

### Features

- **6,600 counts LCD display**
- **100L QFP package**
- 3V DC power supply
- **Conversion rate : 3 times/s**
- Full automatic measurement
  - \*Voltage measurement: 660.0mV – 1000V
  - \*Current measurement:  $\mu\text{A}/\text{mA}/\text{A}$
  - \*Resistance measurement: 660.0 $\Omega$  – 66.00M $\Omega$
  - \*Capacitance measurement: 6.600nF – 66.00mF(6.6sec) (**Taiwan patent no.: 453443**)
  - \*Frequency counter: 660.0Hz – 66.00MHz
- **Current modes for clamp meter with ZERO function**
- Duty cycle measurement: 10.0% – 94.9% (0.66sec)
- Diode measurement
- Continuity check
- 4 ADP modes with external reference voltage and independent “ADP” segment on LCD panel
- **Temperature mode with internal scale translation circuit from  $^{\circ}\text{C}$  to  $^{\circ}\text{F}$**
- **Push functions:**
  - \*KEY function
  - \*Range change function
  - \***Inrush function: ACA for clampmeter only**
  - \*Relative function
  - \***Zero function: DCA for clampmeter only**
  - \*VAHz function (**Taiwan patent no.: 510502**)
  - \*Data hold function
  - \*MAX/MIN function
  - \*Back light function
- **High crest factor signal detection (Taiwan patent no. 234661)**
- Band-gap reference voltage output
- **OL/UL state indicator in ADP modes.**
- **CE selection (DC/AC 1010V, DC/AC 610V)**
- Serial data output (RS232 format)
- LCD segment check when power on

- **Auto power off (30min/15min)**
- Sleep state indicative signal output
- Re-power on
- On-chip buzzer driver
- Low battery detection for 3V or 9V battery

### Description

ES51969 is an integrated analog-to-digital converter (ADC) with 6,600 counts LCD display, automatic range selection, and 3V DC power supply. Automatic range selection is provided for voltage (AC/DC) measurement, resistance measurement, current measurement, capacitance measurement, and frequency counter. Expensive and bulky mechanical range switches are not required. Other features include inrush function, relative value display, zero feature for DCA clampmeter, VAHZ function, data holding, maximum and minimum value holding, duty cycle measurement, diode measurement, temperature measurement, continuity checking, low battery detection, auto power off, re-power on, backlight driver, buzzer driver and RS232 data output.

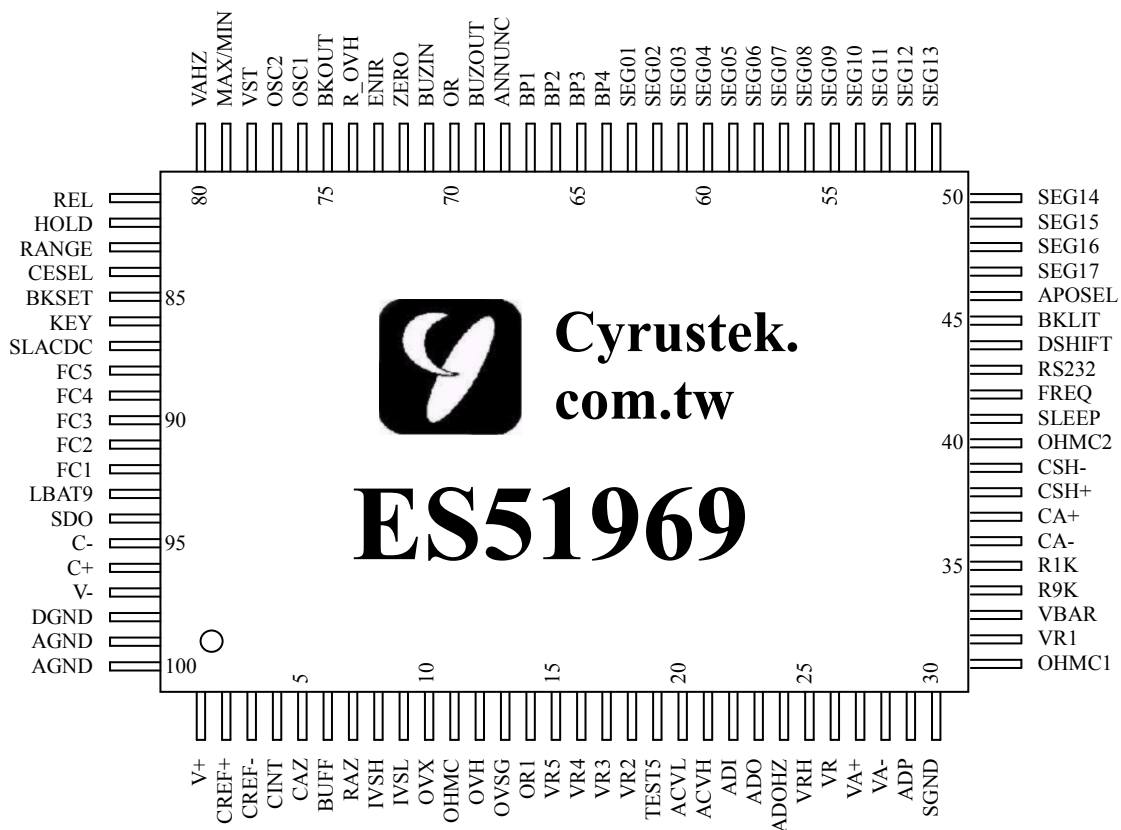
## Application

Digital multimeter

Clamp meter

Thermometer

## Pin Assignment





### Pin Description

Pin No	Symbol	Type	Description
1	V+	O	Output of on-chip DC-DC converter.
2	CREF+	I/O	Positive connection for reference capacitor.
3	CREF-	I/O	Negative connection for reference capacitor.
4	CINT	O	Integrator output. Connect to integral capacitor
5	CAZ	I	Auto-zero capacitor connection.
6	BUFF	O	Buffer output pin. Connect to integral resistor
7	RAZ	O	Buffer output pin in high-speed mode. Connect to high-speed integral resistor.
8	IVSH	I	High current measurement input.
9	IVSL	I	Low current measurement input
10	OVX	I	Input high voltage for resistance measurement
11	OHMC	O	Filter capacitor connection for resistance mode below 6.600MΩ range.
12	OVH	I	Output connection for resistance measurement
13	OVSG	I	Sense low voltage for resistance measurement
14	OR1	O	Reference resistor connection for 660.0Ω range
15	VR5	O	Voltage measurement ÷10000 attenuator(1000V)
16	VR4	O	Voltage measurement ÷1000 attenuator(660.0V)
17	VR3	O	Voltage measurement ÷100 attenuator(66.00V)
18	VR2	O	Voltage measurement ÷10 attenuator(6.600V)
19	TEST5	I/O	Test pin
20	ACVL	O	DC signal low input in ACV/ACA mode. Connect to negative output of external AC to DC converter.
21	ACVH	O	DC signal high input in ACV/ACA mode. Connect to positive output of external AC to DC converter.
22	ADI	I	Negative input of internal AC to DC OP Amp.
23	ADO	O	Output of internal AC to DC OP Amp.
24	ADOHZ	I	Frequency input under voltage/current mode, offset to AGND.
25	VRH	O	Output of band-gap voltage reference. Typically -1.2V
26	VR	I	Reference input voltage connection. Typically -400mV
27	VA+	I	For ADP mode. De-integrating voltage positive input. The input should be higher than VA-.
28	VA-	I	For ADP mode. De-integrating voltage negative input. The input should be lower than VA+.
29	ADP	I	Measurement input in ADP mode.
30	SGND	G	Signal Ground.
31	OHMC1	O	Filter capacitor connection for resistance mode under 660.0KΩ range.
32	VR1	I	Measurement input.
33	VBAR	I	In capacitance mode, a compensation capacitor is connected. In temperature mode, it is used to control decimal point. In μA or mA modes, pull to V- to disable the 'μ <sub>2</sub> ' or 'm <sub>2</sub> ' sign on LCD.
34	R9K	O	Connect to a precise 9KΩ resistor.
35	R1K	O	Connect to a precise 1KΩ resistor.
36	CA-	I/O	Negative auto-zero capacitor connection for capacitor measurement
37	CA+	I/O	Positive auto-zero capacitor connection for capacitor measurement
38	CSH+	O	Positive connection to external capacitor.
39	CSH-	O	Negative connection to external capacitor.
40	OHMC2	O	Filter capacitor connection for 6.600MΩ range in resistance mode.
41	SLEEP	O	Sleep mode indicator, asserts low in SLEEP mode.
42	FREQ	I	Frequency counter input, offset V-/2 internally by the chip.
43	RS232	I	Assert low to enable serial data output.
44	DSHIFT	I	Pull to V- to have 0.01MΩ resolution in 66.00MΩ. Pull to DGND or keep it float will change the resolution to 0.1MΩ.
45	BKLIT	I	Back light function. Pulse low to set BKOUT pin output.



46	APOSEL	I	Auto power off idle time selection.
47 - 63	SEG17 – SEG01	O	LCD segment line 01 – 17
64	BP4	O	LCD backplane 4
65	BP3	O	LCD backplane 3
66	BP2	O	LCD backplane 2
67	BP1	O	LCD backplane 1
68	ANNUNC	O	Square wave output at the backplane frequency, synchronized to BP1. ANNUNC can be used to control display annunciator. Connect a LCD segment to ANNUNC to turn it on; connect an LCD segment to its backplane to turn it off.
69	BUZOUT	O	Outputs a 2KHz audio frequency signal for driving piezoelectric buzzer when BUZIN is low.
70	OR	O	OL/UL state indicator in <b>ADP</b> modes. Origin state is low(V-), it goes to high(DGND) only when the reading is over 6,600 counts. It comes back to low only when the reading is less than 600 counts. It will keep the state when the reading is between 600 and 6600 counts.
71	BUZIN	I	Pull to V- to enable the BUZOUT.
72	ZERO	I	Pulse to V- to enable ZERO function.
73	ENIR	I	Pull to V- to enable the INRUSH function.
74	R_OVH	I	Pull to V- to allow protection resistance increasing at OVH path
75	BKOUT	O	If BKLIT function is enabled, this pin will change from -3V to +3V for 60 sec, once press BKLIT pin again within 60 sec, this pin will change back to -3V.
76	OSC1	I	Crystal oscillator input connection
77	OSC2	O	Crystal oscillator output connection
78	VST	I	Set to V- to enable the auto range voltage mode to start from 660.0V range.
79	MAXMIN	I	Pulse to V- to enable MAX/MIN function.
80	VAHZ	I	Pulse to V- to enable VAHZ mode.
81	REL	I	Pulse to V- to enable Relative function.
82	HOLD	I	Pulse to V- to enable HOLD function.
83	RANGE	I	Pulse to V- to enable manual mode and manual range selection.
84	CESEL	I	CE selection feature control pin.
85	BKSET	I	Set to V- to change the backligh idle time from 60 sec. to 180 sec.
86	KEY	I	Pulse to V- to change mode. In ADP mode, if this pin is connected to V-, the buzzer output will be off when the ADP input overflows. In ACA modes for Clampmeter (FC5=low), pulse low to V- could enable Inrush function.
87	SLACDC	I	Select initial state. Please refer to page 14
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	P/G	Digital ground. Connecting to battery positive terminal.
99 - 100	AGND	P/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+ $\geq$ (AGND/DGND+0.5V)
AGND/DGND	AGND/DGND $\geq$ (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	-25°C to 125°C

## Electrical Characteristics

TA=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	I <sub>DD</sub>	Normal operation	—	1.9	2.2	mA
In DCV mode	I <sub>SS</sub>	In sleep mode	—	2.5	5	μA
Voltage roll-over error	REV	10MΩ input resistor	—	—	±0.1	%F.S <sup>1</sup>
Voltage nonlinearity	NLV	Best case straight line	—	—	±0.1	%F.S
Input Leakage			-10	1	10	PA
Low battery flag voltage		V- to AGND	-2.4	-2.3	-2.2	V
Zero input reading		10MΩ input resistor	-000	000	+000	counts
Reference voltage and open circuit voltage for 660Ω measurement	V <sub>REF</sub>	100KΩ resistor between VRH and AGND	-1.3	-1.2	-1.1	V
Peak to peak backplane drive voltage		-3.5V ≤ V ≤ -2.2V	3.1	3.2	3.3	V
Counter time base period		f <sub>OSC</sub> = 4MHZ	—	1	—	sec
Open circuit voltage for Ω measurement (except 660Ω)		Ω and Continuity Mode	-0.86	-0.78	-0.70	V
Internal pull-high to 0V current		Between V- pin and HOLD, RANGE, KEY, FC1, FC2, FC3, FC4, FC5, BKLIT, MAXMIN	—	1.2	—	μA
		Between V- pin and RS232	—	11	—	
Internal pull-low to V- current		Between GND Pin and SLACDC		1.5		μA
AC frequency response at 6.600V range		±1%	—	40-400	—	HZ
		±5%	—	400-2000	—	
Reference voltage temperature coefficient	TC <sub>RF</sub>	100KΩ resistor Between VRH 0°C < TA < 70°C	—	50	—	ppm/°C

Capacitance measurement accuracy	6.6nF – 66mF	-1.5	—	1.5	%F.S
		-3	—	3	digits

Note:

- 1.Full Scale
- 2.Above specification from 6.6nF to 6.6uF ranges are specified under REL mode.

## Function Description

### 1. Operating Modes

#### 1.1 Voltage Measurement

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

Configuration	Full Scale Range	Divider Ratio	Resister Connection
VR1	660.0mV <sup>1</sup>	1	VR1 (10MΩ)
VR2	6.600V	1/10	VR2 (1.111MΩ)
VR3	66.00V	1/100	VR3 (101KΩ)
VR4	660.0V <sup>2</sup>	1/1000	VR4 (10KΩ)
VR5	1000V	1/10000	VR5 (1KΩ)

Note:

1. 660.0mV range only exists in manual mode
2. If VST is set to V- level, the auto range mode will start from 660.0V range. 660.0mV – 66.00V ranges only exist in manual mode.

#### 1.1.2 CE selection

ES51969 has a CE selection feature archived by configuring a CESEL pin. If pin CESEL is connected to V-, ES51969 will have a 610.0V overflow level in DC and AC 660.0V ranges. And the 1000V range will not occur anymore. If pin CESEL is connected to DGND or floating, the ES51969 will have a 1010V overflow level in DC 1000V range and have a 1010V overflow level in AC 1000V range. The meter will Show OL when the measuring signal reaches the overflow level. The configuration of CESEL is listed below.

CESEL	DCV	ACV
DGND or floating	1010V	1010V
V-	610.0V	610.0V

### 1.1.3 HCF signal detection

ES51969 provides detection of high-crest-factor (HCF) signal in ACV mode. ES51969 senses the signal and determines it as HCF if the  $V_{pp}$  is large enough. Once the signal is determined as HCF, ES51969 will jump up one measuring range regardless of current measurement value. It takes 60ms to jump one range up. The jumping up process will continue until the maximum range is reached. With HCF detection, a more accurate result could be obtained. For example, when a input signal with  $V_{pp}=300V$ ,  $V_{rms}=60V(CF=5)$  was applied, traditional DMMs might stay at 66V range but shows counts with the amount of error up to 10% or even bigger. The error rises from limited input/output swing at internal ADC. With HCF detection, DMM will stay at 660V range and exhibits more accurate results.

In addition to accuracy improvement, HCF will speed up the measuring process for high voltage signals. For example, a 1000Vrms is applied, ES51969 will take about 180ms (3 HCF jumps) to enter 1000V range. And it takes 1 or 2 measuring processes to obtain the stable result. Thus a stable LCD reading could be obtained within 1 sec.

In determining whether the input signal is HCF, ES51969 senses the signal at VR1 for fast response. However if a signal consists of a small ac part and a large enough dc part, ES51969 might incorrectly treat it as HCF. This could incur range-looping phenomenon, i.e., the measurement could not settle to a specific range. When this phenomenon happens and keeps over 5 seconds, ES51969 will change the UL level to 460 or lower counts (the default UL level is 500 counts in ACV mode). The measurement range will stay at the higher one mostly, so the range-looping phenomenon will not occur again.



### 1.1.4 The true RMS-to-DC conversion with ES636

If ES636 is used for true RMS-to-DC measurement, the test circuit is shown in Figure 1. Make ADO and ADI pin short, and keep TEST5 pin float. Connect OVSG pin to AGND through a switch in ACV measurement mode.

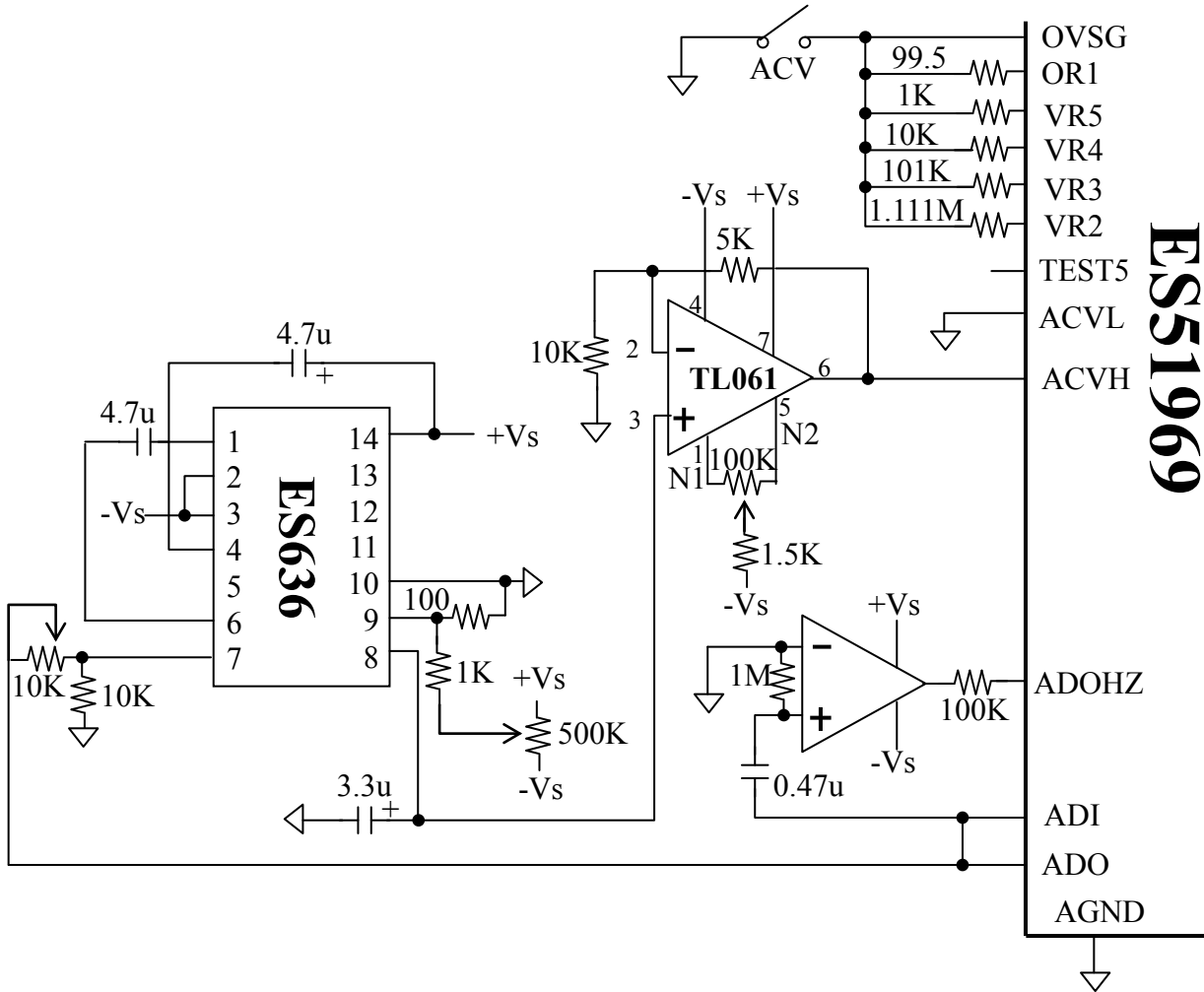


Figure 1. The true RMS-to-DC conversion with ES636



## 1.2 Resistance Measurement

A re-configurable 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. In 66MΩ range, the resolution is 0.1MΩ, if SHIFT is floating or connected to DGND. It will be changed to 0.01MΩ, if DSHIFT is pulled to V-.

Configuration	Full Scale Range	Relative Resistor	Equivalent value
OR1	660.0Ω	OR1	100Ω
OR2	6.600KΩ	VR5	1KΩ
OR3	66.00KΩ	VR4	10KΩ
OR4	660.0KΩ	VR3 // VR1	100KΩ
OR5	6.600MΩ	VR2 // VR1	1MΩ
OR6	66.00MΩ	VR1	10MΩ

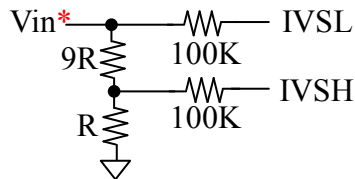
## 1.3 Current measurement for multimeter

ES51969 has 2 automatic and 1 manual current measurement modes for multimeter. The following table summarizes the full-scale range of each mode. When ES51969 operates in the current measurement modes for multimeter, It takes high input from pin IVSH or IVSL, low input from pin SGND and reference voltage from pin VR.

Mode	FC1~4	<sup>2</sup> VBAR	Full Scale	Input Terminal
Automatic1	1,1,0,1	1	660.0μA / 6600μA	<sup>3</sup> IVSL/IVSH V.S. SGND
Automatic2	1,1,1,1	1	66.00mA / 660.0mA	<sup>3</sup> IVSL/IVSH V.S. SGND
Manual	0,0,0,0	X	66.00A	IVSH V.S. SGND

Note:

1. Connect VBAR to V- will disable the “μ<sub>2</sub>” / ”m<sub>2</sub>” symbol on LCD panel, so in the mV range of voltage measurement, this pin must keep floating.
2. The typical connection of input terminal is as the schematic below:



\*The voltage results from the current flows through resistors R and 9R. Its input range is up to 3.3Vrms.

## 1.4 Current measurement for clampmeter

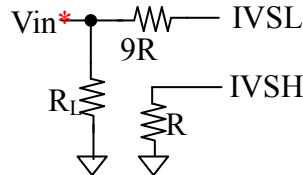
ES51969 has 2 automatic and 4 manual current measurement modes for Clampmeter. The following table summarizes the full-scale range of each mode. When ES51969 operate in the automatic mode1&2, it takes high input from IVSH/IVSL (higher range/lower range), low input from SGND and reference voltage from VR. When ES51969 operate in the manual mode1~4, It takes high input from ADP, low input from SGND and reference voltage from VA+ and VA-.



Mode	FC1~4	VBAR	Full Scale	Input Terminal
Automatic1	1,1,0,1	0	660.0A / 6600A	IVSL/IVSH V.S. SGND
Automatic2	1,1,1,1	0	66.00A / 660.0A	IVSL/IVSH V.S. SGND
Manual1	1,1,0,0	X	6.600A	ADP V.S. SGND
Manual2	1,0,0,0	X	66.00A	ADP V.S. SGND
Manual3	1,0,1,0	X	660.0A	ADP V.S. SGND
Manual4	1,0,0,1	X	6600A	ADP V.S. SGND

Note:

1. Connect VBAR to V- will disable the “ $\mu_2$ ” / ” $m_2$ ” symbol on LCD panel, so in the mV range of voltage measurement, this pin must keep floating.
2. In DC current modes for clampmeter, ES51969 provides **Zero function** for offset removing.
3. In AC current modes for clampmeter and **FC5** is set to **low**, ES51969 provides an **Inrush function** to measure the inrush current of a motor when it's starting up.
4. The typical connection of input terminal is as the schematic below:



\*The voltage results from induced current flows through a load resistor. Its input range is up to 3.3Vrms.

## 1.5 Capacitance Measurement

The following table summarizes the eight ranges of capacitance measurement mode.

Configuration	Full Scale Range	Relative Resistor	Measurement Period
C1	6.600nF	VR1	0.33 sec
C2	66.00nF	VR2	0.33 sec
C3	660.0nF	VR3	0.33 sec
C4	6.600uF	VR4	0.33 sec
C5	66.00uF	R9K / R1K	0.66 sec
C6	660.0uF	R9K / R1K	1.32 sec
C7	6.600mF	R9K / R1K	1.32 sec
C8	66.00mF	R9K / R1K	6.60 sec

Note:

1. In order to obtain an accurate reading, a capacitor must be discharged before measurement begins. The chip has a built-in discharge mode to automatically discharge the capacitor. In discharge mode, the LCD displays **dIS.C**
2. Discharging through the chip is quite slow. We recommend users to discharge the capacitor with some other apparatus.
3. In capacitance mode for clamp-meter (FC1~4={0,1,1,0}, SLACDC=1), the C1~C3 ranges will not occur whatever in the automatic or manual operation. **When R\_OVH (pin74) is pulled to V- in this mode, the charging current for 660uF-6.6mF is reduced. The 66.00mF range will be omitted. OVH path resistance is allowed to be increased. (For better high voltage protection)**

## 1.6 Continuity Check

Continuity check shares the same configuration with 660.0Ω manual resistance measurement mode and has buzzer output to indicate continuity. The buzzer generates 2KHz beep whenever the reading is less than 30Ω. **When R\_OVH (pin74) is pulled to V- in this mode, the buzzer generates 2kHz beep when ever the reading is less than 50Ω.**

## 1.7 Diode Measurement

Diode measurement mode shares the same configuration with 6.600V manual voltage measurement mode and has buzzer output to indicate continuity. The buzzer generates a 2KHz sound whenever the reading is less than 30mV. If the test circuit is open or the voltage drop between the two ports of the device(diode) under test is larger than 2V, the LCD panel will show “OL”.

### 1.8 Frequency counter

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

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

where  $F_{\text{osc}}$  is the frequency of the crystal oscillator. Thus, the counter has a 1-second time base when a 4MHz oscillator is used. The frequency counter can select the proper range automatically or manually. Auto-range operation extends over six decades, from 660.0Hz to 66.00MHz. The following table summarizes the full-scale range of the frequency counter.

Range	Full Scale
FR1*	660.0Hz
FR2	6.600KHz
FR3	66.00KHz
FR4	660.0KHz
FR5	6.600MHz
FR6	66.00MHz

\*If input frequency is less than 10.0Hz, ES51969 will show **00.0Hz**.

### 1.9 Duty cycle measurement

In frequency mode, press the VAHZ bottom will force ES51969 enter duty cycle measurement mode. The duty cycle measurement mode takes high input from FREQ pin, and low input from SGND pin. The annunciator “%” on LCD panel indicates whether the duty cycle measurement mode is activated. When the duty cycle is less than 10.0%, the LCD panel shows UL and the UL bit of RS232 data becomes high. When the duty cycle is more than 94.9%, the LCD panel shows OL and the OL bit of RS232 data becomes high. If the frequency of input signal is less than 10.0Hz, the LCD panel also shows UL and the UL bit of RS232 data becomes high. ES51969 also provides a single duty cycle mode, which FC1~FC4 = {1,1,1,0}, as an independent rotary switch for the meters without a frequency mode configured.

### 1.10 Temperature measurement mode

Temperature measurement mode takes input signal from ADP pin and reference voltage from (VA+ - VA-). ES51969 has a built-in °C-to-°F scale translation circuit, and only needs an external °C scale application circuit. The application circuit for °F scale is not required. In temperature measurement mode, the default range is 6600 °C or °F. The VBAR pin is used to control the first decimal point (DP1) on the LCD panel. When VBAR is pulled to V-, DP1 will be turned on and the full scale becomes 660.0 °C or °F.

### 1.11 Auto power off and Idle Time selection

ES51969 has a default auto power off function. If the meter is idle for more than the given Idle Time, the chip automatically turns the power off. The idle time to trigger the auto power off function is determined by pin 'APOSEL'. If pin APOSEL is connected to V-, the Idle Time will be set to 15 minutes. If pin APOSEL is connected to DGND or floating, the Idle Time will be set to 30 minutes. When APO happens, the state of the meter is saved. The APO sign on the LCD panel indicates whether the auto power off is enabled or not. In some cases, user might want to disable Auto power off. There are two ways to disable this feature as following:

1. Power on the meter when any of the push functions, except for HOLD, is pressed down.
2. In addition, when RS232 output is active, the auto power off function is also disabled.

**Note:** Powering on the meter while pressing HOLD and lasts 2 seconds turns on all LCD segments until HOLD is pressed again.

### 1.12 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.

### 1.13 Re-power on

After auto power-off, pushing any of the push function or changing the rotary mode can turn on the meter again. If the meter is re-powered on by changing the rotary 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 SLACDC, FC1, FC2, FC3, FC4, FC5, and KEY. When FC5 is high, the measurement mode list is below.

SLACDC	FC1	FC2	FC3	FC4	Mode	Function of KEY
0	1	0	1	1	Voltage Measurement	DCV ↔ ACV
0	1	1	0	1	<sup>123</sup> Auto DC Current Measurement(μA)	DCA ↔ ACA
0	1	1	1	1	<sup>123</sup> Auto DC Current Measurement(mA)	DCA ↔ ACA
0	0	0	0	0	<sup>1</sup> 66A DC Current Measurement(A)	DCA ↔ ACA
X	1	1	1	0	Duty Cycle Measurement	—
0	1	1	0	0	<sup>2</sup> Manual DC 6.600A	DCA ↔ ACA
0	1	0	0	0	<sup>2</sup> Manual DC 66.00A	DCA ↔ ACA
0	1	0	1	0	<sup>2</sup> Manual DC 660.0A	DCA ↔ ACA
0	1	0	0	1	<sup>2</sup> Manual DC 6600A	DCA ↔ ACA
0	0	0	1	1	Resistance Measurement	Ω ↔ Continuity
0	0	0	0	1	Continuity Check	Continuity ↔ Diode
0	0	1	1	1	Resistance Measurement	Ω ↔ Continuity ↔ Diode
0	0	0	1	0	Frequency Measurement	—
0	0	1	1	0	Capacitance Measurement	—
0	0	1	0	0	Temperature Measurement	°C ↔ °F
1	1	0	1	1	Voltage Measurement	ACV ↔ DCV
1	1	1	0	1	<sup>123</sup> Auto AC Current Measurement(μA)	ACμA ↔ DCμA
1	1	1	1	1	<sup>123</sup> Auto AC Current Measurement(mA)	ACmA ↔ DCmA
1	0	0	0	0	<sup>1</sup> 66A AC Current Measurement(A)	ACA ↔ DCA
1	1	1	0	0	<sup>2</sup> Manual AC 6.600A	ACA ↔ DCA
1	1	0	0	0	<sup>2</sup> Manual AC 66.00A	ACA ↔ DCA
1	1	0	1	0	<sup>2</sup> Manual AC 660.0A	ACA ↔ DCA
1	1	0	0	1	<sup>2</sup> Manual AC 6600A	ACA ↔ DCA
1	0	0	1	1	*ADP0	—
1	0	0	0	1	*ADP1	—
1	0	1	1	1	*ADP2	—
1	0	0	1	0	*ADP3	—
1	0	1	1	0	Capacitance Measurement (Clamp)	—
1	0	1	0	0	Temperature Measurement	°F ↔ °C
X	0	1	0	1	Resistance Measurement	Ω ↔ Diode

X means “don’t care”.

\*When FC5 is high, the ADP0, ADP1, ADP2 and ADP3 modes can display minus sign.

<sup>1</sup>These modes could be designed for multimeter current modes, please refer to section 1.3.

<sup>2</sup>These modes could be designed for clampmeter current modes, please refer to section 1.4.

<sup>3</sup>These modes could be designed for clampmeter 2-range automatic voltage modes, please refer to section 1.5.

When FC5 is low, the KEY bottom is used to enable Inrush function in ACA modes for clampmeter. The measurement mode list is below.

SLACDC	FC1	FC2	FC3	FC4	Mode	KEY
0	1	0	1	1	DC Voltage Measurement	—
0	1	1	0	1	<sup>123</sup> Auto DC Current Measurement( $\mu$ A)	—
0	1	1	1	1	<sup>123</sup> Auto DC Current Measurement(mA)	—
0	0	0	0	0	<sup>1</sup> 66A DC Current Measurement(A)	—
X	1	1	1	0	Duty Cycle Measurement	—
0	1	1	0	0	<sup>2</sup> Manual DC 6.600A	—
0	1	0	0	0	<sup>2</sup> Manual DC 66.00A	—
0	1	0	1	0	<sup>2</sup> Manual DC 660.0A	—
0	1	0	0	1	<sup>2</sup> Manual DC 6600A	—
0	0	0	1	1	Resistance Measurement	—
0	0	0	0	1	Continuity Check	—
0	0	1	1	1	Diode Measurement	—
0	0	0	1	0	Frequency Measurement	—
0	0	1	1	0	Capacitance Measurement	—
0	0	1	0	0	Temperature Measurement ( $^{\circ}$ C)	—
1	1	0	1	1	AC Voltage Measurement	—
1	1	1	0	1	<sup>123</sup> Auto AC Current Measurement( $\mu$ A)	Inrush function <sup>4</sup>
1	1	1	1	1	<sup>123</sup> Auto AC Current Measurement(mA)	Inrush function <sup>4</sup>
1	0	0	0	0	<sup>1</sup> 66A AC Current Measurement(A)	—
1	1	1	0	0	<sup>2</sup> Manual AC 6.600A	Inrush function
1	1	0	0	0	<sup>2</sup> Manual AC 66.00A	Inrush function
1	1	0	1	0	<sup>2</sup> Manual AC 660.0A	Inrush function
1	1	0	0	1	<sup>2</sup> Manual AC 6600A	Inrush function
1	0	0	1	1	*ADP0	—
1	0	0	0	1	*ADP1	—
1	0	1	1	1	*ADP2	—
1	0	0	1	0	*ADP3	—
1	0	1	1	0	Capacitance Measurement (Clamp)	—
1	0	1	0	0	Temperature Measurement ( $^{\circ}$ F)	—
X	0	1	0	1	Resistance Measurement	—

X means “don’t care”.

\*When FC5 is low, ADP0, ADP1, ADP2 and ADP3 modes can **NOT** display minus sign.

<sup>1</sup>These modes could be designed for multimeter current modes, please refer to section 1.3.

<sup>2</sup>These modes could be designed for clampmeter current modes, please refer to section 1.4.

<sup>3</sup>These modes could be designed for clampmeter 2-range automatic voltage modes, please refer to section 1.5.

<sup>4</sup>In these modes, inrush function is available only when VBAR is pulled to V-.

### 3. Push function

All the enabled push functions will be reset when the measurement mode is changed by rotary switch. Change measurement mode by KEY function will reset enabled Range, Hold, Max/Min, REL and Zero functions. The following table lists the available function versus every measurement mode.

Function Mode	Range	Hold	Max/Min	REL	Zero	VAHz	Inrush
Voltage	O	O	O	O	X	O	X
<sup>1</sup> 2-Range Auto Voltage mode	O	O	O	O	X	O	X
<sup>2</sup> Current Mode for Multimeter	O	O	O	O	X	O	X
<sup>3</sup> Current Mode for Clampmeter	O	O	O	AC	DC	AC	AC
Resistance	O	O	O	O	X	X	X
Frequency	O	O	O	O	X	X	X
Duty cycle	X	O	O	O	X	X	X
Capacitance	O	O	O	O	X	X	X
Continuity	X	O	O	O	X	X	X
Diode	X	O	O	O	X	X	X
Temperature	X	O	O	O	X	X	X

Note:

<sup>1</sup>Include auto 66.00V/660.0V and auto 660.0V/1000V modes, please refer to **section 1.5**.

<sup>2</sup>Include automatic  $\mu$ A, automatic mA and manual 66A modes, please refer to **section 1.3**.

<sup>3</sup>Include 2 automatic modes and 4 manual modes, please refer to **section 1.4**.

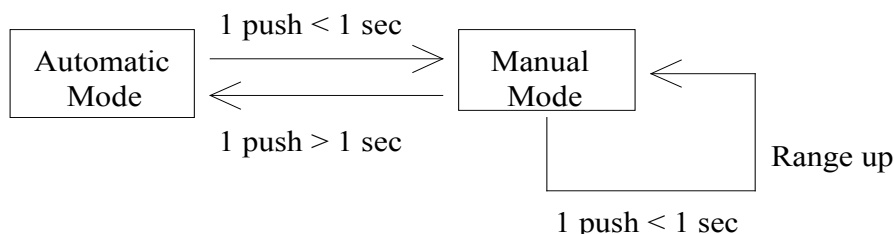
#### 3.1 HOLD

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 switches 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
V(DC/AC)	VR2 – VR5	VRi → VRi + 1, VR5 → VR1	660.0mV – 1000V	6.600V
Auto 66V/660V (DC/AC)	R1 – R2	R1 → R2, R2 → R1	66.00V – 660.0V	66.00V
Auto 660V/1000V (DC/AC)	R1 – R2	R1 → R2, R2 → R1	660.0V – 1000V	660.0V
Auto μA(DC/AC)	R1 – R2	R1 → R2, R2 → R1	660.0μA – 6600μA	660.0μA
Auto mA(AC/DC)	R1 – R2	R1 → R2, R2 → R1	66.00mA – 660.0mA	66.00mA
66 A(DC/AC)	fixed	fixed	66.00A	66.00A
Auto 66A/660A (DC/AC)	R1 – R2	R1 → R2, R2 → R1	66.00A – 660.0A	66.00A
Auto 660A/6600A (DC/AC)	R1 – R2	R1 → R2, R2 → R1	660.0A – 6600A	660.0A
Capacitance	C1 – C8	Ci → Ci + 1, C8 → C1	6.600nF – 66.00mF	6.600nF
Clamp Capacitance (When R_OVH is floating)	C4 – C8	Ci → Ci + 1, C8 → C4	6.600μF – 66.00mF	6.600μF
Clamp Capacitance (When R_OVH is pulled to V-)	C4 – C7	Ci → Ci + 1, C7 → C4	6.600μF – 6.600mF	6.600μF
Ω	OR1 – OR6	ORi → ORi + 1, OR6 → OR1	660.0Ω – 66.00MΩ	660.0Ω
Continuity	fixed	fixed	660.0Ω	660.0Ω
Diode	fixed	fixed	6.600V	6.600V
Frequency	FR1 – FR6	FRi → FRi + 1 FR6 → FR1	660.0Hz – 66.00MHz	660.0Hz

Note: Pushing RANGE resets all existing special modes.

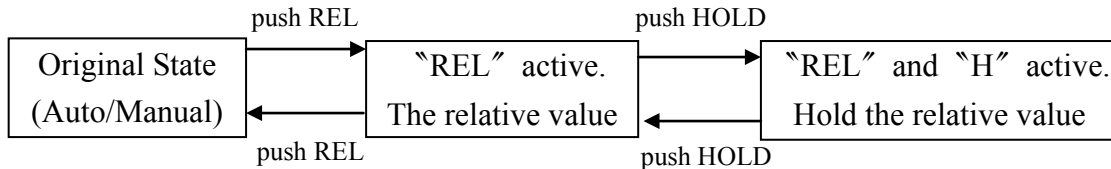
### 3.3 KEY

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

In ACA modes for clampmeter, pulse low to V- could enable Inrush Function.

### REL + HOLD

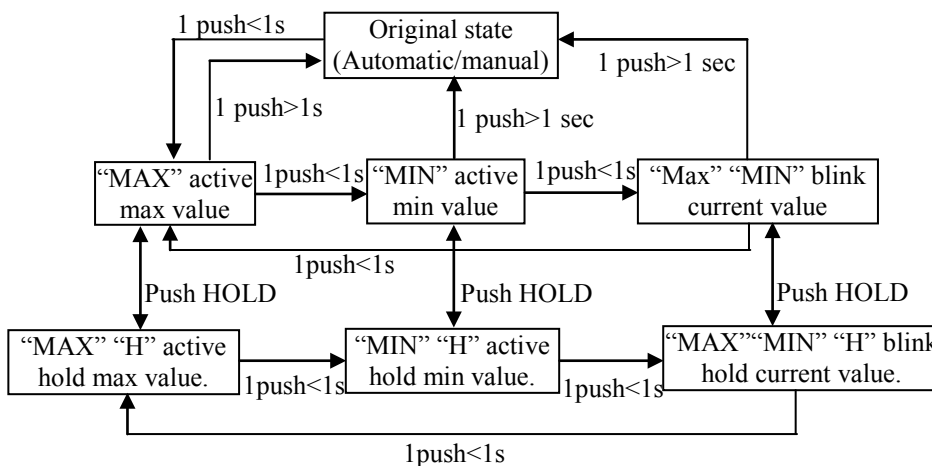
In REL mode, the LCD panel displays  $D_{N+K} - D_N$ , where  $N = 1, 2, 3, \dots$ ,  $D_N$  is the last value before REL is pushed, and  $D_{N+K}$  is the current value. The meter returns to normal operation if REL is pressed again. Pressing HOLD in REL mode makes the meter stop updating the LCD panel.



Note: It's possible that the relative value exceeds 6,600 or -6,600 counts, but never exceeds 9,999 or -9,999 counts. Such relative values are displayed. The LCD shows OL in REL mode only if  $D_N$  or  $D_{N+K}$  is more than 6,600 counts or the relative value is more than 9,999.

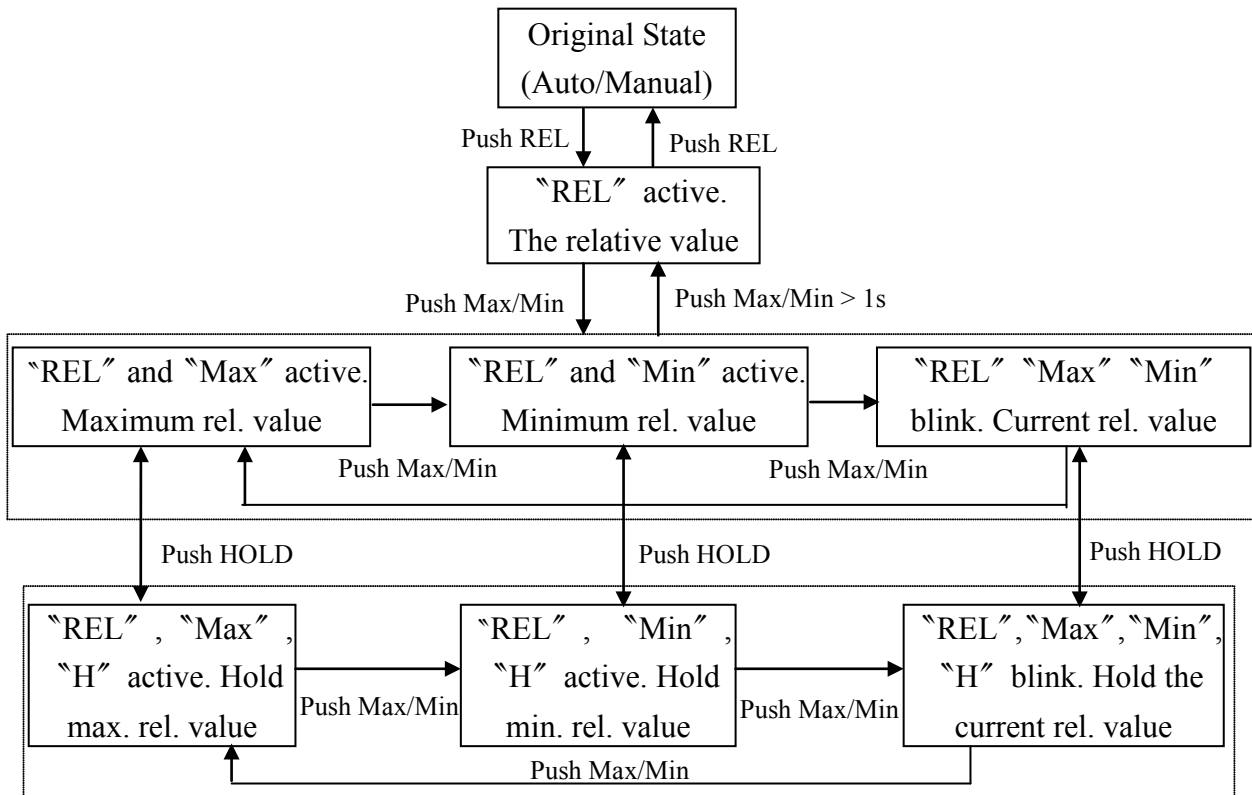
### 3.4 Max/Min + HOLD

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. The meter displays the minimum value, when it is pressed again. When Max/Min is pressed for the third time, the meter displays current 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.



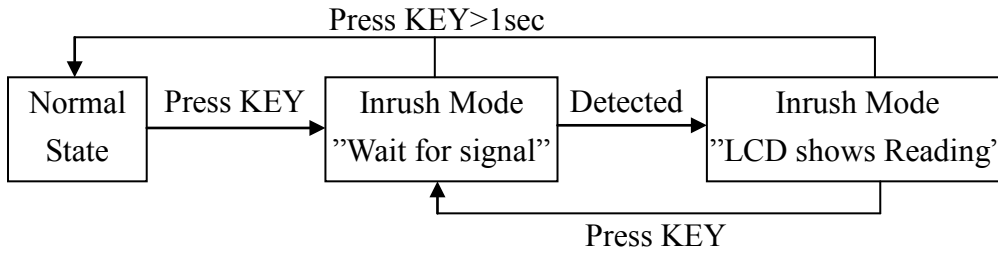
### 3.5 Relative + Max/Min + HOLD

Max/Min mode can be nested in REL mode. The meter displays the maximum or minimum value relative to the reference when Max/Min is pressed in REL mode. Pressing HOLD under REL + Max/Min makes the meter stop updating the LCD panel.

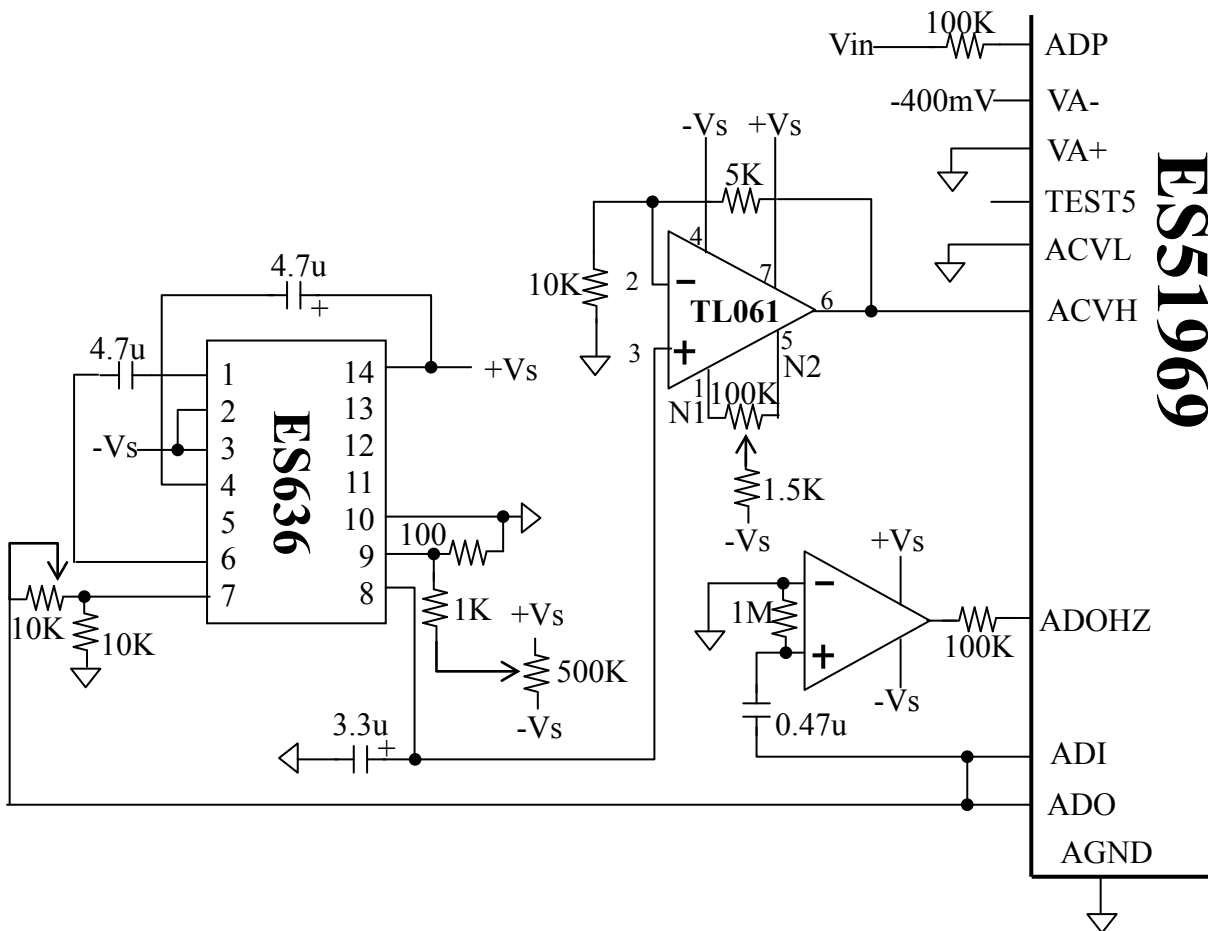


### 3.6 INRUSH function

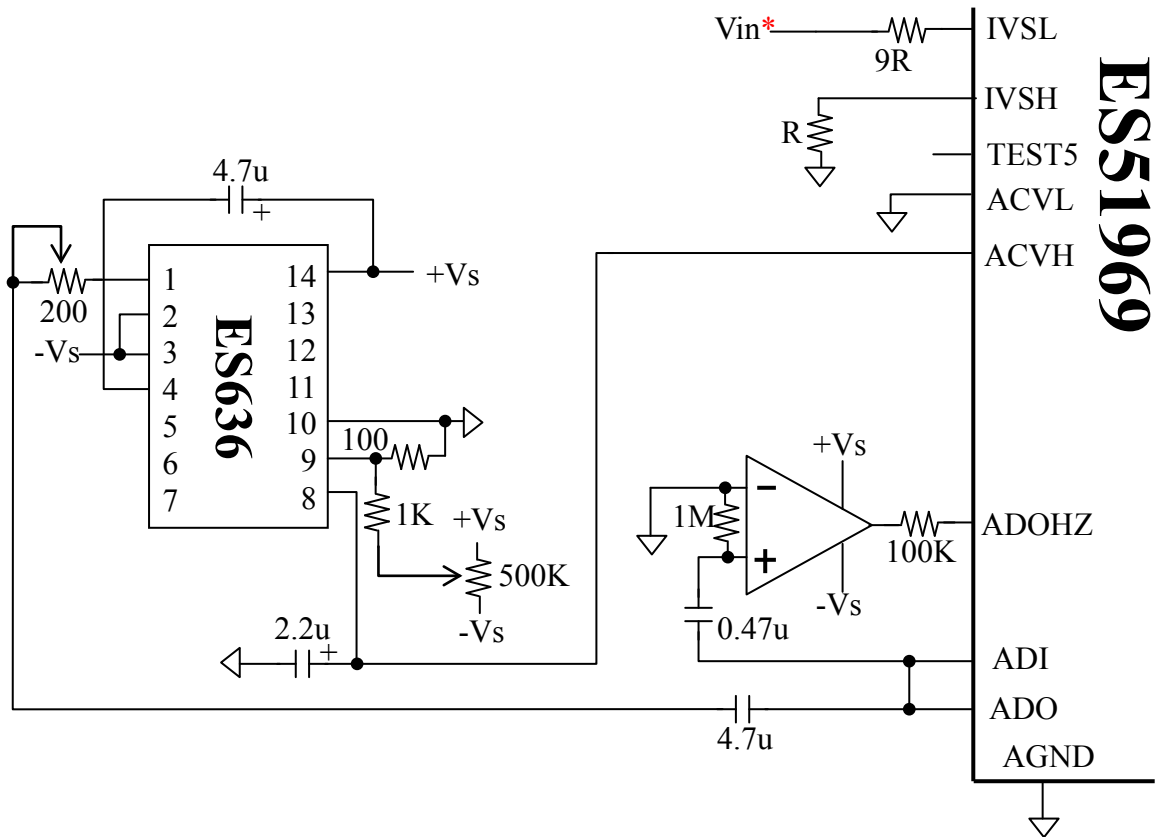
ES51969 provides a **INRUSH function** for **AC current measurement for clampmeter** to detect the starting-up current of a motor. Connect pin ENIR to V-, or the INRUSH function will be not available. In ACA modes for clampmeter and the **FC5 is set to low**, press **KEY** button will force meter to enter INRUSH mode. Then LCD displays “- - - -” until the motor starting up and being detected. The detection will be done only one time and the output reading will be hold. When it done, press **KEY** could enter INRUSH mode again. To exit INRUSH mode, **press KEY button more than one second**. Enter INRUSH mode in automatic ACA modes will force the range be locked in higher one. The test circuit and flow chart for inrush function is located at next pages. Any change of the component value may have influence on the INRUSH characteristic. So it's not recommended to have any change on these component value. For INRUSH function, an external **true RMS-to-DC ES636 IC** must be required.



Flow chart of Inrush function



Inrush function test circuit for **manual current mode** of clampmeter.



\*Input full-scale range is up to 3.3V rms.

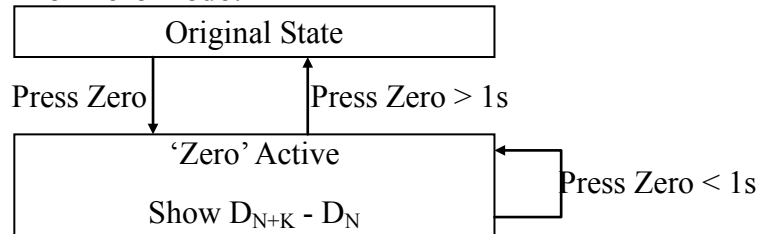
### Inrush function test circuit for 2-range automatic current mode of clampmeter

#### 3.7 ZERO function

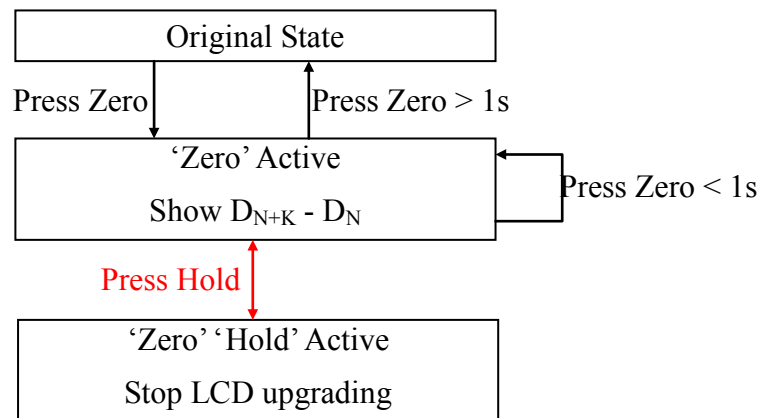
In manual DC 6.600A, 66.00A, 660.0A and 6600A, auto DC 66.00A/660.0A and auto DC 660.0A/6600A measurement modes, ES51969 provides Zero function to remove the residual current value. Push ZERO bottom less than one second to enter Zero mode. In Zero mode, the LCD panel displays  $D_{N+K} - D_N$ , where  $N = 1, 2, 3, \dots$ ,  $D_N$  is the last conversion value before Zero is pushed, and  $D_{N+K}$  is the current conversion value. If Zero is pushed again in Zero mode, the meter will refresh the  $D_N$  value and displays the  $D_{N+K} - D_N$  again. The meter returns to normal operation if Zero is pressed and held for longer than one second. Pressing HOLD in Zero mode makes the meter stop updating the LCD panel. In 2-range auto DCA modes for clampmeter (660.0A/6600A or 66.00A/660.0A), the system will stay in automatic mode, even if the Zero function is activated. In other words, It could achieve real automatic operation. In automatic mode, Zero function could not be entered from higher range, but it could be still activated if current range is lower one. This is because most residual current value is so small that the range could not be higher one in automatic mode. When enter Zero mode from

lower range, the system will store the nonzero counts (residual current value). If the range goes up to higher one automatically, the nonzero counts will be divided by ten. So this function will still work well in automatic modes.

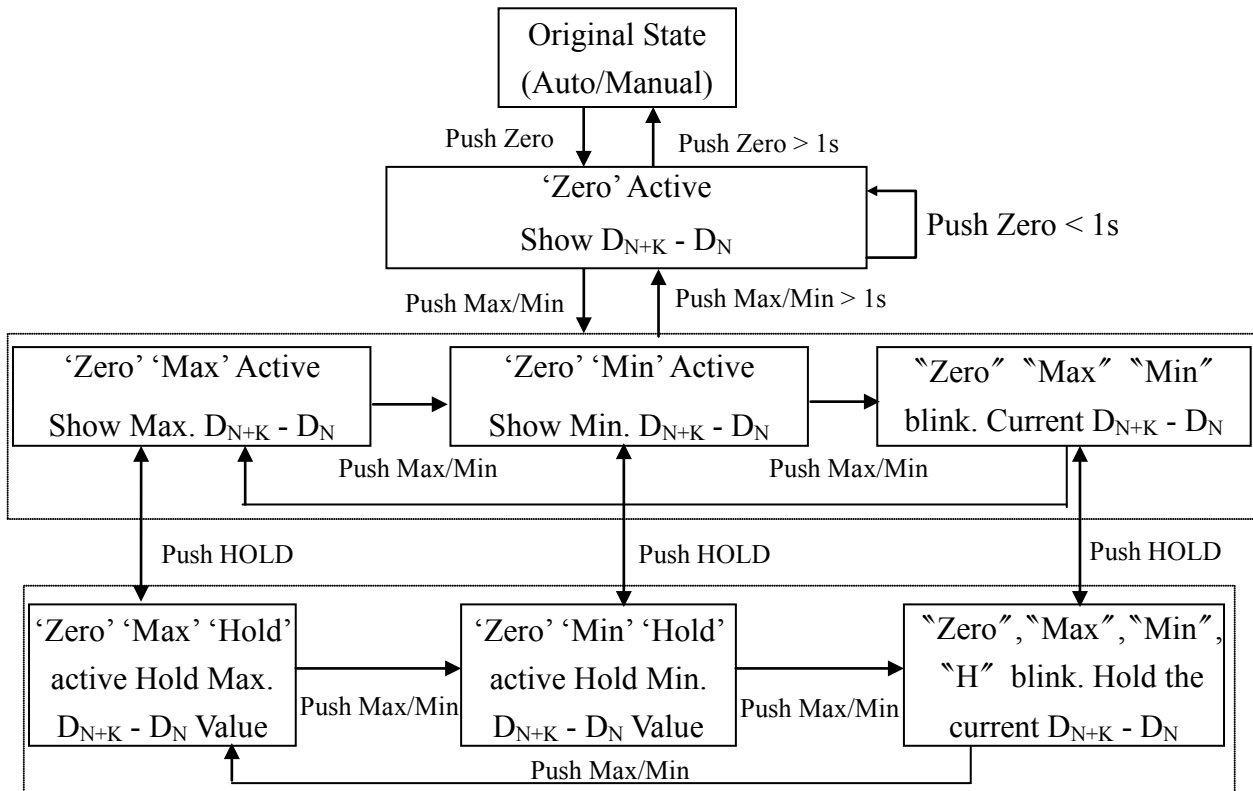
**State diagram for Zero mode:**



**State diagram for Zero + HOLD mode:**

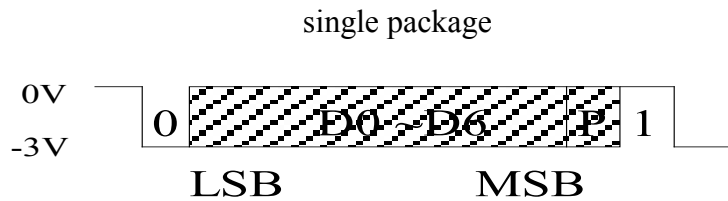


**State diagram for Zero + Max/Min + HOLD mode:**

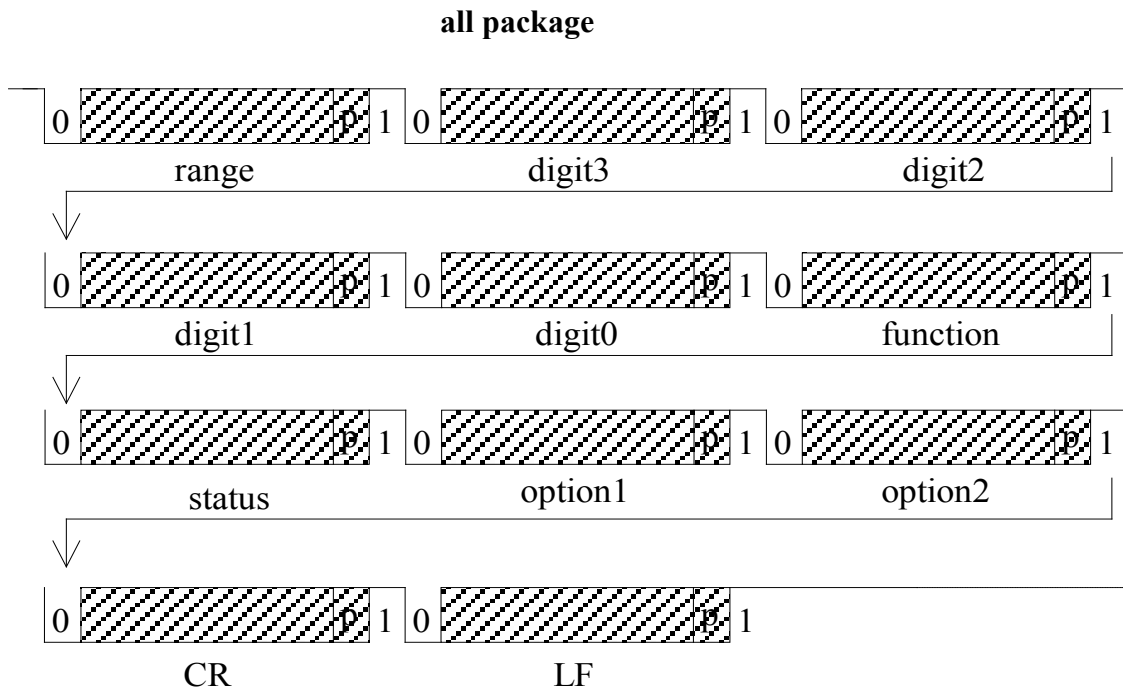


#### 4. Serial Data Output

The RS232 function will be activated if the RS232 pin is pulled to and asserts at V-. The serial data sent to SDO pin once every A/D conversion cycle. The data format complies with JIS 7Bits transmission code with a baud rate of 19230. The host can use RS232 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 are just the digits on the LCD panel. The function packet indicates the measurement mode of the meter. Status, option 1 and option 2 give 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 FUNCTUON

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-FC5 switch.

Code	Measurement Mode	VBAR=0	VBAR=1
0111011	Voltage	Don't care	
<sup>3</sup> 0111101	Auto $\mu$ A Current	Auto $\mu$ A Current	Auto 660.0A/6600A
<sup>3</sup> 0111111	Auto mA Current	Auto mA Current	Auto 66.00A/660.0A
0110000	66 A current	Don't care	
0111001	Manual A Current		
0110011	$\Omega$		
0110101	Continuity		
0110001	Diode		
0110010	Frequency		
0110110	Capacitance		
0110100	<sup>2</sup> Temperature		
0111110	<sup>1</sup> ADP/Duty		

<sup>1</sup>When the function code = 0111110, the measurement mode is determined by judge bit of Status packet.

If judge bit is 1, it means duty cycle mode. If judge bit is 0, it means ADP mode.

<sup>2</sup>When the function code = 0110100, the judge bit in the Status packet determines whether the unit is Celsius or Fahrenheit.

<sup>3</sup>When the function code = 0111101 or 0111111, the measurement mode is determined by VBAR bit of OPTION1 packet.

#### 4.2 RANGE

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

Code	V	*2-range auto V/A	66 A	Manual A	ADP	$\Omega$	Frequency	Capacitor
0110000	6.600V	Lower Range(IVSL)	66.00 A	6.600A	ADP3	660.0 $\Omega$	660.0Hz	6.600nF
0110001	66.00V	Higher Range(IVSH)		66.00A	ADP2	6.600K $\Omega$	-	66.00nF
0110010	660.0V			660.0A	ADP1	66.00K $\Omega$	6.600KHz	660.0nF
0110011	1000V			6600A	ADP0	660.0K $\Omega$	66.00KHz	6.600 $\mu$ F
0110100	660.0mV					6.600M $\Omega$	660.0KHz	66.00 $\mu$ F
0110101						66.00M $\Omega$	6.600MHz	660.0 $\mu$ F
0110110							66.00MHz	6.600mF
0110111								66.00mF

\*It includes auto  $\mu$ A, mA, 66.00V/660.0V, 660.0V/1000V, 66.00A/660.0A, 660.0A/6000A.



### 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.

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

Note: Because the cycle time of measurement for continuity/diode mode is only 82.5ms, the least significant digit may not be accurate

### 4.4 STATUS

The format of this package shown below. In Temperature mode, judge is 1 if the unit is °C and is 0 if the unit is °F. In ACA modes for clampmeter, the judge bit is 1 when the INRUSH function is activated. Sign field indicates whether the minus sign on the LCD panel is on or off. BATT field is one when battery low condition is true. OL indicates input overflow. In VAHz mode, the judge is 1 if the duty cycle mode is active.

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

0	1	1	UL	0	VBAR	0
BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0

The UL bit will be 1 only in following conditions:

1. The reading is less than 10.0Hz(LCD shows UL) in FR1 range of frequency mode.
2. The input frequency is less than 10.0Hz or the duty cycle value is less than 10.0% in duty cycle measurement mode.

The VBAR bit will be 1, when the VBAR pin is connected to V-.

#### 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, either voltage or current. 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.

0	1	1	DC	AC	AUTO	VAHZ
BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0

#### 4.7 CR

Carriage return. The transmitted code is 0001101.

#### 4.8 LF

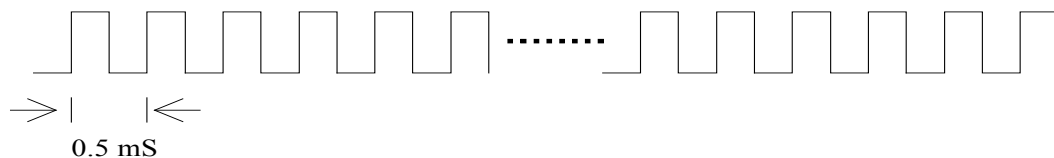
Line feed. The transmitted code is 0001010.

### 5. Miscellaneous

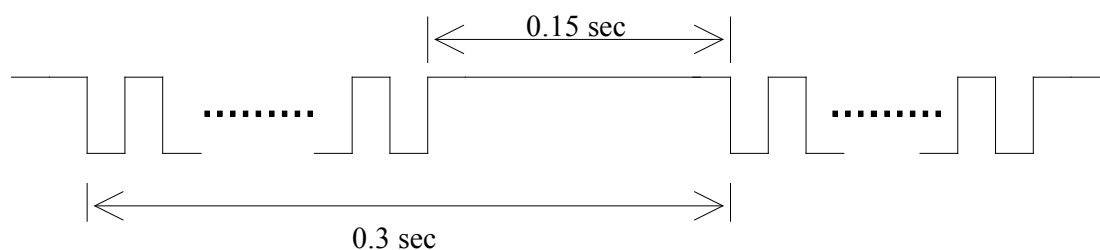
The conditions, which the meter turns on the buzzer, include:

- (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 mode generates one beep every 0.3 seconds (or 3.33 beeps per second.)
- (5) Continuity(diode) check generates a continuous 2KHz beep whenever the measurement is less then 30Ω(30mV)
- (6) Auto power off generates a 2KHz beep which lasts for 1.5 seconds.

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

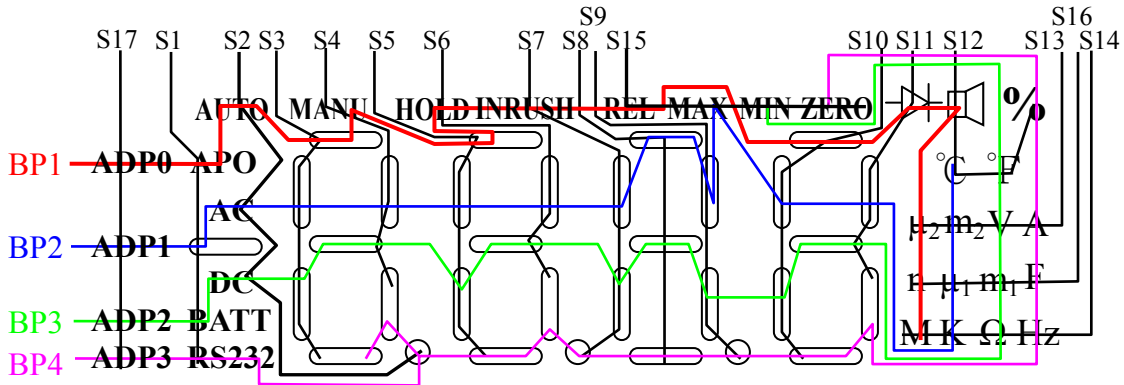


(a) Continuous 2KHz beep



(b) 3.33 beep/sec

### 5.1 LCD Panel

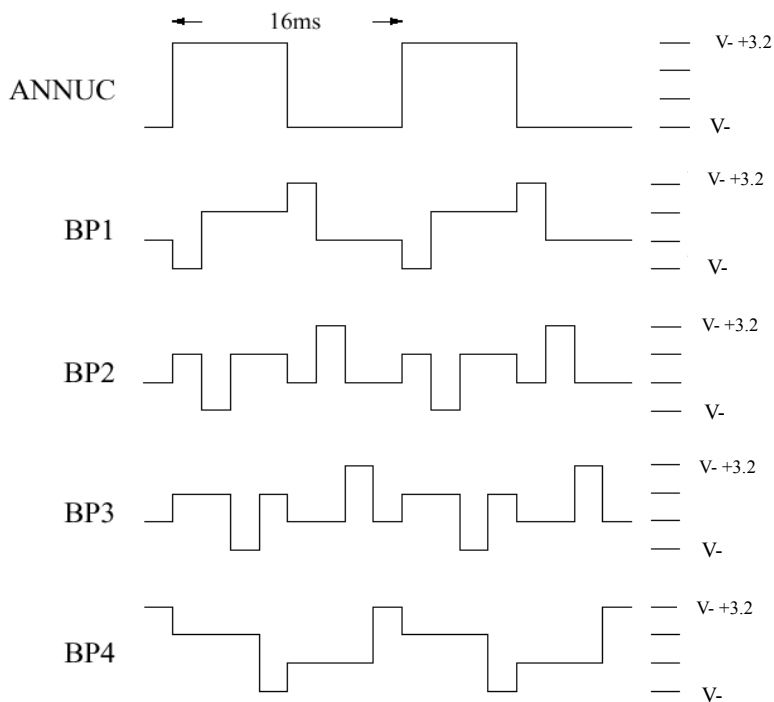


	SEG01	SEG02	SEG03	SEG04	SEG05	SEG06	SEG07	SEG08	SEG09
BP1	APO	AUTO	A4	MANU	A3	HOLD	INRUSH		
BP2	-	AC	F4	B4	F3	B3	F2	A2	B2
BP3	BATT	DC	E4	G4	E3	G3	E2	G2	C2
BP4	RS232	DP3	D4	C4	D3	C3	DP2	D2	DP1



  

	SEG10	SEG11	SEG12	SEG13	SEG14	SEG15	SEG16	SEG17
BP1	A1			μ <sub>2</sub>	M	REL	n	ADP0
BP2	F1	B1	°C	m <sub>2</sub>	K	MAX	μ <sub>1</sub>	ADP1
BP3	E1	G1	°F	V	Ω	MIN	m <sub>1</sub>	ADP2
BP4	D1	C1	%	A	Hz	ZERO	F	ADP3

### LCD Backplane Waveform



## 5.2 LCD display on condition

LCD Annunciator	Condition
V	In voltage measurement mode, and diode measurement mode.
A	In current measurement mode.
$\Omega$	In resistance measurement mode, and continuity mode.
F	In capacitance measurement mode.
	In continuity check mode.
	In diode mode.
%	In duty cycle measurement.
Hz	In frequency mode.
ADP1	In ADP1 mode
ADP2	In ADP2 mode
ADP3	In ADP3 mode
ADP4	In ADP4 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 Relative function is enabled.
Max / Min	When Max or Min function is enabled.
ZERO	When ZERO function is enabled.
INRUSH	When INRUSH function is enabled.
$m_1$	In capacitor measurement mode and the full scale range is in the order of mF.
$\mu_1$	In capacitor measurement mode and the full scale range is in the order of uF.
n	In capacitor measurement mode and the full scale range is in the order of nF.
$m_2$	In voltage or current measurement mode and the full scale range is in the order of $10^{-3}$ .
$\mu_2$	In current measurement mode and the full scale range is in the order of uA.
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 $\Omega$
$^{\circ}\text{C}$	In temperature measurement mode and when the unit is $^{\circ}\text{C}$
$^{\circ}\text{F}$	In temperature measurement mode and when the unit is $^{\circ}\text{F}$
APO	When auto power off function is enabled.
RS232	When RS232 output is enabled.

## 5.3 Operating Timing

ES51969 incorporates a dual slope ADC with four phases: ZI, AZ, INT and DINT.

The timing of each phase are listed below.

\*Voltage / Ohm /ADP / Manual Current (for clampmeter) measurement:

Phase	Time
ZI	40ms
AZ	25ms
INT	100ms
DINT	165ms

**P.S.** In the DC voltage and ohm measurement with auto mode, if the range is changed, the internal clock rate will increase four times and the new measurement cycle becomes 1/4 times of the original cycle until the range is stable.

\*Current mode for multimeter / Auto Current mode for clampmeter / 2-range auto

voltage mode

Phase	Time
ZI	40ms
AZ	25ms
INT	100ms
DINT	82.5ms

\*Continuity/Diode measurement

Phase	Time
ZI	10ms
AZ	6.25ms
INT	25ms
DINT	41.25ms

\*Capacitance measurement:

Range	Total Measurement Time
6.600nF	0.33sec
66.00nF	0.33sec
660.0nF	0.33sec
6.600μF	0.33sec
66.00μF	0.66sec
660.0μF	1.32sec
6.600mF	1.32sec
66.00mF	6.6sec

\*Duty cycle measurement

Every conversion takes 0.66 second.

\*Frequency measurement

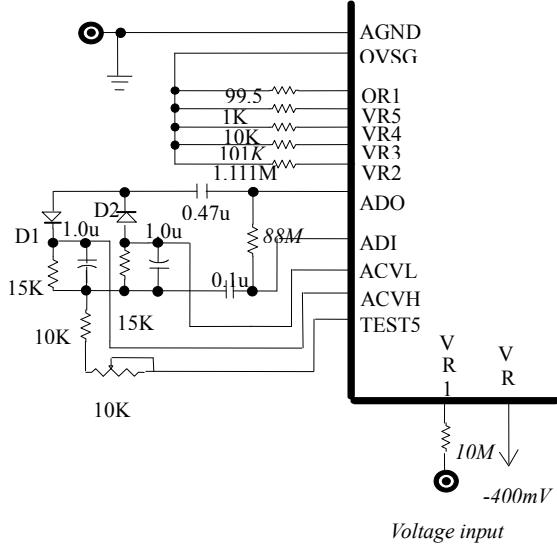
In 660.0Hz range, the measurement cycle = 0.25 ~ 0.5 sec

In range 6.6KHz~66MHz, the measurement cycle = 1.05 sec

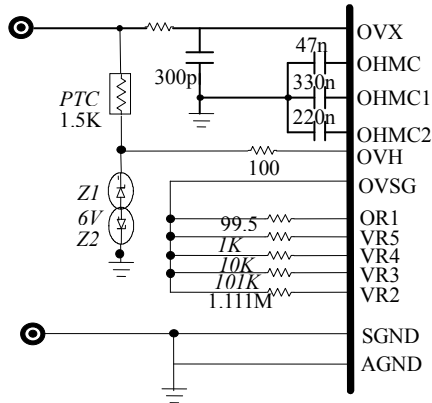
**P.S.** In the frequency measurement with auto mode, if the range is changed, the internal clock rate will increase ten times and the new measurement cycle becomes 1/10 times of the original cycle until the range is stable.

## 6. Test Circuit

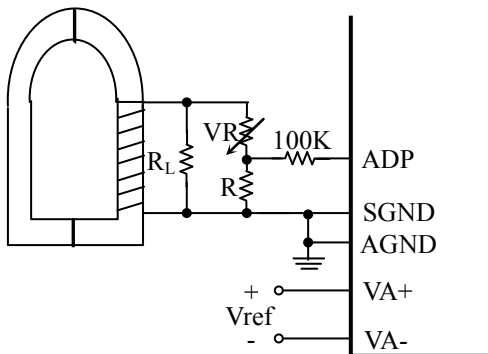
### 1. Voltage test



### 2. Resistor test

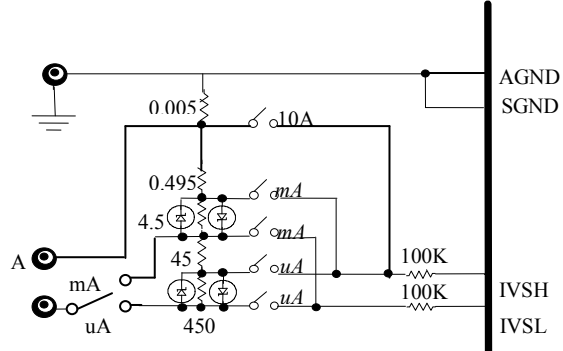


### 3. Current test for clamp meter

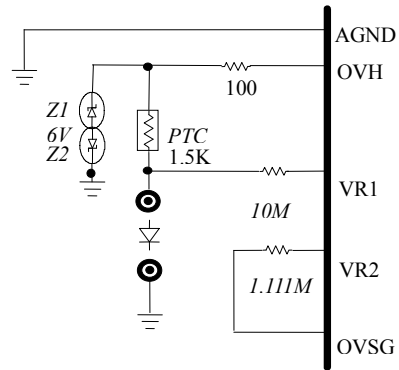


v2.61

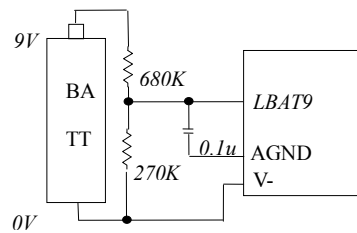
### 4. Current test



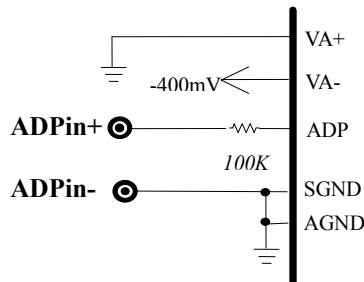
### 5. Diode test



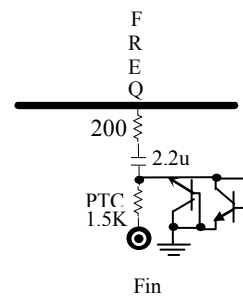
### 6. Low battery



### 7. ADP test



### 8. Frequency test



30

10/09/27



## 8. Package

### 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	551.2
A		0.425			16.7	
B	0.20	0.30	0.40	7.9	11.8	11.8
C		0.65			25.6	
d	1.05	1.20	1.35	41.3	47.2	47.2
a	2.57	2.72	2.87	101.2	107.1	107.1
D		2.50			98.4	
$\theta$	0°		10°			