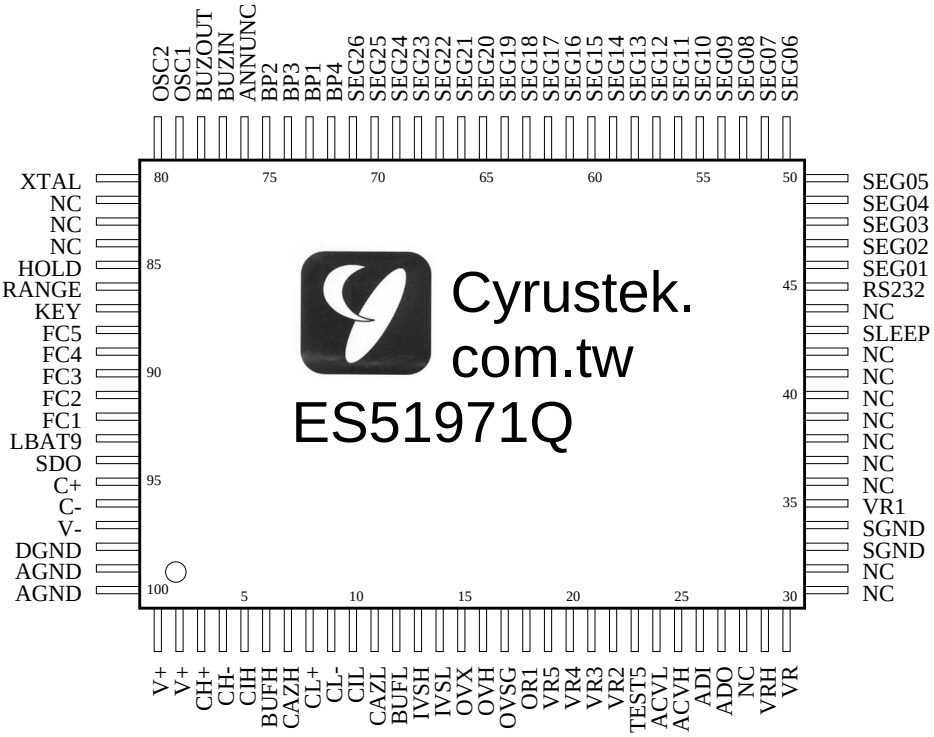
Application

Digital Multimeter.

Block Diagram



Pin Assignment



Pin Description

Pin No.	Symbol	Type	Description
1	V+	P	Positive supply voltage, output of on-chip DC-DC converter.
2	V+	P	Positive supply voltage, output of on-chip DC-DC converter
3	CH+	IO	High speed positive connection for reference capacitor.
4	CH−	IO	High speed negative connection for reference capacitor.
5	CIH	O	High speed integrator output. Connected to integral capacitor.
6	BUFH	O	Integration resistor connection for high speed buffer output.
7	CAZH	O	High speed auto-zero capacitor connection.
8	CL+	IO	High resolution positive connection for reference capacitor.
9	CL−	IO	High resolution negative connection for reference capacitor.
10	CIL	O	High resolution integrator output. Connected to integral capacitor.
11	CAZL	O	High resolution auto-zero capacitor connection.
12	BUFL	O	Integral resistor connection for high resolution buffer output.
13	IVSH	I	High current measurement input.
14	IVSL	I	Low current measurement input.
15	OVX	I	Input high voltage for resistance measurement.
16	OVH	I	Output connection for resistance measurement.
17	OVSG	I	Sense low voltage for resistance measurement.
18	OR1	O	Reference resistor connection for 399.9Ω range.
19	VR5	O	Voltage measurement ÷10000 attenuator (3400V.)
20	VR4	O	Voltage measurement ÷1000 attenuator (340.0V.)
21	VR3	O	Voltage measurement ÷100 attenuator (34.00V.)
22	VR2	O	Voltage measurement ÷10 attenuator (3.400V.)
23	TEST5	IO	Testing pin.
24	ACVL	O	Negative output of AC to DC converter.
25	ACVH	O	Positive output of AC to DC converter.
26	ADI	I	Negative input of internal AC to DC OpAmp .
27	ADO	O	Output of internal AC to DC OpAmp.
28	NC	–	No connection.
29	VRH	O	Output of band-gap voltage reference. Typically -1.2V.
30	VR	I	Reference input voltage connection. Typically -100mV.
31	NC	–	No connection.
32	NC	–	No connection.
33	SGND	G	Signal ground.
34	SGND	G	Signal Ground.
35	VR1	I	Measurement input.
36	NC	–	No connection.
37	NC	–	No connection.
38	NC	–	No connection.
39	NC	–	No connection.
40	NC	–	No connection.
41	NC	–	No connection.
42	NC	–	No connection.
43	SLEEP	O	Asserts low in the sleep mode.
44	NC	–	No connection.
45	RS232	I	Pulse low to enable serial data output.
46 – 71	SEG01 – SEG26	O	LCD segment line 01 – 26.

continued on next page...

...continued from previous page

Pin No.	Symbol	Type	Description
72	BP4	O	LCD backplane 4.
73	BP1	O	LCD backplane 1.
74	BP3	O	LCD backplane 3.
75	BP2	O	LCD backplane 2.
76	ANNUNC	O	Square wave output at the backplane frequency, synchronized to BP1. ANNUNC can be used to control display annunciator. Connect an LCD segment to ANNUNC to turn it on; connect an LCD segment to its backplane to turn it off.
77	BUZIN	I	Enables the buzzer. Low active.
78	BUZOUT	O	Outputs an 2KHz audio frequency signal for driving piezoelectric buzzer when BUZIN is low.
79	OSC1	I	Crystal oscillator input connection.
80	OSC2	O	Crystal oscillator output connection.
81	XTAL	I	The chip uses internal RC oscillator if this pin is connected to V−, and uses external crystal oscillator if this pin is floating or connected to DGND.
82	NC	–	No connection.
83	NC	–	No connection.
84	NC	–	No connection.
85	HOLD	I	Pulse low to enable HOLD mode.
86	RANGE	I	Pulse low to enable manual mode and manual range selection.
87	KEY	I	Pulse low to change mode.
88	FC5	I	Switch 5 for function selection.
89	FC4	I	Switch 4 for function selection.
90	FC3	I	Switch 3 for function selection.
91	FC2	I	Switch 2 for function selection.
92	FC1	I	Switch 1 for function selection.
93	LBAT9	I	Low battery configuration. If 3V battery is used, connect it to AGND. The default low-battery threshold voltage is −2.3V. If 9V battery is used, the low battery annunciator is displayed when the voltage of this pin is less than VRH (−1.2V).
94	SDO	O	RS232 compliant serial data output.
95	C+	O	Positive capacitor connection for on-chip DC-DC converter.
96	C−	O	Negative capacitor connection for on-chip DC-DC converter.
97	V−	P	Negative supply voltage. Connecting to battery negative terminal.
98	DGND	G	Digital ground, connected to battery positive terminal.
99	AGND	G	Analog ground.
100	AGND	G	Analog ground.

Absolute Maximum Ratings

Characteristic	Rating
Supply Voltage (V− to AGND)	-4V
Analog Input Voltage	V− − 0.6 to V+ + 0.6
V+	V+ ≥(AGND/DGND + 0.5V)
AGND/DGND	AGND/DGND ≥ (V− − 0.5V)
Digital Input	V− − 0.6 to DGND + 0.6
Power Dissipation, Flat Package	500mW
Operating Temperature	0°C to 70°C
Storage Temperature	−40°C to 125°C

Electrical Characteristics

$T_A = 25°C, V- = -3V$

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Units
Power supply	V−		-3.5	-3.0	-2.2	V
Operating supply current in DCV mode	I_{DD}	Normal operation	–	1.2	1.7	mA
	I_{SS}	In sleep mode	–	0.1	5	μA
Voltage roll-over error	REV	10MΩ input resistor	–	–	±0.1	%F.S.[1]
Bar graph roll-over error	REB		–	–	±0.5	%F.S.
Voltage nonlinearity	NLV	Best case straight line	–	–	±0.1	%F.S.
Bar graph nonlinearity	NLB		–	–	±0.5	%F.S.
Input leakage			-10	1	10	pA
Low battery flag voltage		V−to AGND	−2.5	−2.3	−2.1	V
Zero input reading		10MΩ input resistor	−000	000	+000	counts
Reference voltage and open circuit voltage for 400Ω measurement	V_{REF}	100KΩ resistor between VRH and AGND	−1.3	−1.2	−1.1	V
Peak to peak backplane drive voltage		$-3.5 \le V- \le -2.2$	3.00	3.2	3.40	V
Counter time base period		f_{osc} = 4MHz	–	1	–	sec.
Open circuit voltage for Ω measurement (except 400 Ω)		Ω and Continuity mode	−0.54	−0.47	−0.4	V
Internal pull-high to 0V current		Between V−pin and HOLD, RANGE, KEY, FC1, FC2, FC3, FC4, FC5	–	1.2	–	μA
		Between V−pin and RS232, XTAL	–	11	–	
AC frequency response at 4.000V range		±1% error	–	40 – 650	–	Hz
		±5% error	–	40 – 2700	–	
Reference voltage temperature coefficient	TC_{RF}	100KΩ resistor Between VRH and AGND, $0°C \le T_A \le 70°C$	–	50	–	ppm/°C

Note:
1. Full Scale

Functional Description

1 Operating Modes

1.1 Voltage Measurement

A reconfigurable voltage divider automatically provides a suitable full scale range in voltage measurement mode. The following table summarizes the full scale ranges in each configuration.

Configuration	Full Scale Range	Divider Ratio	Resistor Connection
VR1[1]	340.0mV	1	–
VR2	3.400V	$\frac{1}{10}$	$\frac{R_2}{R_1+R_2}$
VR3	34.00V	$\frac{1}{100}$	$\frac{R_3}{R_1+R_3}$
VR4	340.0V	$\frac{1}{1000}$	$\frac{R_4}{R_1+R_4}$
VR5	3400V	$\frac{1}{10000}$	$\frac{R_5}{R_1+R_5}$

Note: For DC measurement only.

1.2 Resistance Measurement

A reconfigurable voltage divider automatically provides a suitable full scale range in resistance measurement mode. The following table summarizes the full scale ranges and the reference resistors in each configuration.

Configuration	Full Scale Range	Reference Resistor	Recommended Value
OR1	340.0Ω	R_6	100Ω
OR2	3.400KΩ	R_5	1KΩ
OR3	34.00KΩ	R_4	10KΩ
OR4	340.0KΩ	$R_1 \| R_3$	100KΩ
OR5	3.400MΩ	$R_1 \| R_2$	1MΩ
OR6	34.00MΩ	R_1	10MΩ

1.3 Current Measurement

Current measurement has three modes. The following table summarizes the full scale range of each mode.

Mode	Range Selection	Full Scale
Automatic Mode 1	μA	340.0μA 3400μA
Automatic Mode 2	mA	34.00mA 340.0mA
Manual Mode	A	34.00A

1.4 Continuity Check

Continuity check mode shares the same configuration with 340.0Ω manual resistance measurement mode, but with buzzer output to indicate continuity. The buzzer generates a 2KHz sound whenever the test is less than 35Ω.

1.5 Diode Measurement

Diode measurement mode shares the same configuration with 3.400V manual voltage measurement mode. If the test circuit is open or the voltage drop between the two ports of the device (diode) under test is larger than 2 V, the LCD panel will show "OL". If the test is less than 0.25V, the chip generates a 2KHz beep.

1.6 Auto Power Off

ES51971 has a default auto power off function. If the meter idles for more than 10 minutes, the chip automatically turns the power off. When this happens, the state of the meter is saved. In order to disable auto power off function, power on the meter when any of the push function, except for HOLD, is pressed down.In addition, when RS232 output is actived, the auto power off function is also disabled.The APO sign on the LCD panel indicates whether the auto power-off function is enabled or not.

Note: Powering on the meter while pressing HOLD turns on all LCD segment until HOLD is pressed again.

The meter enters sleep mode after auto power off. The SLEEP pin asserts low (-3V) in the sleep mode, and asserts high (+3V, not 0V) after re-power on.

1.7 Re-power On

Pushing any of the push function or changing the rotary mode after auto power off can turn on the meter again. If the meter is re-powered on by changing the rotary mode, or if the meter is in the logic measurement mode, the saved state is cleared. If the meter is re-powered on by push functions, the chip restores the saved state and enters HOLD mode. The LCD displays the saved value.

2 Measurement Mode Switching

Measurement mode depends on the logic level of FC1, FC2, FC3, FC4, FC5, and KEY. When FC5 is HIGH, the measurement modes are listed in the following table.

FC1	FC2	FC3	FC4	Mode	Function of KEY
1	0	1	1	Voltage Measurement	DCV $\longleftrightarrow$ ACV
1	1	0	1	Current Measurement (μA)	DCA $\longleftrightarrow$ ACA
1	0	0	1	Current Measurement (mA)	DCA $\longleftrightarrow$ ACA
1	1	1	1	Current Measurement (A)	DCA $\longleftrightarrow$ ACA
0	0	1	1	Resistance Measurement	$\Omega \longleftrightarrow$ Continuity
0	1	0	1	Resistance Measurement	$\Omega \longleftrightarrow$ Diode
0	1	1	1	Continuity Check	Continuity $\longleftrightarrow$ Diode
0	0	0	1	Resistance Measurement	$\Omega \longleftrightarrow$ Continuity $\longleftrightarrow$ Diode

When FC5 is LOW, KEY is disable. The corresponding measurement modes are listed below.

FC1	FC2	FC3	FC4	Mode
1	0	1	1	AC Voltage Measurement
1	1	0	1	AC Current Measurement (μA)
1	0	0	1	AC Current Measurement (mA)
1	1	1	1	AC Current Measurement (A)
0	0	1	1	Resistance Measurement
0	1	0	1	Resistance Measurement + Continuity Check
0	1	1	1	Continuity Check
0	0	0	1	Diode Measurement

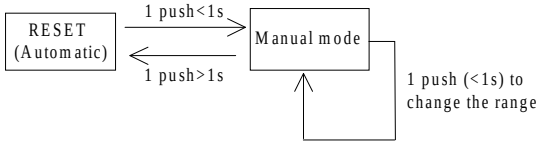
3 Push Functions

3.1 HOLD

HOLD mode makes the meter stop updating the LCD panel. This mode can be nested in most of the special modes. Enabling HOLD function in automatic mode makes the meter switch to manual mode, but the full scale range remains the same. HOLD function can be cancelled by changing the measurement mode, pressing RANGE, or push HOLD again.

3.2 RANGE

RANGE pin switchs to and from automatic and manual mode, and while in manual mode, changes the full scale range. The following figure shows the state transition.



Measurement Mode	Auto	Manual	Control Range	Initial Range
DCV	VR1 – VR5	VRi → VRi + 1, VR5 → VR1	340.0mV – 3400V	340.0mV
ACV	VR2 – VR5	VRi → VRi + 1, VR5 → VR2	3.400V – 3400V	3.400V
μA (DC/AC)	R1 – R2	R1 → R2, R2 → R1	340.0μA – 3400μA	340.0μA
mA (DC/AC)	R1 – R2	R1 → R2, R2 → R1	34.00mA – 340.0mA	34.00mA
A (DC/AC)	fixed	fixed	34.00A	34.00A
Ω	OR1 – OR6	ORi → ORi + 1, OR6 → OR1	340.0Ω – 34.00MΩ	340.0Ω
Continuity	fixed	fixed	340.0Ω	340.0Ω
Diode	fixed	fixed	3.400V	3.400V

Note: Pushing RANGE resets all existing special modes.

3.3 KEY

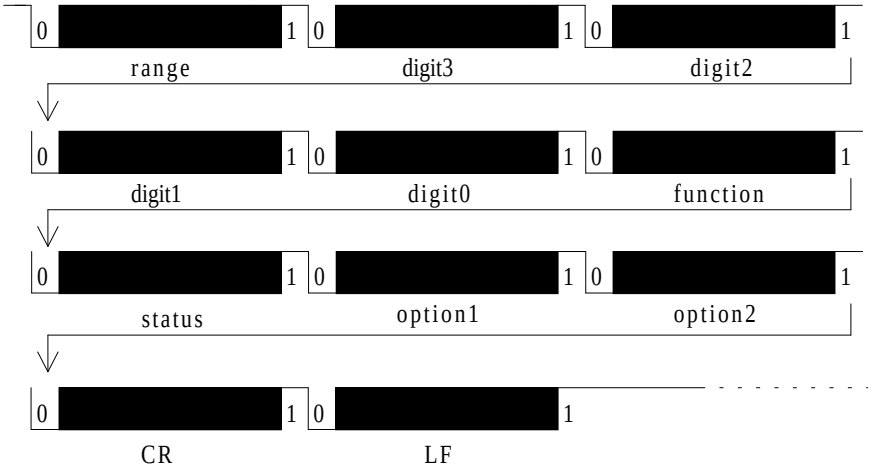
See Section "Measurement Mode Switching" for the function of this pin.

4 Serial Data Output

The serial data is sent to SDO pin twice every A/D conversion cycle. The data format complies with JIS 7BIT transmission code with a baud rate of 2400. The host can use RS-232 interface to read the data. A single data packet includes a start bit (always 0), 7 data bits, an odd parity check bit, and a stop bit (always 1). The following figure shows the data format of a single packet. The LSB is sent first and the MSB is sent last.



One data block consists of 11 packets, or 110 bits. The following figure shows the format of a data block. The range packet indicates the full scale range of the meter. Digit 3 through digit 0 is just the digits on the LCD panel. The function packet indicates the measurement mode of the meter. Status, option 1 and option 2 gives the status of the meter. CR and LF are delimiters used to separate the blocks.



The meter always outputs the current input value to the serial port. Each block is repeated twice in one conversion cycle. The detailed data format of each packet is listed below.

4.1 FUNCTION

This packet indicates the measurement mode of the meter. The following table summaizes the transmitted code for each mode. Note that the encoding of this packet is different from the encoding of FC1–FC4 switch.

Code	Measurement Mode
0111011	Voltage
0111101	μA Current
0111001	mA Current
0111111	A Current
0110011	Ω
0110101	Continuity
0110001	Diode

4.2 RANGE

This packet indicates the full scale range of the meter. When the meter operates in continuity mode, diode mode, or current (A) mode, this packet is always 0110000 since the full scale range in these modes are fixed. The following table lists the code for each range in each measurement mode.

Code	V	mA	μA	Ω
0110000	340.0mV	34.00mA	340.0μA	340.0Ω
0110001	3.400V	340.0mA	3400μA	3.400KΩ
0110010	34.00V			34.00KΩ
0110011	340.0V			340.0KΩ
0110100	3400V			3.400MΩ
0110101				34.00MΩ

4.3 DIGIT 3 – DIGIT 0

Digit 3 is the most significant digit on the LCD panel, and digit 0 is the least significant digit. When the LCD panel shows OL, the serial port outputs 3400.

Digit	Code
0	0110000
1	0110001
2	0110010
3	0110011
4	0110100
5	0110101
6	0110110
7	0110111
8	0111000
9	0111001

4.4 STATUS

The format of this packet is shown below. Sign field indicates whether the minus sign on the LCD panel is on or off. BATT field is one if battery low condition is true. OL indicates input overflow. Bit 3 is reserved. It can be either zero or one.

0	1	1	×	Sign	BATT	OL
Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

4.5 OPTION 1

This packet is always a constant for this chip. A constant packet is inserted here for compatibility with other chips in ERSO DMM series.

0	1	1	0	0	0	0
Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

4.6 OPTION 2

This packet contains information on the operation mode of the meter. The format is shown below. The DC field indicates that the meter operates in DC measurement mode, either voltage or current. The AC field indicates that the meter operates in AC measurement mode. The AUTO field is set to one if the meter operates in automatic mode, and is set to zero when the meter operates in manual mode. The APO field indicates whether auto power off function is enabled or not.

0	1	1	DC	AC	AUTO	APO
Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

4.7 CR

Carrage return. The transmitted code is 0001101.

4.8 LF

Line feed. The transmitted code is 0001010.

5 Miscellaneous

5.1 The Buzzer

The conditions which the meter turns on the buzzer include:

(1) Changing measurement mode generates one beep.

(2) Pressing any of the push functions generates one beep, if the function is valid.

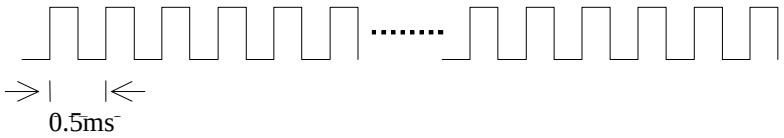
(3) Power on and re-power on generate one beep.

(4) Input overflow in voltage and current measurement mode generates one beep every 0.3 seconds (or 3.33 beeps per second.)

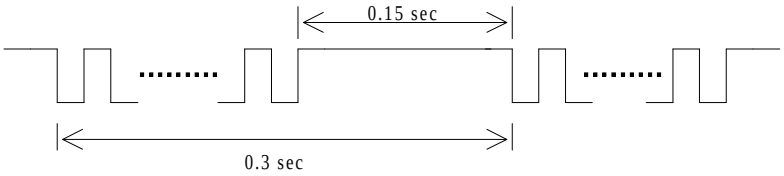
(5) Continuity check and diode measurement generate a continuous 2KHz beep whenever the bar graph count is less than 3.

(6) Auto power off generates a 2KHz beep which lasts for 1.5 seconds.

The following figures shows the output waveform from the BUZOUT pin.



(a) Continuous 2KHz beep



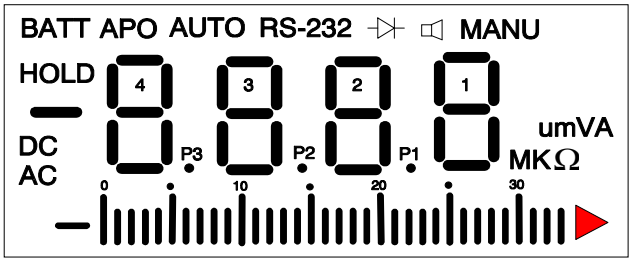
(b) 3.33 beep/sec

5.2 LCD Pin Assignment

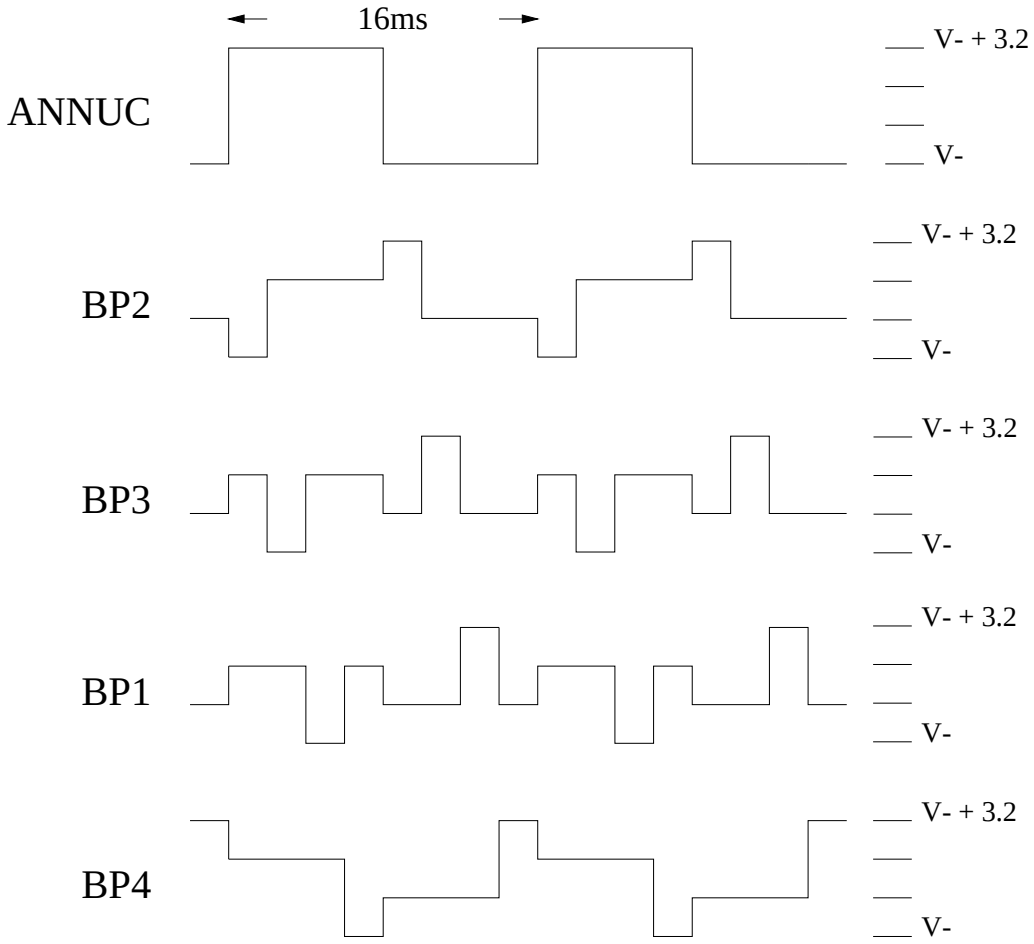
	SEG1	SEG2	SEG3	SEG4	SEG5	SEG6	SEG7	SEG8	SEG9	SEG10
BP1	bar33	MANU	m	1_b	1_a	1_f	2_b	2_a	2_f	3_b
BP2	bar31	Ω	K	BATT	1_d	bar30	P1	2_d	bar29	P2
BP3	bar32	V	M	1_c	1_g	1_e	2_c	2_g	2_e	3_c
BP4	bar34	A	μ					RS232		

	SEG11	SEG12	SEG13	SEG14	SEG15	SEG16	SEG17	SEG18
BP1	3_a	3_f	4_b	4_a4_g		DC	bar25	bar24
BP2	3_d	bar28	P3	4_d		AC	bar27	bar22
BP3	3_g	3_e	4_c	4_e	–	HOLD	bar26	bar23
BP4	AUTO		APO					

	SEG19	SEG20	SEG21	SEG22	SEG23	SEG24	SEG25	SEG26
BP1	bar19	bar18	bar13	bar12	bar7	bar6	bar1	
BP2	bar21	bar16	bar15	bar10	bar9	bar4	bar3	bar-
BP3	bar20	bar17	bar14	bar11	bar8	bar5	bar2	bar0
BP4								



5.3 LCD Backplane Waveform



5.4 LCD Display On Condition

LCD Annunciator	Condition
V	In voltage measurement mode and diode measurement mode.
A	In current measurement mode.
Ω	In resistance measurement mode and continuity check mode.
	In continuity check mode.
	In diode mode.
DC	In DC voltage or DC current mode.
AC	In AC voltage or AC current mode.
AUTO	When automatic full scale range selection is enabled.
MANU	In manual mode.
HOLD	When HOLD function is enabled.
m	In voltage or current measurement mode and the full scale range is in the order of 10^{-3}.
u	In current measurement mode and the full scale range is in the order of μA.
M	In resistance measurement mode and the full scale range is in the order of MΩ.
K	In resistance measurement mode and the full scale range is in the order of KΩ.
APO	When auto power off function is enabled.
–	In voltage or current measurement mode and when the input is negative.
bar graph	Always indicates the current input value.

5.5 Operation Timing

ES51971 incorporates a dual slope ADC with four phases: ZI, AZ, INT, and DINT. The ADC consists of a high resolution part for digital display and a high speed part for bar graph display. The timing of each phase of the two parts are listed below.

- Voltage measurement:

Phase	High Resolution	High Speed
ZI	100ms	10ms
AZ	150ms	15ms
INT	100ms	10ms
DINT	400ms	40ms

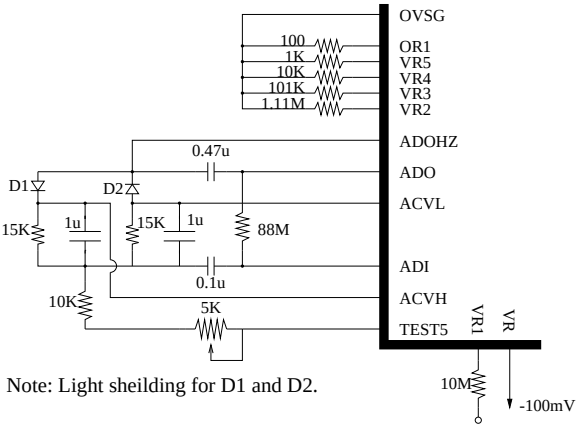
- Current measurement:

Phase	High Resolution	High Speed
ZI	100ms	10ms
AZ	150ms	15ms
INT	100ms	10ms
DINT	200ms	20ms

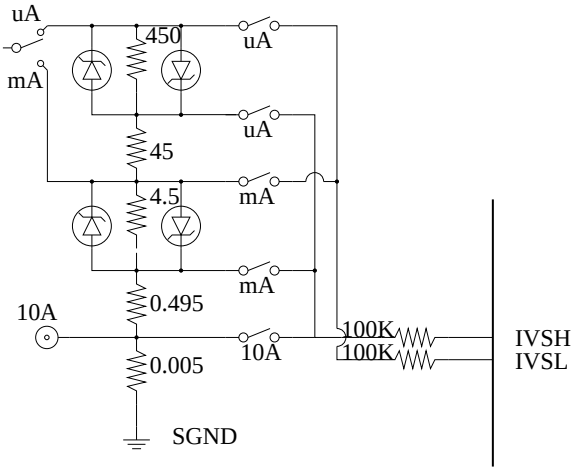
- Continuity check:

Phase	High Resolution	High Speed
ZI	100ms	5ms
AZ	150ms	7.5ms
INT	100ms	5ms
DINT	400ms	20ms

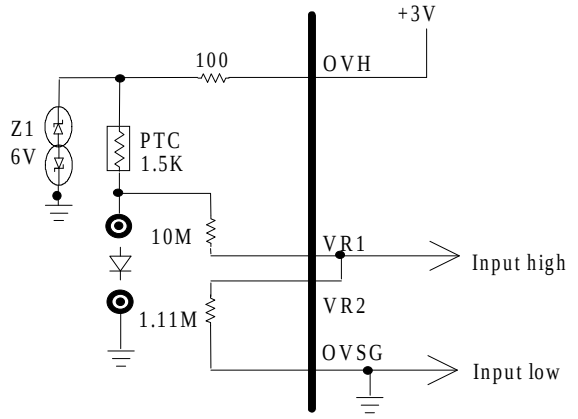
Test Circuit



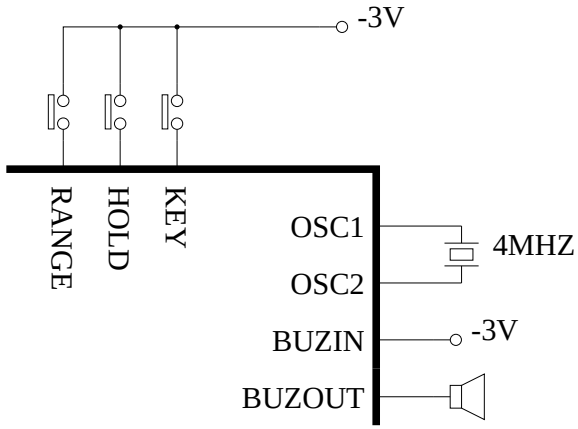
(a) Testing voltage measurement.



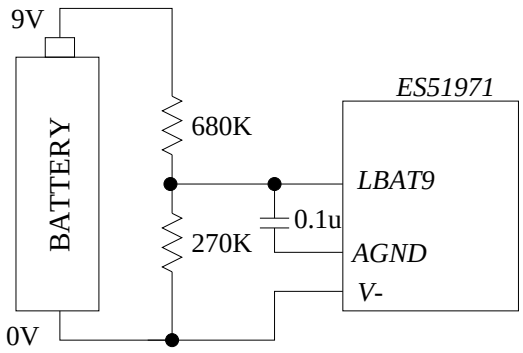
(b) Testing current measurement.



(c) Testing diode mode.

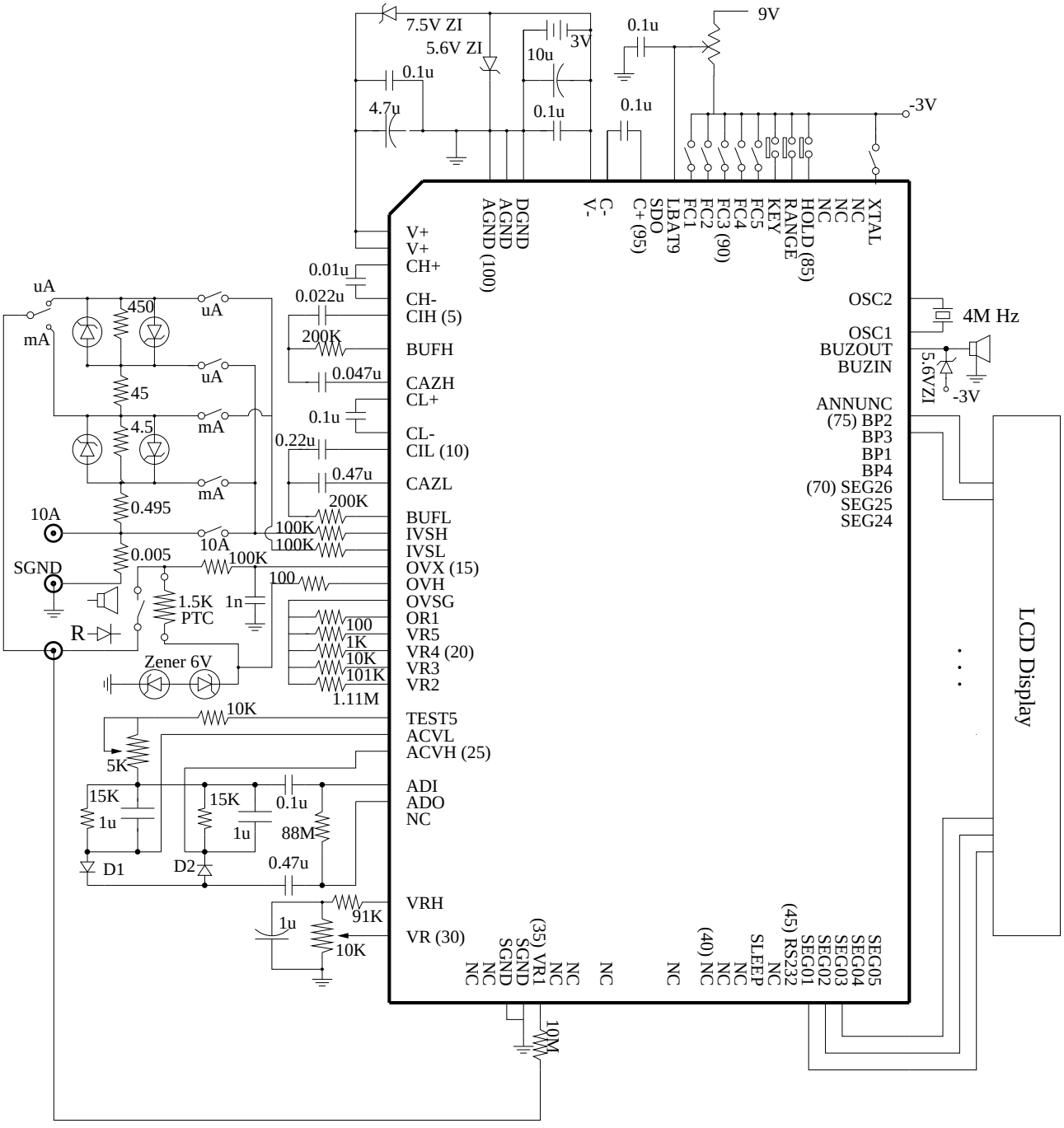


(d) Testing function switch.



(e) Testing battery-low function.

Application Circuit

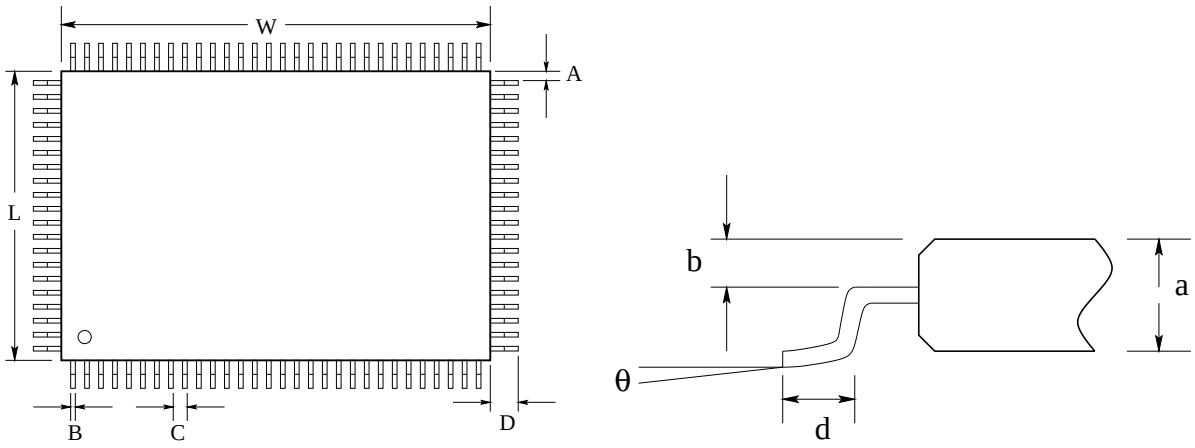


Note: Light shielding for the diodes and Zeners

Note: Most of pins are protected by the ESD protection circuits, however pins, V-, V+, AGND, DGND and VR1 are not protected enough because the parasitic effect must be decreased. Therefore enough external protection is needed for assembling, carrying and keeping. In addition, components connecting to these unprotected pins have to be soldered on board before the IC is soldered.

Packaging

1 100 Pin QFP Package



2 Dimension Paramenters

Symbol	Milimeter			Mill		
	Min.	Typ.	Max.	Min.	Typ.	Max.
W	19.90	20.00	20.10	783.5	787.4	791.3
L	13.90	14.00	14.10	547.2	551.2	555.1
A		0.425			16.7	
B	0.20	0.30	0.40	7.9	11.8	15.7
C		0.65			25.6	
d	1.05	1.20	1.35	41.3	47.2	53.1
a	2.57	2.72	2.87	101.2	107.1	113.0
D		2.50			98.4	
θ	0°		10°			