



Features

- Full automatic measurement
 - * Voltage measurement
 - * Current measurement
 - * Resistor measurement
- 4000 count display
- Range change function
- Data hold function
- Relative / Maximum / Minimum modes
- Diode measurement
- Continuity check
- Peak hold mode
- RPM measurement
- VAHZ mode measures frequency in voltage or current mode
- 40MHz Frequency counter
- ADP mode
- External reference voltage
- Serial data output (RS232 format)
- Auto power off and re-power on
- Low battery detect (3V and 9V)
- 3V DC power supply
- 100 pin flat package

Description

ES51989 is an integrated analog-to-digital converter (ADC) with 4000 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, current measurement, frequency counter under V/A measurement, frequency counter and RPM measurement. Expensive and bulky mechanical range switches are not required. Other features include data holding, relative/maximum/minimum/peak measurement, diode measurement, temperature measurement, continuity checking, low battery detection, auto power off, re-power on, and RS232 data output.

Application

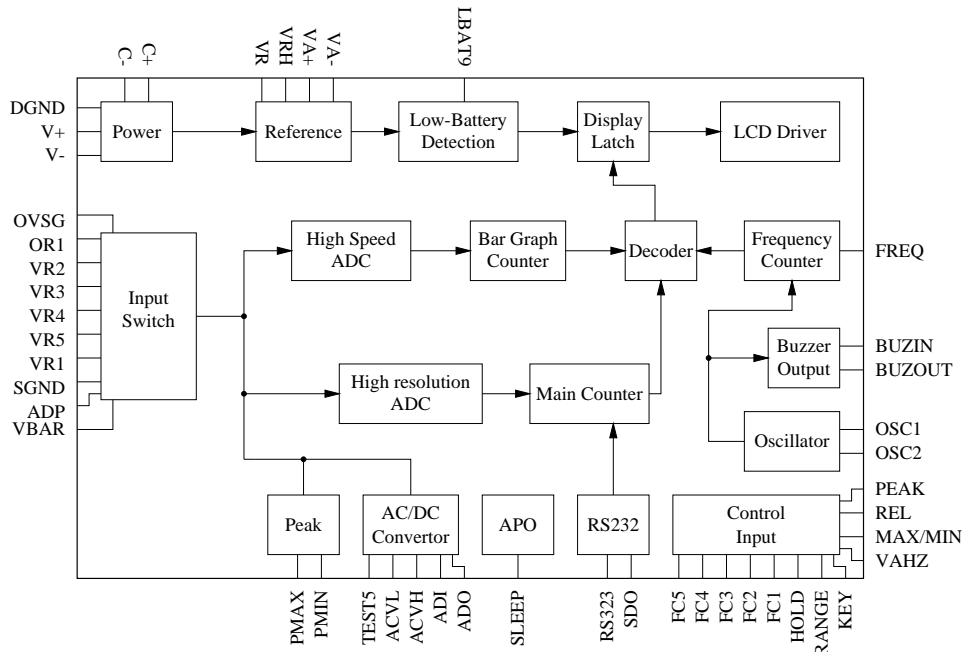
Digital Multimeter.

Taiwan patents: 476,418; 510,502

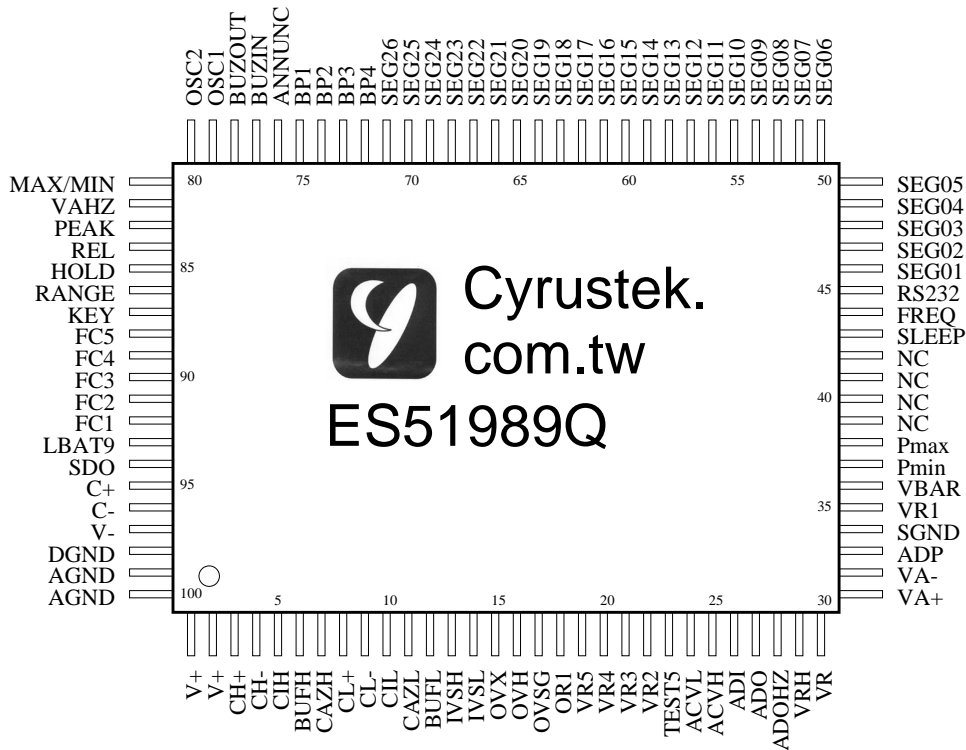
US patent: 6,429,696



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 (4000V.)
20	VR4	O	Voltage measurement ÷1000 attenuator (400.0V.)
21	VR3	O	Voltage measurement ÷100 attenuator (40.00V.)
22	VR2	O	Voltage measurement ÷10 attenuator (4.000V.)
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	ADOHZ	I	Frequency input under voltage/current mode, offset to AGND.
29	VRH	O	Output of band-gap voltage reference. Typically -1.2V.
30	VR	I	Reference input voltage connection. Typically -100mV.
31	VA+	I	For ADP. De-integrating voltage positive input. The input should be higher than VA-.
32	VA-	I	For ADP. De-integrating voltage negative input. The input should be lower than VA+.
33	ADP	I	ADP Input.
34	SGND	G	Signal Ground.
35	VR1	I	Measurement input.
36	VBAR	I	In ADP mode, if this pin connect to V-, the bar graph will not display.
37	P _{MIN}	O	Minimum peak hold output.
38	P _{MAX}	O	Maximum peak hold output.
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.

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Pin No.	Symbol	Type	Description
44	FREQ	I	Frequency counter input, offset to $\frac{V-}{2}$ internally by the chip.
45	RS232	I	Pulse low to enable serial data output.
46 - 71	SEG01 - SEG26	O	LCD segment line 01 - 26.
72	BP4	O	LCD backplane 4.
73	BP3	O	LCD backplane 3.
74	BP2	O	LCD backplane 2.
75	BP1	O	LCD backplane 1.
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	MAX/MIN	I	Pulse low to enable MAX/MIN mode.
82	VAHZ	I	Pulse low to show the frequency of input signal in V(DC/AC), I(DC/AC.)
83	PEAK	I	Pulse low to enable PEAK mode.
84	REL	I	Pulse low to enable REL mode.
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. In ADP mode, if this pin is connected to V-, the buzzer output will be off when the ADP input overflows.
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 ≤ V- ≤ -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 MAX/MIN, PEAK, REL, HOLD, RANGE, KEY, FC1, FC2, FC3, FC4, FC5, VAHZ	-	1.2	-	μA
		Between V- pin and RS232	-	11	-	
AC frequency response at 4.000V range		±1% error	-	40 - 650	-	Hz
		±5% error	-	40 - 2700	-	
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Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Units
Reference voltage temperature coefficient	TC_{RF}	100 K Ω resistor Between VRH and AGND, $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$	-	50	-	ppm/ $^{\circ}\text{C}$
Maximum and minimum peak value accuracy		Use 10nF polyester mylar capacitor, 10 μs pulse, V- = -3.0V, ADP, 470 Ω input	-2	-	2	%F.S.
			-25	-	25	counts
Capacitance measurement accuracy		4nF range	-1.5	-	1.5	%F.S.
			-2	-	2	counts
		40nF - 4 μF range	-0.8	-	0.8	%F.S.
			-2	-	2	counts
		4 μF ~4mF range	-1.1	-	1.1	%F.S.
40mF range	-2	-	2	%F.S.		
RPM Measurement			-3	-	3	counts

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	400.0mV	1	-
VR2	4.000V	$\frac{1}{10}$	$\frac{R_2}{R_1+R_2}$
VR3	40.00V	$\frac{1}{100}$	$\frac{R_3}{R_1+R_3}$
VR4	400.0V	$\frac{1}{1000}$	$\frac{R_4}{R_1+R_4}$
VR5	4000V	$\frac{1}{10000}$	$\frac{R_5}{R_1+R_5}$

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	400.0 Ω	R_6	100 Ω
OR2	4.000K Ω	R_5	1K Ω
OR3	40.00K Ω	R_4	10K Ω
OR4	400.0K Ω	$R_1 \parallel R_3$	100K Ω
OR5	4.000M Ω	$R_1 \parallel R_2$	1M Ω
OR6	40.00M Ω	R_1	10M Ω



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	400.0 μA 4000 μA
Automatic Mode 2	mA	40.00mA 400.0mA
Manual Mode	A	40.00A

1.4 Continuity Check

Continuity check mode shares the same configuration with 400.0 Ω manual resistance measurement mode, but with buzzer output to indicate continuity. The buzzer generates a 2KHz sound whenever the measurement is less than 35 Ω .

1.5 Diode Measurement

Diode measurement mode shares the same configuration with 4.000V 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". The buzzer generates a 2KHz sound whenever the test is less than 0.25V.

1.6 Frequency Counter

The time base of the frequency counter is derived from an external crystal oscillator by

$$T_{counter} = \frac{4,000,000}{f_{osc}},$$

where f_{osc} is the frequency of the crystal oscillator. Thus, the counter will operate with a 1 second time base when a 4 MHz oscillator is used. The frequency counter can select the proper range automatically or manually. Auto-range operation extends over five decades, from 4.000KHz to 40.0MHz. The following table summarizes the full scale range of the frequency counter.

Range	Full Scale
FR1	4.000KHz
FR2	40.00KHz
FR3	400.0KHz
FR4	4.000MHz
FR5	40.00MHz

1.7 RPM Measurement

Like the frequency measurement mode, the counter will operate with a 1 second time base. The following table summarizes the full scale range of RPM measurement mode.

Range	Full Scale
RP1	40.00KRPM
RP2	400.0KRPM
RP3	4.000MRPM
RP4	40.00MRPM
RP5	400.0MRPM



1.8 Auto Power Off

ES51989 has a default auto power off function. If the meter idles for more than 30 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 activated, 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.

1.9 Sleep

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.

1.10 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 \leftrightarrow ACV
1	1	0	1	Current Measurement (μ A)	DCA \leftrightarrow ACA
1	0	0	1	Current Measurement (mA)	DCA \leftrightarrow ACA
1	1	1	1	Current Measurement (A)	DCA \leftrightarrow ACA
0	0	1	1	Resistance Measurement	Ω \leftrightarrow Continuity
0	1	0	1	Resistance Measurement	Ω \leftrightarrow Diode
0	1	1	1	Continuity Check	Continuity \leftrightarrow Diode
0	0	0	1	Resistance Measurement	Ω \leftrightarrow Continuity \leftrightarrow Diode
0	0	1	0	Frequency Measurement	Frequency \leftrightarrow RPM
0	1	0	0	Temperature ($^{\circ}$ C)	-

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 (μ A)
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
0	0	1	0	RPM
0	1	0	0	Temperature ($^{\circ}$ F)

The other combinations of FC1, FC2, FC3, and FC4 are for ADP modes. In ADP modes, if FC5 is LOW, the minus sign on the LCD panel will not be displayed. VBAR controls the bar graph in ADP mode. If VBAR



is LOW, the bar graph is not displayed. And if KEY pin is floating, the buzzer beeps when the input signal is overflow. The ADP mode function is summarized below.

FC1	FC2	FC3	FC4	VBAR	Mode
1	1	1	0	floating	ADP0
1	1	0	0	floating	ADP1
1	0	0	0	floating	ADP2
1	0	1	0	floating	ADP3
1	1	1	0	LOW	ADP0 without bar graph
1	1	0	0	LOW	ADP1 without bar graph
1	0	0	0	LOW	ADP2 without bar graph
1	0	1	0	LOW	ADP3 without bar graph

Note: Temperature measurement mode takes input signal from ADP pin. In temperature measurement mode, VBAR pin is used to control the right most digit point on the LCD panel. When VBAR is LOW, this digit point is displayed.

3 Push Functions

Push functions control the special measurement modes of the meter. Some special modes can be nested in other special modes, while some push functions reset all existing special mode. The following table summarizes the available push functions in each special mode.

Active mode	Push Functions						
	RANGE ¹	KEY ¹	HOLD	REL	MAX/MIN	PEAK	VAHZ ²
HOLD	○	○	○	×	×	×	×
REL	○	○	○	○	○	×	×
MAX/MIN	○	○	○	×	○	×	×
PEAK	○	○	○	×	×	○	×
VAHZ	○	×	○	×	×	×	○

Note:

1. KEY and RANGE reset all special modes other than VAHZ mode.
2. VAHZ is only used to toggle between frequency measurement mode and voltage or current measurement mode, and thus can not be nested in any other special modes.
3. The bar graph always shows the current value, regardless of the special mode.

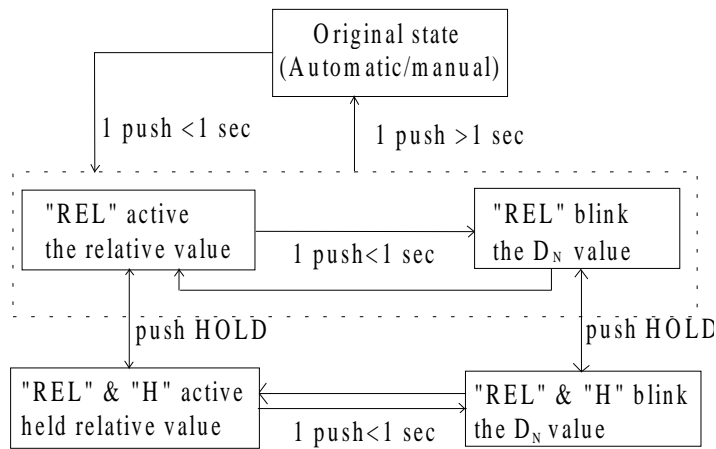
The state transition of the push functions are described below.

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 REL + HOLD

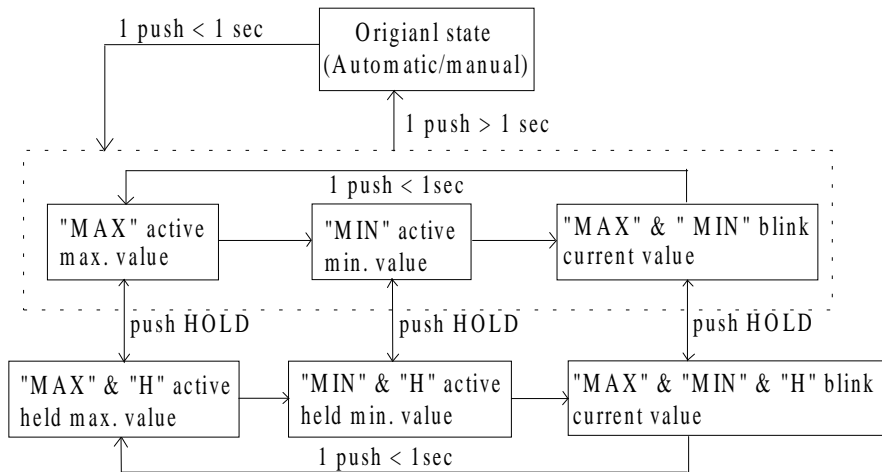
In REL mode, the LCD panel displays $D_{N+K} - D_N$, where $K = 1, 2, 3, \dots$, D_N is the last value before REL is pushed, and D_{N+K} is the current value. If REL is pressed again in REL mode, the meter displays the reference value. The meter returns to normal operation if REL is pressed and held for longer than one second. Pressing HOLD in REL mode makes the meter stop updating the LCD panel.



Note: It is possible for the relative value to exceed 4000 or -4000 counts. Such relative values are displayed. The LCD shows OL only if either D_N or D_{N+K} is greater than 3999 counts or less than -3999 counts.

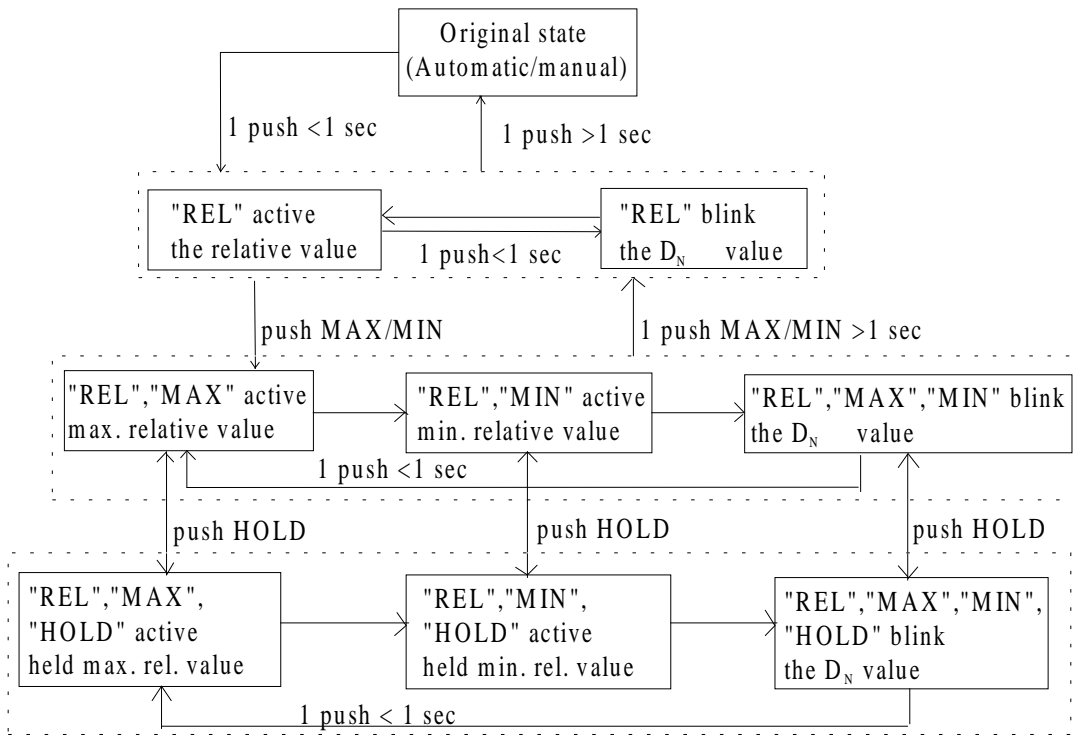
3.3 MAX/MIN + HOLD

The meter displays the maximum or minimum value of the input in MAX/MIN mode. When MAX/MIN is pressed for the first time, the meter displays the maximum value. When MAX/MIN is pressed again, the meter displays the minimum value. When MAX/MIN is pressed for the third time, the meter displays current input value. The meter returns to normal operation if MAX/MIN is pressed and held for longer than one second. Pressing HOLD in MAX/MIN mode makes the meter stop updating the maximum or the minimum value.



3.4 REL + MAX/MIN + HOLD

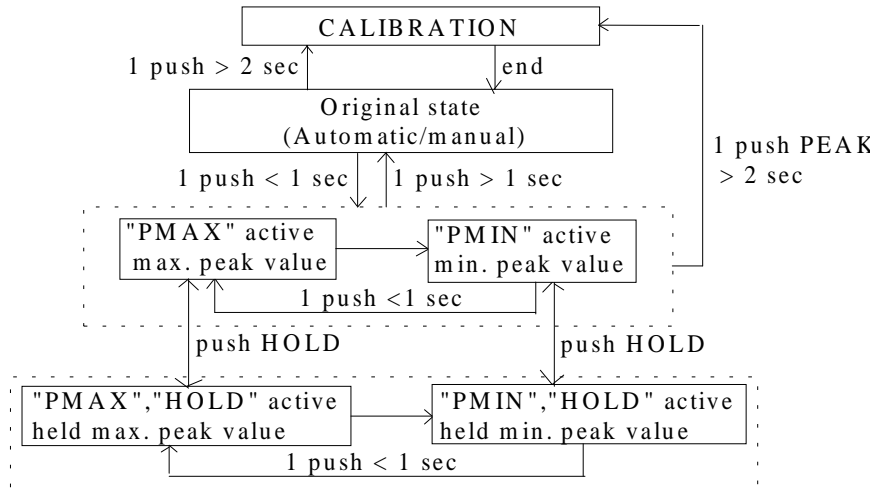
MAX/MIN mode can be nested in REL mode. The meter displays the maximum or the minimum value relative to the reference when MAX/MIN is pressed in REL mode.



3.5 PEAK + HOLD

PEAK mode takes input from P_{MAX} pin or P_{MIN} pin. The peak values are stored in external capacitors. Polyester mylor capacitors are recommended.

The precision of PEAK mode measurement can be enhanced by calibration. Calibration for PEAK mode is invoked by pressing PEAK for more than 2 seconds. The calibration process measures and stores the offset voltage of internal operation amplifiers. High precision is achieved by subtracting this offset from the reading.



3.6 VAHZ

If VAHZ is pushed in voltage or current measurement mode, the meter enters frequency counter mode with automatic range selection. Therefore, pressing RANGE in VAHZ mode does not change the frequency range.

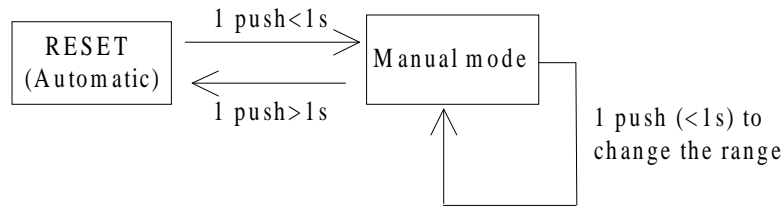


However, RANGE changes the sensitivity of frequency detection. If the input signal has a small amplitude, the user shall increase the sensitivity.

Note: Since VAHZ mode is treated as a temporary frequency measurement in voltage or current mode, pressing RANGE in VAHZ mode also changes the full scale range of the original voltage or current mode after VAHZ mode is cancelled.

3.7 RANGE

RANGE pin switches to and from automatic and manual mode, and while in manual mode, changes the full scale range. In VAHZ mode, RANGE is not use to change the full scale frequency range, but change the sensitivity of frequency measurement. The following figure shows the state transition.



Measurement Mode	Auto	Manual	Control Range	Initial Range
V (DC/AC)	VR1 – VR5	VR _i → VR _i + 1, VR ₅ → VR ₁	400.0mV – 4000V	400.0mV
μA (DC/AC)	R1 – R2	R1 → R2, R2 → R1	400.0μA – 4000μA	400.0μA
mA (DC/AC)	R1 – R2	R1 → R2, R2 → R1	40.00mA – 400.0mA	40.00mA
A (DC/AC)	fixed	fixed	40.00A	40.00A
Ω	OR1 – OR6	OR _i → OR _i + 1, OR ₆ → OR ₁	400.0Ω – 40.00MΩ	400.0Ω
Continuity	fixed	fixed	400.0Ω	400.0Ω
Diode	fixed	fixed	4.000V	4.000V
Frequency	FR1 – FR5	FR _i → FR _i + 1, FR ₅ → FR ₁	4.000KHz – 40.0MHz	4.000KHz
RPM	RP1 – RP5	RP _i → RP _i + 1, RP ₅ → RP ₁	40.00KRPM – 400MRPM	40.00KRPM

Note: Pushing RANGE resets all existing special modes except for VAHZ mode.

3.8 KEY

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

4 Serial Data Output

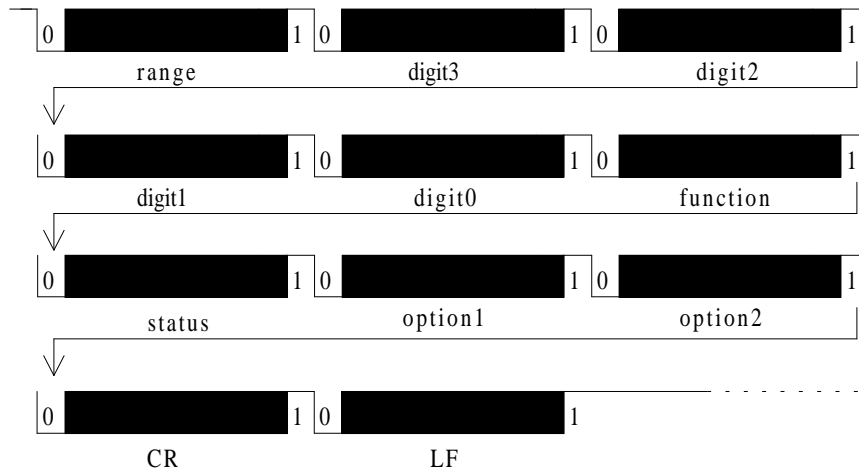
The serial data is sent to SDO pin twice every A/D conversion cycle. The data format complies with JIS 7BIT transmission code with a baud rate of 2400. The host can use RS-232 interface to read the data. A single data



packet includes a start bit (always 0), 7 data bits, an odd parity check bit, and a stop bit (always 1). The high and low voltage levels correspond to DGND and V- respectively. SDO remains at 1 (high) when it is inactive. Hence the start bit (0) could be used as the triggering signal to begin the reading process. 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 in spite of HOLD mode. 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 summarizes 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	μ A Current
0111001	mA Current
0111111	A Current
0110011	Ω
0110101	Continuity
0110001	Diode
0110010	Frequency / RPM ¹
0110110	Capacitance
0110100	Temperature ²
0111110	ADP0
0111100	ADP1
0111000	ADP2
0111010	ADP3



Note:

1. The Judge bit in the Status packet determines whether it is frequency mode or RPM mode.
2. The Judge bit in the Status packet determines whether the unit is Celcius or Fahrenheit.

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	μ A	Ω	Frequency	RPM
0110000	400.0mV	40.00mA	400.0 μ A	400.0 Ω	4.000KHz	40.00KRPM
0110001	4.000V	400.0mA	4000 μ A	4.000K Ω	40.00KHz	400.0KRPM
0110010	40.00V			40.00K Ω	400.0KHz	4.000MRPM
0110011	400.0V			400.0K Ω	4.000MHz	40.00MRPM
0110100	4000V			4.000M Ω	40.00MHz	400.0MRPM
0110101				40.00M Ω		

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 4000.

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. The Judge field is meaningful only when the Function packet indicates Frequency/RPM mode or Temperature mode. In Temperature mode, judge is 1 if the unit is $^{\circ}C$ and is 0 if the unit is $^{\circ}F$. In Frequency/RPM mode, judge is 1 if the meter operates in RPM mode; otherwise, it is 0. 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.

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

4.5 OPTION 1

This packet contains information on special measurement modes. The format of this packet is shown below. The three non-constant fields is set to one when the meter operates in the corresponding special modes.

0	1	1	P _{MAX}	P _{MIN}	0	VAHZ
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.

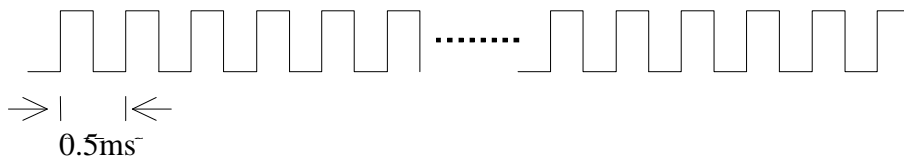
5 Miscellaneous

5.1 The Buzzer

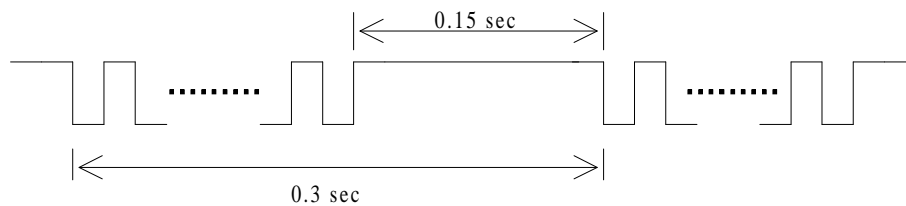
The conditions which the meter turns on the buzzer include:

- (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 generates 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

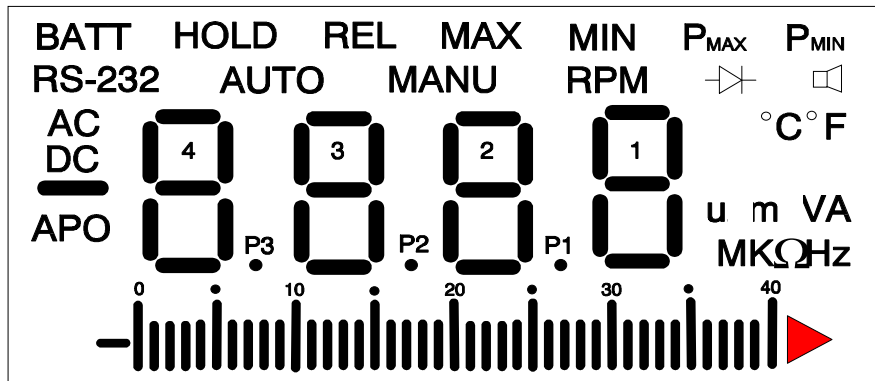


5.2 LCD Pin Assignment

	SEG1	SEG2	SEG3	SEG4	SEG5	SEG6	SEG7	SEG8	SEG9	SEG10
BP1	bar40	bar37	bar36	m_2	bar33	bar32	bar29	bar28	bar25	bar24
BP2	bar39	bar38	Hz	bar35	bar34	bar31	bar30	bar27	bar26	1_d
BP3		$^{\circ}F$		$^{\circ}C$	Ω	u	K	M	1_c	1_g
BP4	A	V		P_{MIN}				P_{MAX}	1_b	1_a

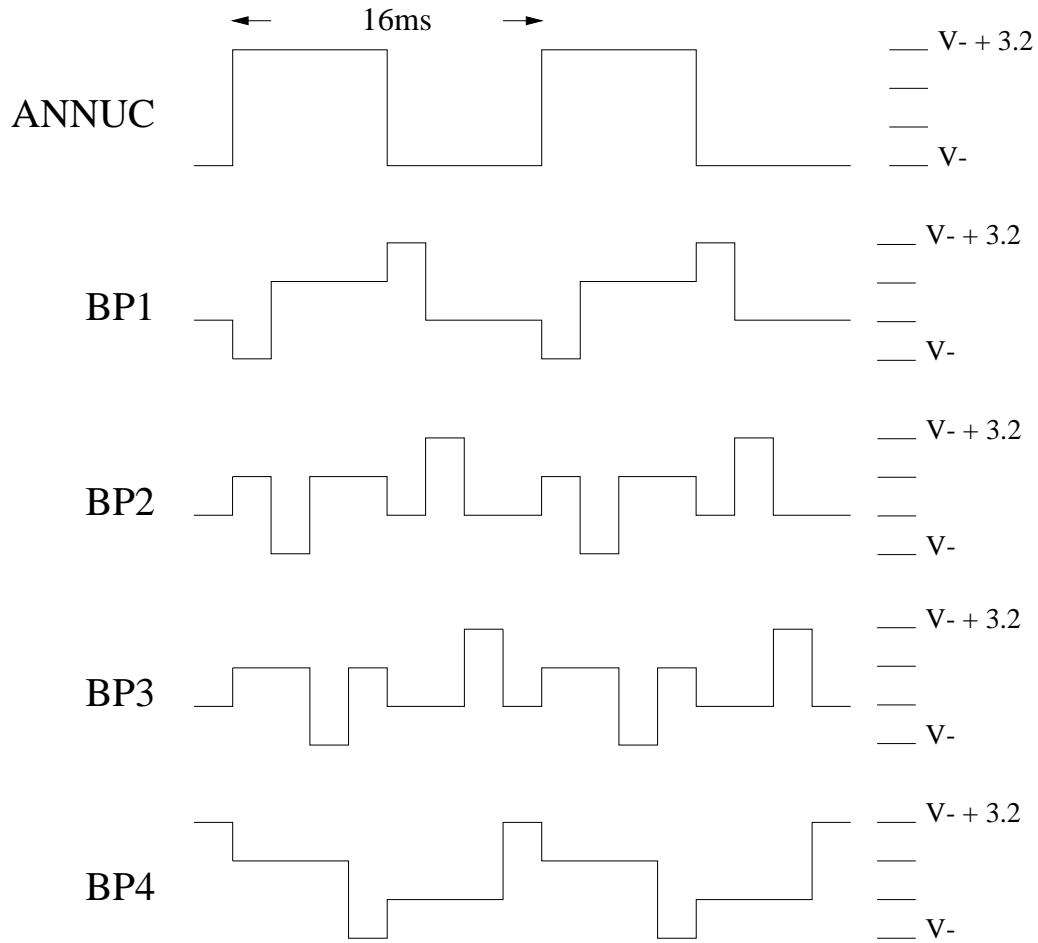
	SEG11	SEG12	SEG13	SEG14	SEG15	SEG16	SEG17	SEG18
BP1	bar22	bar21	bar19	bar18	bar16	bar15	bar13	bar12
BP2	bar23	P1	bar20	2_d	bar17	P2	bar14	3_d
BP3	1_e	RPM	2_c	2_g	2_e	MANU	3_c	3_g
BP4	1_f	MIN	2_b	2_a	2_f	MAX	3_b	3_a

	SEG19	SEG20	SEG21	SEG22	SEG23	SEG24	SEG25	SEG26
BP1	bar10	bar9	bar7	bar6	bar4	bar3	bar1	bar0
BP2	bar11	bar8	P3	4_d	bar5	bar2	APO	bar-
BP3	3_e	AUTO	4_c	4_g	4_e	RS232	DC	-
BP4	3_f	REL	4_b	4_a	4_f	HOLD	BATT	AC





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.
Hz	In frequency mode, VAHZ 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.
REL	When REL function is enabled. When the LCD displays the reference value, REL blinks.
MAX	When the LCD displays max value in MAX/MIN mode. When the LCD displays current value, MAX blinks.
MIN	When the LCD displays min value in MAX/MIN mode. When the LCD displays current value, MIN blinks.
P _{MAX}	When the LCD displays max value in PEAK mode.
P _{MIN}	When the LCD displays min value in PEAK mode.
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 $M\Omega$.
K	In resistance measurement mode and the full scale range is in the order of $K\Omega$.
RPM	In RPM measurement mode.
$^{\circ}C$	In temperature measurement mode and when the unit is $^{\circ}C$.
$^{\circ}F$	In temperature measurement mode and when the unit is $^{\circ}F$.
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

ES51989 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

- PEAK mode voltage measurement:

Phase	High Resolution	High Speed
ZI	100ms	10ms
AZ	150ms	15ms
INT	100ms	10ms
DINT	500ms	50ms

- Current measurement:

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

- PEAK mode current measurement:

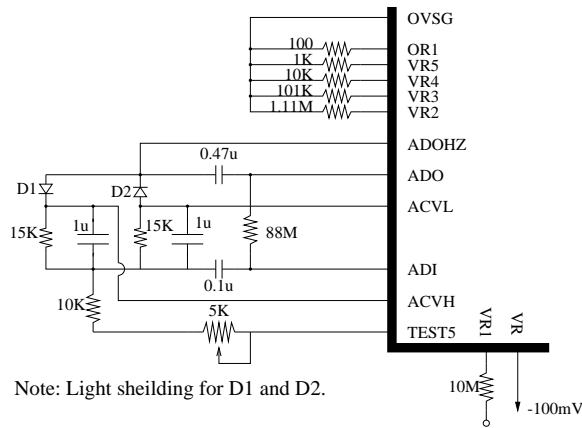
Phase	High Resolution	High Speed
ZI	100ms	10ms
AZ	150ms	15ms
INT	100ms	10ms
DINT	250ms	25ms

- Continuity check:

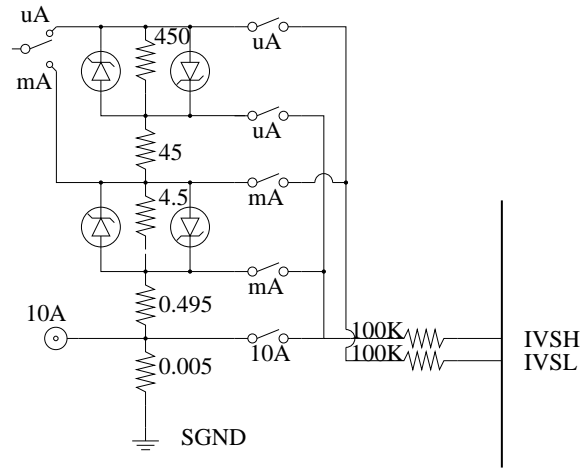
Phase	High Resolution	High Speed
ZI	100ms	5ms
AZ	150ms	7.5ms
INT	100ms	5ms
DINT	400ms	20ms



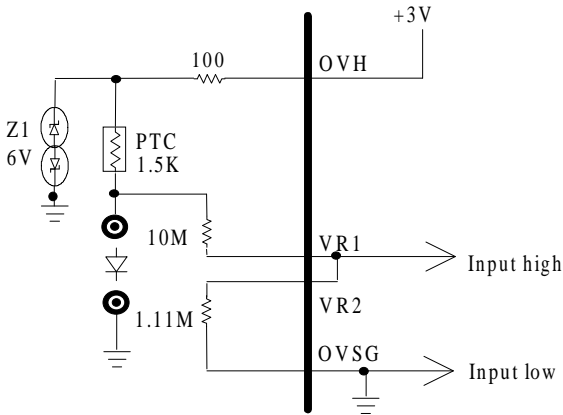
Test Circuit



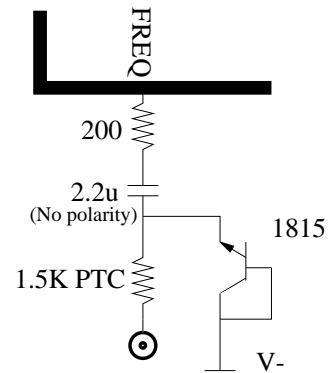
(a) Testing voltage measurement.



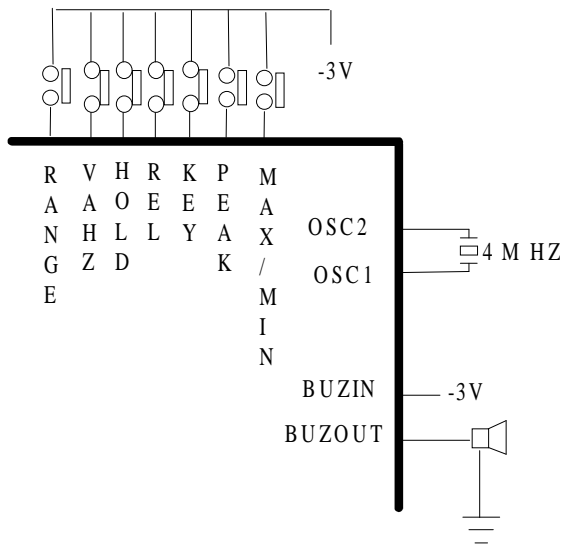
(b) Testing current measurement.



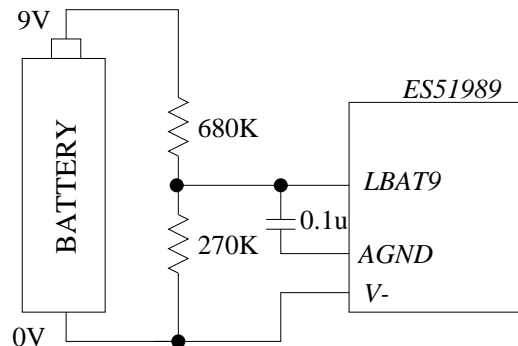
(c) Testing diode mode.



(d) Testing frequency mode.



(e) Testing function switch.

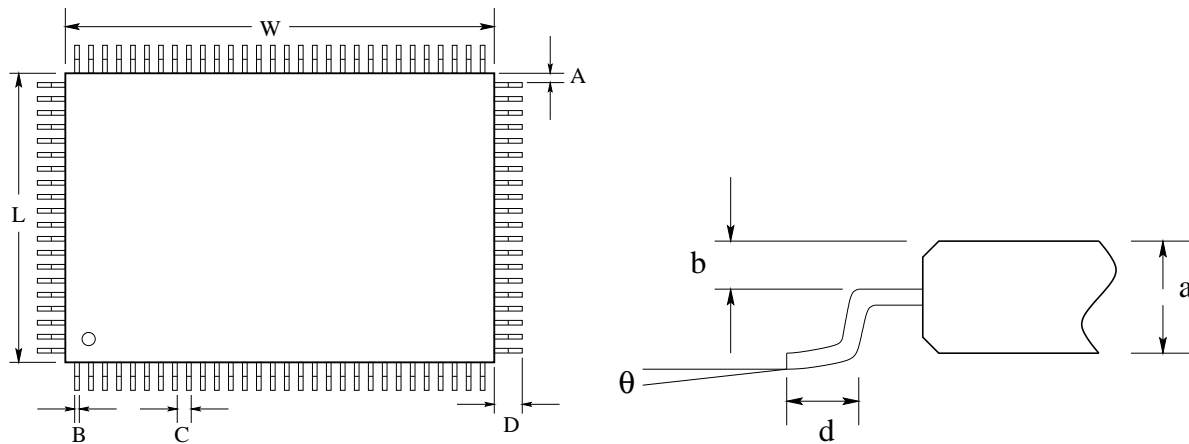


(f) Testing battery-low function.



Packaging

1 100 Pin QFP Package



2 Dimension Parameters

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°			