



## Features

- 5000 counts dual LCD display
- 128L QFP package
- 3V DC power supply
- ADC Conversion rate : 3.3 times/s
- Full automatic measurement
  - \*Voltage measurement: 500.0mV – 1000V
  - \*Current measurement: 50.00A/500.0A, 500A/5000A
  - \*Flame rod DCuA mode measurement: 500.0uA/5000uA both manual ranges
  - \*Not contact AC electric field detection
  - \*Frequency mode active on sub-display for ACA 500.0Hz ~ 5000Hz
  - \*Resistance measurement: 500.0Ω – 50.00MΩ
  - \*Frequency counter with duty cycle display: 500.0Hz – 50.00MHz
  - 5% – 95% (< 10kHz)
- ZERO function for DCA mode
- Voltage high crest factor detection (Taiwan patent no.: 234661)
- Voltage & Current measured simultaneously ACV+ACA, DCV+DCA
- Diode measurement & continuity check
- Auto range temperature mode(500.0 °C /5000 °C)
- Temperature mode with internal scale translation circuit from °C to °F
- Push functions:
  - \*Single Select key operation:
    - Zero for DCA
    - Hz for ACA
  - \*Range change function
  - \*Data hold function
  - \*Back light function
  - \*Semi-auto Calibration Operation (Taiwan patent no.: 367334)
- Low pass filter for ACA measurement
- Band-gap reference voltage output

- CE selection (DC/AC 1010V, DC/AC 610V)
- LCD segment check when power on
- Auto power off (30min/15min)
- Sleep state indicative signal output
- Re-power on
- On-chip buzzer driver
- High Voltage (HV) danger indication
- Low battery multi-level detection

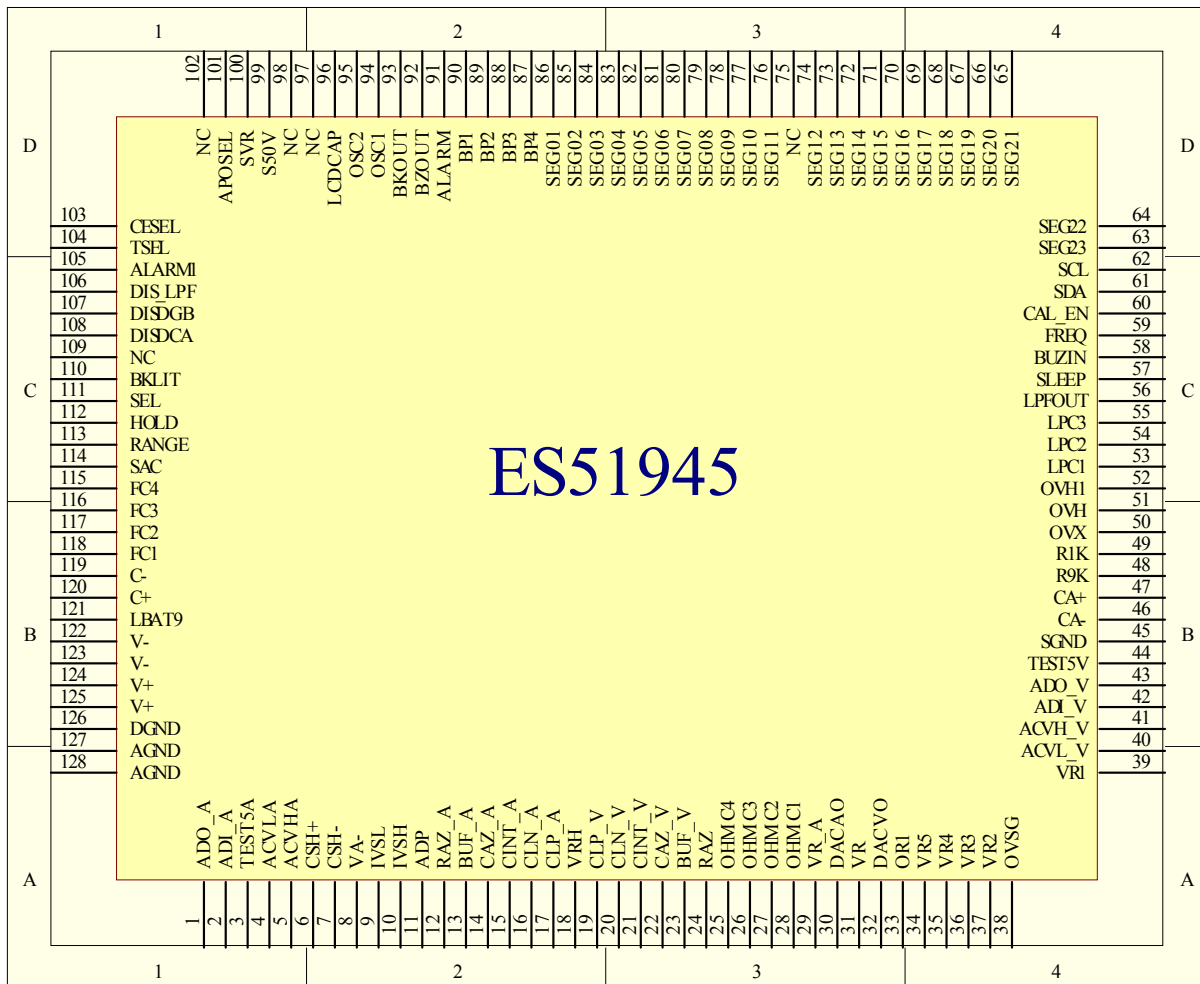
## Description

ES51945 is an integrated analog-to-digital converter (ADC) with dual 5,000-count LCD display, which 4-digit main-display (AC/DC Voltage) and 4-digit sub-display (AC/DC Current), automatic range selection, and 3V DC power supply. ES51945 could be designed for a clamp-meter with V & A measurement simultaneously. Automatic range selection is provided for voltage (AC/DC) measurement, resistance measurement, current measurement and frequency counter. Other features include offset removing feature for DCA clampmeter, data holding, duty cycle measurement, diode measurement, temperature measurement, continuity checking, multi-level low battery detection, auto power off, re-power on, backlight driver, and buzzer output driver.



**Application**  
Clamp meter

**Pin Assignment**  
**LQFP-128L**





### Pin Description

Pin No	Symbol	Type	Description
1	ADO_A	O	Output of internal AC to DC OP Amp for ACA mode.
2	ADI_A	I	Negative input of internal AC to DC OP Amp for ACA mode.
3	TEST5_A	O	Buffer output of SGND for ACA mode
4	ACVL_A	O	DC signal low input in ACA mode. Connect to negative output of external AC to DC converter.
5	ACVH_A	O	DC signal high input in ACA mode. Connect to positive output of external AC to DC converter.
6	CSH+	I/O	Cap for duty-cycle mode
7	CSH-	I/O	Cap for duty-cycle mode
8	VA-	I	For ADP mode. De-integrating voltage negative input
9	IVSL	I	Current measurement input for higher range.
10	IVSH	I	Current measurement input for lower range.
11	ADP	I	Measurement input in ADP mode. (Current/Temperature/NCV mode)
12	RAZ_A	O	Buffer output pin in AZ and ZI phase for ADC_A.
13	BUF_A	O	Buffer output pin for ADC_A. Connect to integral resistor
14	CAZ_A	O	Auto-zero capacitor connection for ADC_A.
15	CINT_A	O	Integrator output for ADC_A. Connect to integral capacitor.
16	CLN_A	I/O	Negative connection for reference capacitor of ADC_A.
17	CLP_A	I/O	Positive connection for reference capacitor of ADC_A.
18	VRH	O	Output of band-gap voltage reference. Typically -1.23V
19	CLP_V	I/O	Positive connection for reference capacitor of ADC_V.
20	CLN_V	I/O	Negative connection for reference capacitor of ADC_V.
21	CINT_V	O	Integrator output for ADC_V. Connect to integral capacitor.
22	CAZ_V	O	Auto-zero capacitor connection for ADC_V.
23	BUF_V	O	Buffer output pin for ADC_V. Connect to integral resistor
24	RAZ_V	O	Buffer output pin in AZ and ZI phase for ADC_V.
25-28	OHMC1-4	O	Filter capacitor connection1-4 for resistance mode.
29	VR_A	I	Reference input voltage in current mode or ADP. Typically -400mV
30	DAC_AO	O	DAC output for current mode or ADP input mode
31	VR	I	Reference input voltage in voltage mode. Typically -400mV
32	DAC_VO	O	DAC output for voltage mode
33	OR1	O	Reference resistor connection for 500.00Ω range
34	VR5	O	Voltage measurement ÷10000 attenuator(1000V)
35	VR4	O	Voltage measurement ÷1000 attenuator(500.0V)
36	VR3	O	Voltage measurement ÷100 attenuator(50.00V)
37	VR2	O	Voltage measurement ÷10 attenuator(5.000V)
38	OVSG	O	Sense low voltage for resistance/voltage measurement
39	VR1	I	Measurement Input. Connect to a precise 10MΩ resistor.
40	ACVL_V	O	DC signal low input in ACV mode. Connect to negative output of external AC to DC converter.
41	ACVH_V	O	DC signal high input in ACV mode. Connect to positive output of external AC to DC converter.
42	ADI_V	I	Negative input of internal AC to DC OP Amp for ACV mode.
43	ADO_V	O	Output of internal AC to DC OP Amp for ACV mode.
44	TEST5_V	O	Buffer output of OVSG for ACV mode
45	SGND	G	Signal Ground.
46	CA-	I/O	AC-coupled cap. for ACA Hz mode
47	CA+	I/O	AC-coupled cap. for ACA Hz mode
48	R9K	O	Connect to a 9KΩ resistor for duty cycle measurement.
49	R1K	O	Connect to a 1KΩ resistor for duty cycle measurement.
50	OVX	I	Sense input for resistance measurement
51	OVH	O	Output connection for resistance measurement
52	OVH1	O	Output connection for resistance measurement (Optional)



53	LPFC1	O	Capacitor C1 connection for internal low-pass filter
54	LPFC2	O	Capacitor C2 connection for internal low-pass filter
55	LPFC3	O	Capacitor C3 connection for internal low-pass filter
56	LPFOUT	O	Capacitor C1 connection for internal low-pass filter
57	SLEEP	O	Sleep mode indicator, asserts low in SLEEP mode.
58	BUZIN	I	Pull to V- to enable the BUZOUT.
59	FREQ	I	Frequency counter input, offset V-/2 internally by the chip.
60	CAL_EN	I	Pulled to V- to enable the semi-auto calibration scheme.
61	SDA	I/O	Input/Output from/to EEPROM 24C02 data
62	SCL	O	Output to EEPROM 24C02 clock
63-86	SEG24-SEG01	O	LCD segment output driver 01-24 (SEG signals)
87-90	BP4-BP1	O	LCD backplane 1-4 (COM signals)
91	ALARM	O	LED control output driver for HV indication and NCV detection
92	BUZOUT	O	Outputs a 2KHz audio frequency signal for driving piezoelectric buzzer when BUZIN is low or functional key is active.
93	BKOUT	O	If BKLIT function is enabled, this pin will change from V- to V+ For 60 sec, once press BKLIT pin again within 60 sec, this pin will Change back to V-.
94	OSC1	I	Crystal oscillator input connection
95	OSC2	O	Crystal oscillator output connection
96	LCDCAP	I	LCD bias voltage bypass capacitor connection
97	NC	-	Not connected
98	NC	-	Not connected
99	S50V	I	Switch control for function selection
100	SVR	I	Switch control for function selection
101	APOSEL	I	Auto power off idle time selection
102	NC	-	Not connected
103	CESEL	I	OL selection feature control pin in Voltage mode.
104	TSEL	I	Pulled to V- to cancel the 500°C auto range mode
105	ALARM1	O	LED control output driver for short-circuit detected in Cont. mode.
106	DIS_LPF	I	Pulled to V- to disable the low-pass-filter path in ACA mode
107	DIS_DGB	I	Pulled to V- to disable the buzzer beeper when HV danger appears.
108	DIS_DCA	I	Pulled to V- to disable DCA function in DCV mode.
109	NC	-	Not connected
110	BKLIT	I	Back light function. Pulse to V- to set BKOUT pin output.
111	SEL	I	Pulse to V- to enable function selection
112	HOLD	I	Pulse to V- to enable HOLD function.
113	RANGE	I	Pulse to V- to enable manual mode and manual range selection.
114	SAC	I	Switch for AC/DC function selection.
115-118	FC4-FC1	I	Switches for function selection.
119	C-	O	Negative capacitor connection for on-chip DC-DC converter.
120	C+	O	Positive capacitor connection for on-chip DC-DC converter.
121	LBAT9	I	Multi-level low battery configuration input. Simple external resistor divider is required.
122	V-	P	Negative supply voltage.
123	V-	P	Negative supply voltage.
124	V+	O	Output of on-chip DC-DC converter and positive supply voltage.
125	V+	O	Output of on-chip DC-DC converter and positive supply voltage.
126	DGND	P/G	Digital ground.
127	AGND	P/G	Analog ground.
128	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- = -3.0V

Parameter	Symbol	Test Condition	Min.	Typ.	Max	Units
Power supply	V-		-2.5	-3.0	-3.5	V
Operating supply current	I <sub>DD</sub>	Normal operation	—	1.9	2.2	mA
In DCV+DCA mode	I <sub>SS</sub>	In sleep mode	—	5	10	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 <sup>1</sup>
Input Leakage			-10	1	10	PA
Zero input reading		10MΩ input resistor	-000	000	+000	counts
Band-gap reference voltage	V <sub>REF</sub>	100KΩ resistor between VRH and AGND	-1.29	-1.23	-1.17	V
Open circuit voltage for 500Ω measurement			—	-3.0	—	V
Open circuit voltage for other Ω measurement			-1.19	-1.08	-0.97	V
Peak to peak backplane drive voltage		-3.5V ≤ V- ≤ -2.5V	2.9	3.1	3.3	V
Internal pull-high to 0V current	I <sub>pull-up</sub>	Pin97-118 inputs	—	1.2	—	μA
AC frequency response at 5.000V range		±1%	—	40-400	—	HZ
		±5%	—	400-2000	—	
Multi-level low battery detector	V <sub>t1</sub>	LBAT9 vs. V-	—	2.15	—	V
	V <sub>t2</sub>		—	1.82	—	
3dB Bandwidth for ACA mode	f <sub>3dB</sub>	Low-pass-filter ON		4		kHz
Reference voltage temperature coefficient	TC <sub>RF</sub>	100KΩ resistor between VRH/GND 0°C < TA < 70°C	—	100	—	ppm/°C

Note:

1. Full Scale

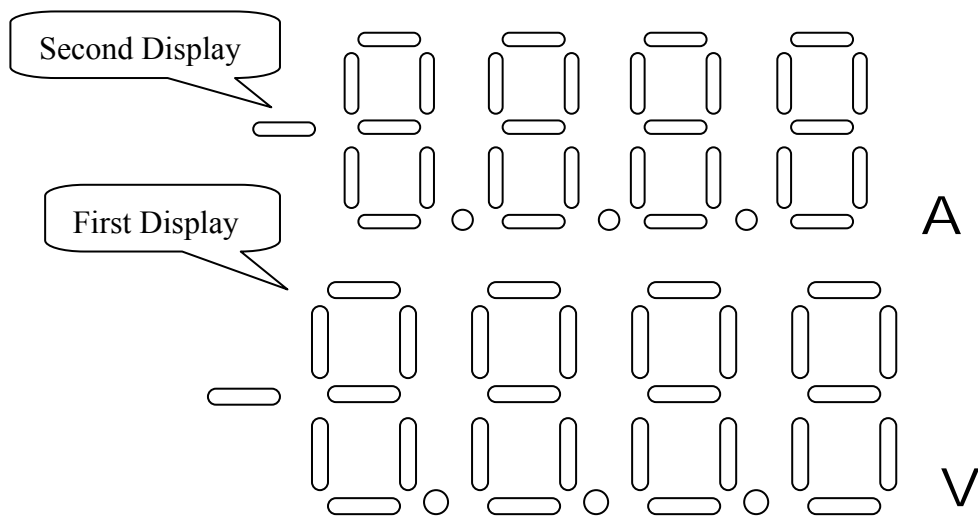


## Function Description

### 1. Dual Display

#### 1.1 Introduction

ES51945 configures a dual display LCD driver for DMM applications. The dual display includes first-display and second-display. Each display has 4 digits to show up to 5000 counts. The simplified representation of dual display is shown below. First-display usually shows Volts readings in ACV/DCV mode or Hz readings in Frequency mode. Second-display usually shows Amps/Hz readings in ACA/DCA mode or Duty-cycle readings in Frequency mode. By the dual display feature, ES51945 can shows Amps and Volts readings at the same time. Other features achieved by dual display will be introduced in later sections. The full LCD configuration is shown at [section 3.4 of page 23](#).





### 1.2 Dual display V.S. measurement mode

The dual display default mode configuration is shown at the table below.

Main measurement mode	First-display	Second-display (defaulted)
DC voltage	DC voltage	N/A
AC voltage	AC voltage	N/A
NCV mode	EF	Electrical field strength
Resistance mode	Resistance	N/A
Frequency mode	Frequency	Duty cycle
Continuity Check	Resistance	N/A
Diode mode	Voltage	N/A
Temperature mode	°C	°F
DCuA mode	N/A	DCuA

### 1.3 Push key operation

With dual display, user can use single push key “SEL” to active the Volts and Amps readings simultaneously.

<i>Push function</i>	<i>First-display</i>	<i>Second-display</i>
SEL in DCV mode (function selection)	DC Voltage	DCA <sup>1</sup> → DCA/Zero <sup>2</sup> See <b>Fig.1</b>
SEL in ACV mode (function selection)	AC Voltage	ACA ↔ ACA Hz <sup>3</sup> See <b>Fig.2</b>
Hold	Stop updating	Stop updating

NOTE:

1. DCA mode is not available if DIS\_DCA (pin108) is pulled to V-.
2. DCA/Zero means the readings shown on LCD is offset-cancelled readings.
3. Hz mode is the frequency reading of ACA mode.



Fig.1 SEL key operation in DCV + DCA(zero) mode

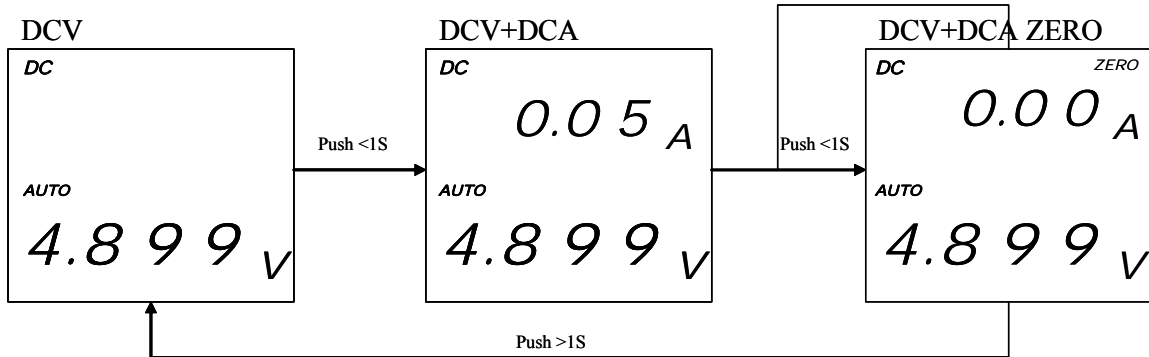
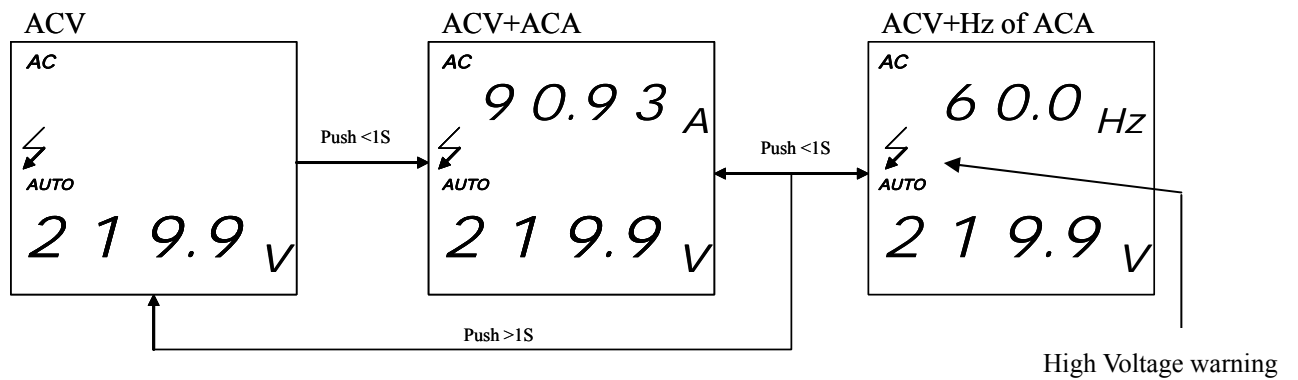


Fig. 2 SEL key operation in ACV + ACA(Hz) mode



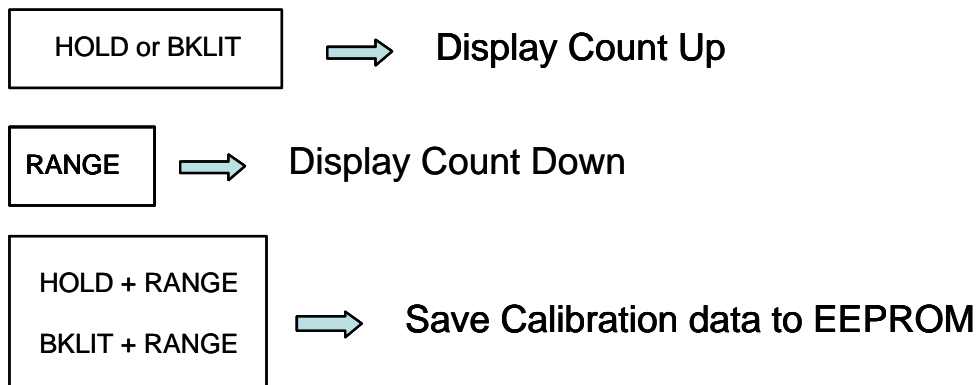




## 2. Operating Modes

### 2.1. Semi-auto calibration scheme

ES51945 includes DMM & CLAMP\_ON meter features in single chip. DMM manufacturers need the calibration process in production. The traditional solution needs the variable resistors for calibration by manual adjustment. ES51945 provide another calibration scheme and the variable resistors could be ignored. When ES51945 is at OFF-state, pull CAL\_EN (pin 60) to V- to active the calibration scheme after re-power on. A digital controlled voltage output will be active from DAC\_AO & DAC\_VO. When semi-auto calibration scheme is active, use **HOLD** (or **BKLIT**) key to decrease voltage and use **RANGE** key to increase the voltage. Decrease the reference voltage means the counts on display will be increased. Increase the reference voltage means the counts on display will be decreased. The adjustment step is approximate one count. If coarse adjustment is required, push **HOLD** (or **BKLIT**) and **RANGE** larger than one second to speed up to approximate 30 counts per second. After calibration process is finished, push **HOLD** (or **BKLIT**) and **RANGE** (less than one second) simultaneously to save the digital control code to external EEPROM (24C02).





The semi-auto calibration scheme supports the following seven measurement modes. When *CAL\_EN* pin is active, set the proper function switches and push *SEL* key to choose the target measurement mode. When mode is selected, the LCD segment of Unit at related measurement will be blinking.

Mode	Default range for CAL	Remark
DC Voltage measurement	5.000V	Accuracy of other ranges is guaranteed by external resistor
AC Voltage measurement		
DC Current measurement	50.00A or 500.0A or 5000A	Lower range in auto ACA mode
AC Current measurement		
DC $\mu$ A measurement	500 $\mu$ A or 5000 $\mu$ A	-
Temperature measurement	500.0°C or 5000 °C	Lower range in Auto Temperature mode

After calibration procedure is finished, set the ES51945 to OFF-state and set *CAL\_EN* to DGND to return to normal mode operation after re-power on.

## 2.2. 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
<sup>1</sup> VR1	500.0mV	1	VR1 (10M $\Omega$ )
VR2	5.000V	1/10	VR2 (1.111M $\Omega$ )
VR3	50.00V	1/100	VR3 (101K $\Omega$ )
VR4	500.0V	1/1000	VR4 (10.01K $\Omega$ )
VR5	1000V	1/10000	VR5 (1K $\Omega$ )

Note:

- 500.0mV range only exists in manual mode.

### 2.2.1 CE selection & high voltage (HV) indication

ES51945 has a CE selection feature archived by configuring the pin CESEL. In automatic voltage mode, ES51945 will show OL when the voltage is over than the overflow level. If CESEL is connected to V- or DGND, ES51945 will have a 610.0V or 1010V overflow level in voltage mode relatively.. The configuration of CESEL is listed below.

For fully automatic voltage modes:

CESEL	DCV	ACV
V-	610V	610V
DGND or floating	1010V	1010V

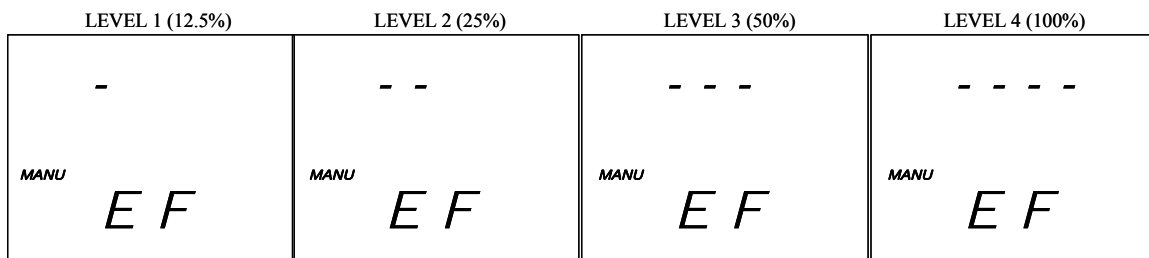


During voltage measurement is in operation (DCV or ACV), the HV indication will be active when input voltage is larger than 30V or OL in manual range. The HV indication includes:

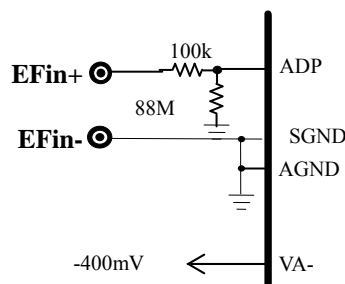
- HV warning LCD segment active
- Buzzer output active if DIS\_DGB (pin107) is kept floating
- ALARM (pin91) LED output active.

### 2.2.2 NCV mode

ES51945 supports a non-contact AC voltage measurement, which is called electric field measurement also. The EF mode is selected by setting function control mode FC1-FC4 = [1,0,0,1]. The ADC input is configured from ADP pin vs. SGND. When no or less electric field is detected, the first-display LCD shows “EF” and the second-display LCD shows “Blank”. If the electric field is detected, the strength will be showed on the second-display LCD by “-“ not digits type. Level 1(equivalent to 12.5% full scale of ADC) is “-“ and the level 4(equivalent to 100% full scale of ADC) is “----“. Additional beeper (BUZOUT pin) and LED alarm (ALARM pin) will be output from ES51945. The frequency of buzzer and LED alarm depends on the strength of electric field also. The Faster beeper means the stronger electric field (AC voltage) is sensed.



EF test circuit



### 2.3 Current measurement for clampmeter

#### (1) ACA/DCA

ES51945 has 2 automatic and 3 manual current measurement modes for Clampmeter. The following table summarizes the full-scale range of each mode. When ES51945 operate in the automatic VA1 ~ VA2, it takes high input from IVSH/IVSL (higher range/lower range), low input from SGND and reference voltage from VR\_A (pin29). When ES51945 operates in the manual VA3 ~ VA5, It takes high input from ADP, low input from SGND and reference voltage from VA- (pin8).

Mode	FC1~4	Full Scale	Input Terminal
VA1	0,0,0,0	50.00A / 50.00A	IVSL/IVSH V.S. SGND (500mV)
VA2	0,0,0,1	500.0A / 5000A	IVSL/IVSH V.S. SGND (500mV)
VA3	0,1,0,0	50.00A	ADP V.S. SGND (500mV)
VA4	0,1,0,1	500.0A	ADP V.S. SGND (500mV)
VA5	0,1,1,0	5000A	ADP V.S. SGND (500mV)

Note:

1. In DCA current modes (SAC = 0) , ES51945 provides **Zero function** (push SEL key) for offset removing.

#### (2) DCuA mode

ES51945 has 2 manual DCuA current measurement modes for flame rod application. The following table summarizes the full scale range of each mode.

Mode	FC1~4	Full Scale	Input Terminal
DCuA1	0,0,1,0	500.0uA	ADP V.S. SGND (500mV)
DCuA2	0,0,1,1	5000uA	ADP V.S. SGND (500mV)

#### (3) Low pass filter (LPF) mode for ACA mode

A 3<sup>rd</sup> order low-pass filter (3dB bandwidth = 4kHz typ.) with is built in ES51945 to reduce the influence of high frequency noise. The LPF mode is active in ACA only if DIS\_LPF is connected to DGND or floating.

### 2.4 Resistance Measurement ( R )

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.

Configuration	Full Scale Range	Relative Resistor	Equivalent value
OR1	500.0Ω	OR1	100Ω
OR2	5.000KΩ	VR5	1KΩ
OR3	50.00KΩ	VR4    VR1	10KΩ
OR4	500.0KΩ	VR3    VR1	100KΩ
OR5	5.000MΩ	VR2    VR1	1MΩ
OR6	50.00MΩ	VR1	10MΩ

### 2.5 Continuity Check ( S )

Continuity check shares the same configuration with 500.0Ω manual resistance measurement mode and has buzzer output to indicate continuity. The buzzer generates 2KHz beep and ALARM1 (pin 105) drive high output (V+ level) whenever the reading is less than 30Ω. The ES51945 built in a high speed short detection circuit and the detection could be less than 10ms.

### 2.6 Diode Measurement ( D )

Diode measurement mode shares the same configuration with 5.000V manual voltage measurement mode and has buzzer output to indicate continuity. The buzzer generates a 2KHz sound and Alarm1 (pin 105) drive high output (V+ level) whenever the reading is less than 30mV. If the test circuit is open or the voltage drop between the two ports of the diode under test is larger than 2V, the LCD panel will show “OL”.

### 2.7 Frequency counter

In frequency mode, main-display shows frequency and sub-display shows duty cycle at the same time. 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  $F_{osc}$  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 seven decades, from 500.0Hz to 50.00MHz. The following table summarizes the full-scale range of the frequency counter.

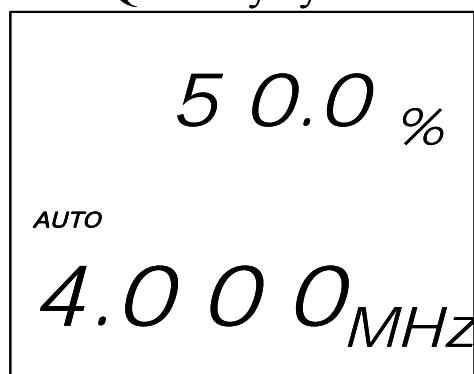
Configuration	Full Scale range
FR1	500.0Hz
FR2	5.000KHz
FR3	50.00KHz
FR4	500.0KHz
FR5	5.000MHz
FR6	50.00MHz

\*If input frequency is less than 5.0Hz, ES51945 will show **0.0Hz**

## 2.8 Duty Cycle measurement

The duty cycle measurement is available in frequency mode simultaneously. The duty cycle mode range is available within 5.0% to 95.0% (< 10kHz@3Vpp). The minimum resolution is 0.1%. If the source frequency duty cycle is smaller than 1.0%, the 0.0% will be shown on the LCD display. If the duty cycle is larger than 98.9%, the **OL** will be shown on the LCD sub-display. When the frequency is zero, the duty cycle display will be 0.0%.

### FREQ + Duty cycle



## 2.9 Temperature measurement mode

Temperature measurement mode takes input signal from ADP pin and reference voltage from VA-. ES51945 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.

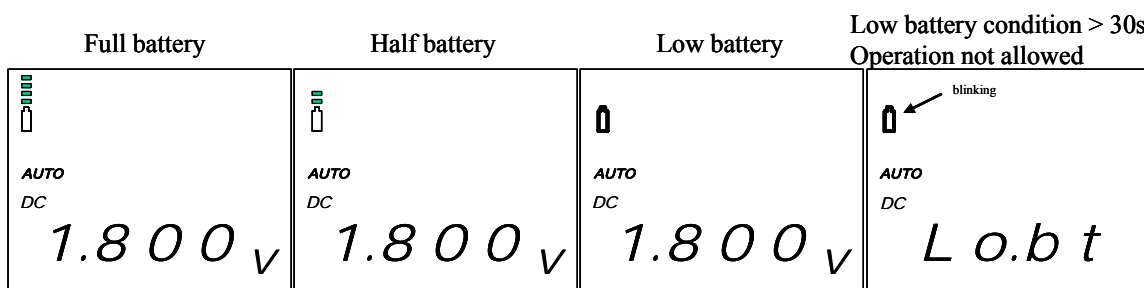


The °C & °F readings are shown on the dual-display LCD simultaneously. In temperature2 measurement mode, the default range is 5000 °C or 9032 °F manual range. In temperature1 measurement mode, the default range is 500.0/5000 °C or 932.0/9032 °F auto range. The TSEL pin (pin104) is pulled to V-, the temperature1 measurement mode will be set to 500.0 °C manual mode.

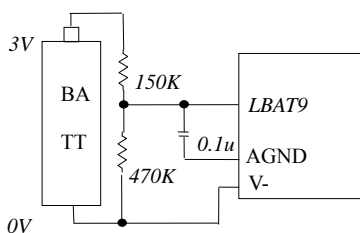
Range	Full scale range	Input terminal
Temp1	Auto 500.0°C / 5000°C	ADP V.S. SGND (50mV/500mV)
Temp2	Manual 5000°C	ADP V.S. SGND (500mV)

### 2.10 Multi-level low battery voltage detection

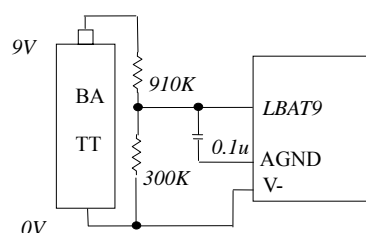
ES51945 provides a voltage detection input (pin 121: LBAT9) for multi-level low battery application. There are two internal voltage reference Vt1 & Vt2 for comparing with LBAT9. If LBAT9 is larger than Vt1, the LCD segment of SLB3 – SLB1 will active always. This status implies Full battery. When LBAT9 is less than Vt1 but larger than Vt2, the LCD segment of SLB3 will disappear and this status implies Half battery. When LBAT9 is less than Vt2, the LCD segment of SLB2 will disappear and this status implies Low battery. When the Low battery status lasts for 10 seconds, the LCD segment of SLB1 will be blinking. When the SLB1 is blinking for 20 seconds, the operation of meter will be inhibited and LCD panel will show “Lo.bt”. In this case, it is suggested to replace a new battery immediately. After “Lo.bt” appears and lasts for 60 seconds, ES51945 will enter to auto power off mode.



Low battery test circuit (a)



Low battery test circuit (b)





### 2.11 Auto power off (APO) and idle time selection

ES51945 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 30 minutes. If pin APOSEL is connected to DGND or floating, the Idle Time will be set to 15 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. If user might want to disable Auto power off, power on the meter when any of the push functions, except for HOLD, is pressed down.

**Note:**

1. Powering on the meter while pressing HOLD and lasts 2 seconds turns on all LCD segments until HOLD is pressed again.
2. When low battery status happened (LCD show "Lo.b"), the APO idle time will be reset to 60 sec.

### 2.12 Sleep

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

### 2.13 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.





### 3. Measurement Mode Switching

Measurement mode depends on the logic level of SVR, S50V, SAC, FC1, FC2, FC3 and FC4.

SVR	S50V	SAC	FC1	FC2	FC3	FC4	Function mode	Remark
0	X	1	0	0	0	0	ACV (5.000V) + ACA (50.00A / 500.0A)	VA1
0	X	1	0	0	0	1	ACV (5.000V) + ACA (500.0A / 5000A)	VA2
0	X	1	0	1	0	0	ACV (5.000V) + ACA (50.00A)	VA3
0	X	1	0	1	0	1	ACV (5.000V) + ACA (500.0A)	VA4
0	X	1	0	1	1	0	ACV (5.000V) + ACA (5000A)	VA5
1	0	1	0	0	0	0	ACV (50.00V) + ACA (50.00A / 500.0A)	VA1
1	0	1	0	0	0	1	ACV (50.00V) + ACA (500.0A / 5000A)	VA2
1	0	1	0	1	0	0	ACV (50.00V) + ACA (50.00A)	VA3
1	0	1	0	1	0	1	ACV (50.00V) + ACA (500.0A)	VA4
1	0	1	0	1	1	0	ACV (50.00V) + ACA (5000A)	VA5
1	1	1	0	0	0	0	ACV (500.0V) + ACA (50.00A / 500.0A)	VA1
1	1	1	0	0	0	1	ACV (500.0V) + ACA (500.0A / 5000A)	VA2
1	1	1	0	1	0	0	ACV (500.0V) + ACA (50.00A)	VA3
1	1	1	0	1	0	1	ACV (500.0V) + ACA (500.0A)	VA4
1	1	1	0	1	1	0	ACV (500.0V) + ACA (5000A)	VA5
0	X	0	0	0	0	0	DCV (5.000V) + DCA (50.00A / 500.0A)	VA1
0	X	0	0	0	0	1	DCV (5.000V) + DCA (500.0A / 5000A)	VA2
0	X	0	0	1	0	0	DCV (5.000V) + DCA (50.00A)	VA3
0	X	0	0	1	0	1	DCV (5.000V) + DCA (500.0A)	VA4
0	X	0	0	1	1	0	DCV (5.000V) + DCA (5000A)	VA5
1	0	0	0	0	0	0	DCV (50.00V) + DCA (50.00A / 500.0A)	VA1
1	0	0	0	0	0	1	DCV (50.00V) + DCA (500.0A / 5000A)	VA2
1	0	0	0	1	0	0	DCV (50.00V) + DCA (50.00A)	VA3
1	0	0	0	1	0	1	DCV (50.00V) + DCA (500.0A)	VA4
1	0	0	0	1	1	0	DCV (50.00V) + DCA (5000A)	VA5
1	1	0	0	0	0	0	DCV (500.0V) + DCA (50.00A / 500.0A)	VA1
1	1	0	0	0	0	1	DCV (500.0V) + DCA (500.0A / 5000A)	VA2
1	1	0	0	1	0	0	DCV (500.0V) + DCA (50.00A)	VA3
1	1	0	0	1	0	1	DCV (500.0V) + DCA (500.0A)	VA4
1	1	0	0	1	1	0	DCV (500.0V) + DCA (5000A)	VA5
X	X	0	0	0	1	0	DCuA (500.0uA)	DCuA1
X	X	0	0	0	1	1	DCuA (5000uA)	DCuA2
X	X	X	1	0	0	0	FREQ + Duty cycle	Fmode
X	X	X	1	0	0	1	NCV (EF)	EFmode
X	X	X	1	0	1	0	Temp (500.0 °C / 5000 °C) (AUTO) <sup>1</sup>	Temp1
X	X	X	1	0	1	1	Temp (5000 °C)	Temp2
X	X	0	1	1	0	0	R (Resistance mode)	R
X	X	0	1	1	0	1	S (Continuity mode)	S
X	X	0	1	1	1	0	D (Diode check mode)	D
X	X	1	1	1	0	0	R,S	RS
X	X	1	1	1	0	1	R,S,D	RSD

X means "don't care".

<sup>1</sup> 50mV full scale is for 500 °C range and 500mV full scale is for 5000 °C range. When TSEL (pin104) is pulled to V-, the 500 °C range is fixed



**Push function**

All the enabled push functions will be reset when the measurement mode is changed by rotary switch. The following table lists the available function versus every measurement mode.

	<b>RANGE</b>	<b>HOLD</b>	<b>SEL</b>	<b>BKLIT</b>
<b>DCV</b>	O	O	O	O
<b>DCV + DCA</b>	O ( V only)	O	O	O
<b>ACV</b>	O	O	O	O
<b>ACV + ACA</b>	O ( V only)	O	O	O
<b>DCuA</b>	X	O	X	O
<b>Frequency</b>	O	O	X	O
<b>NCV ( EF )</b>	X	X	X	O
<b><sup>2</sup>Temp1</b>	O	O	X	O
<b>Temp2</b>	X	O	X	O
<b>Resistance</b>	O	O	X	O
<b>Continuity</b>	X	O	X	O
<b>Diode</b>	X	O	X	O
<b>R , S<sup>1</sup></b>	O ( R only)	O	O	O
<b>R , S<sup>1</sup> , D</b>	O ( R only)	O	O	O

Note:

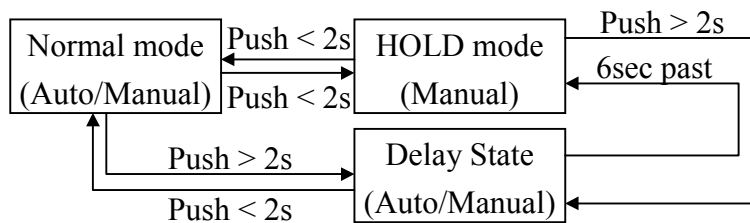
<sup>1</sup>Continuity mode

<sup>2</sup>Auto range configuration



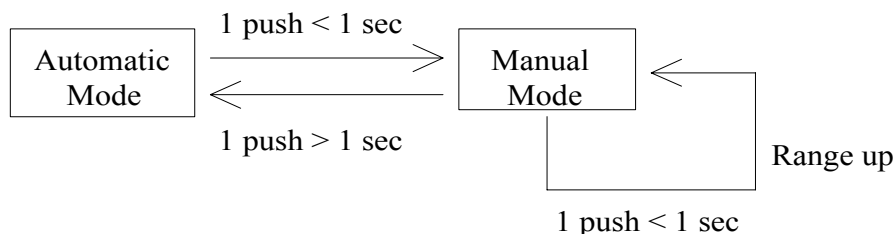
### 3.1. HOLD and Delay Hold feature

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. ES51945 provides a Delay HOLD feature. To activate Delay HOLD feature, press down the HOLD bottom and last for 2 seconds. The meter will delay for 6 seconds, than enters HOLD mode. In the 6-second delayed time, the HOLD symbol on LCD panel will blink. HOLD function and the delayed state can be cancelled by changing the measurement mode, pressing RANGE, or push HOLD again.



### 3.2. Range

RANGE pin configuration is shown below. It is available for voltage, resistance, frequency and temperature (Temp1) modes.



Measurement Mode	Auto	Manual	Control Range	Initial Range
V(DC/AC)	VR2 – VR5	VRi → VRi + 1, VR5 → VR1	500.0mV – 1000V	5.000V <sup>1</sup>
Auto A(DC/AC)	IR1 – IR2	N/A <sup>3</sup>	500.0A – 5000A	500.0A
Auto A(AC/DC)	IR1 – IR2	N/A <sup>3</sup>	50.00A – 500.0A	50.00A
Manual A(AC/DC)	fixed	fixed	50.00A	50.00A
			500.0A	500.0A
			5000A	5000A
Manual DCuA	fixed	fixed	500.0uA	500.0uA
			5000uA	5000uA
Ω	OR1 – OR6	ORi → ORi + 1, OR6 → OR1	500.0Ω – 50.00MΩ	500.0Ω
Continuity	fixed	fixed	500.0Ω	500.0Ω
Diode	fixed	fixed	5.000V	5.000V
Temp1	T1-T2	T1 → T2 T2 → T1	500.0°C – 5000°C	500.0°C
Frequency	FR1 – FR6	FRi → FRi + 1 FR6 → FR1	500.0Hz – 50.00MHz	500.0Hz

Note: Pushing RANGE resets all existing special modes.

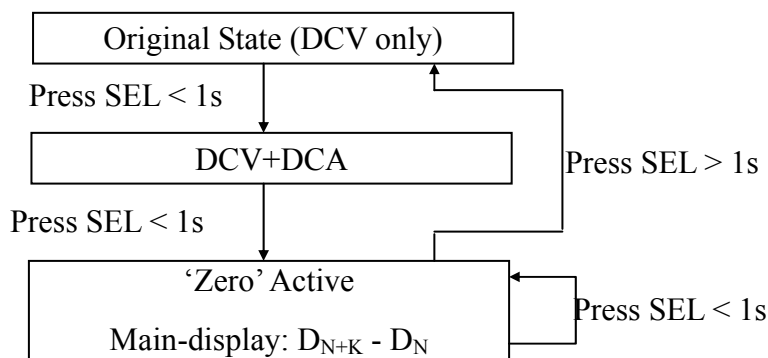
<sup>1</sup> Initial range depends on status of SVR & S50V. See Measurement Mode Switching



### 3.3. ZERO function

In manual DC 50.00A, 500.0A and 5000A, auto DC 50.00A/500.0A and auto DC 500.0A/5000A measurement modes, ES51945 provides Zero function to remove the residual current value. During DCV and DCA mode are active simultaneously, push *SEL* key less than one second to enter Zero mode. In Zero mode, second-display shows  $D_{N+K} - D_N$ , where  $N = 1, 2, 3, \dots$ ,  $D_N$  is the last conversion value before *SEL* is pushed, and  $D_{N+K}$  is the current conversion value. If *SEL* is pushed again in Zero mode, second-display will update the  $D_N$  value and displays the  $D_{N+K} - D_N$  again. The meter returns to DCV operation only if *SEL* is pressed and held for longer than one second. In 2-range auto DCA modes for clampmeter (500.0A/5000A or 50.00A/500.0A), 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 should stay at lower one in automatic mode. When enter Zero mode in lower range, the system will store the nonzero counts (residual current value). If the range goes up to higher one automatically, the non-zero counts will be divided by ten. So this function will still work well in automatic modes.

#### State diagram for Zero mode:



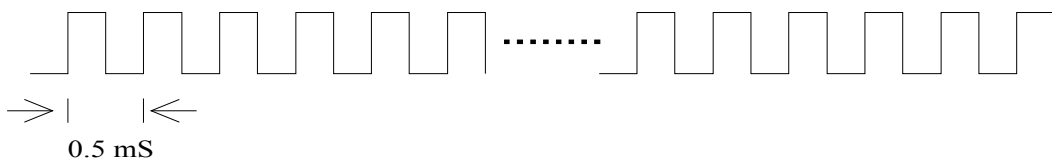


**Miscellaneous**

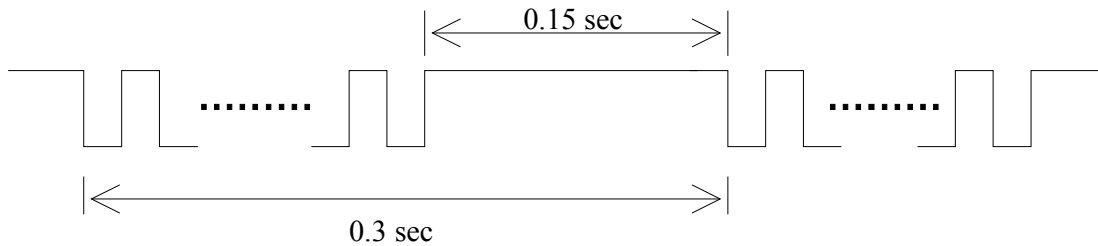
The conditions, which the meter turns on the buzzer, include:

- (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  $30\Omega(30mV)$
- (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

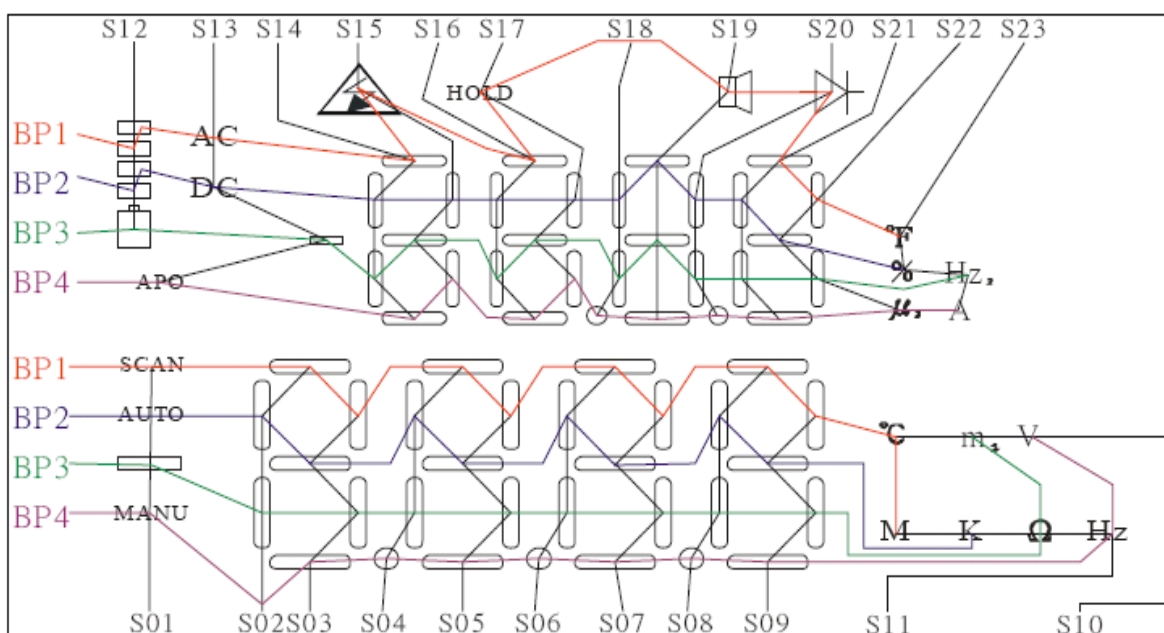


(b) 3.33 beep/sec



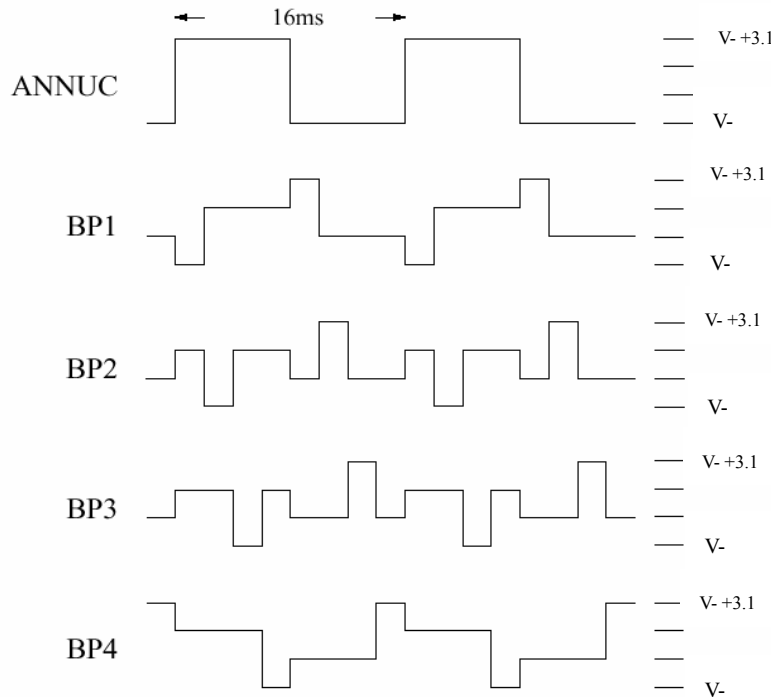
3.4. LCD Panel

	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23
BP1	SLB3	AC	S4A		S3A	HOLD				S1A	S1B	°F
BP2	SLB2	DC	S4F	S4B	S3F	S3B	S2F	S2A	S2B	S1F	S1G	%
BP3	SLB1	SMINUS	S4E	S4G	S3E	S3G	S2E	S2G	S2C	S1E	S1C	Hz <sub>2</sub>
BP4		APO	S4D	S4C	S3D	S3C	SDP2	S2D	SDP1	S1D	μ <sub>2</sub>	A
	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11	
BP1	SCAN	4A	4B	3A	3B	2A	2B	1A	1B	°C	M	
BP2	AUTO	4F	4G	3F	3G	2F	2G	1F	1G		K	
BP3	MINUS	4E	4C	3E	3C	2E	2C	1E	1C	m <sub>2</sub>	Ω	
BP4	MANU		4D	DP3	3D	DP2	2D	DP1	1D	V	Hz	





LCD Backplane Waveform



3.5. 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.
	In continuity check mode.
	In diode mode.
%	In duty cycle measurement.
Hz	Hz for Frequency mode (voltage signal to FREQ input)
Hz <sub>2</sub>	Hz for ACA mode (ADP/IVSH/IVSL)
DC	In DC voltage or current mode.
AC	In AC voltage or current mode.
AUTO	When automatic range selection is enabled. (Voltage, resistance, frequency mode)
MANU	In manual mode.
HOLD	When HOLD function is enabled.
m <sub>2</sub>	In voltage measurement mode and the full scale range is in the order of 10 <sup>-3</sup> .
$\mu_2$	In DCuA 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 $\Omega$
	When the reading is exceeding 30V or OL in DCV or ACV, the HV warning symbol will be displayed.
°C	In temperature measurement mode and when the unit is °C
°F	In temperature measurement mode and when the unit is °F
SLB3	When voltage (ref. to V-) of LBAT9 pin is less than Vt1, SLB3 will disappear.
SLB2	When voltage (ref. to Vo) of LBAT9 pin is less than Vt2, SLB2 will disappear.
SLB1	When SLB2 disappears for 8 seconds, SLB1 will be blinking.
APO	When auto power off function is enabled.





### 3.6. Operating Timing

ES51945 incorporates a dual slope ADC with four phases: ZI, AZ, INT and DINT. The timing of each phase is listed below.

\*Voltage / Current / Ohm / ADP / Temperature (High range) measurement:

Phase	Period
ZI	50ms
AZ	24ms
INT	100ms
DINT	126ms

\* Temperature mode (Low range: 500°C mode)

Phase	Period
ZI	50ms
AZ	24ms
INT	1000ms
DINT	126ms

\*Frequency + Duty cycle mode measurement

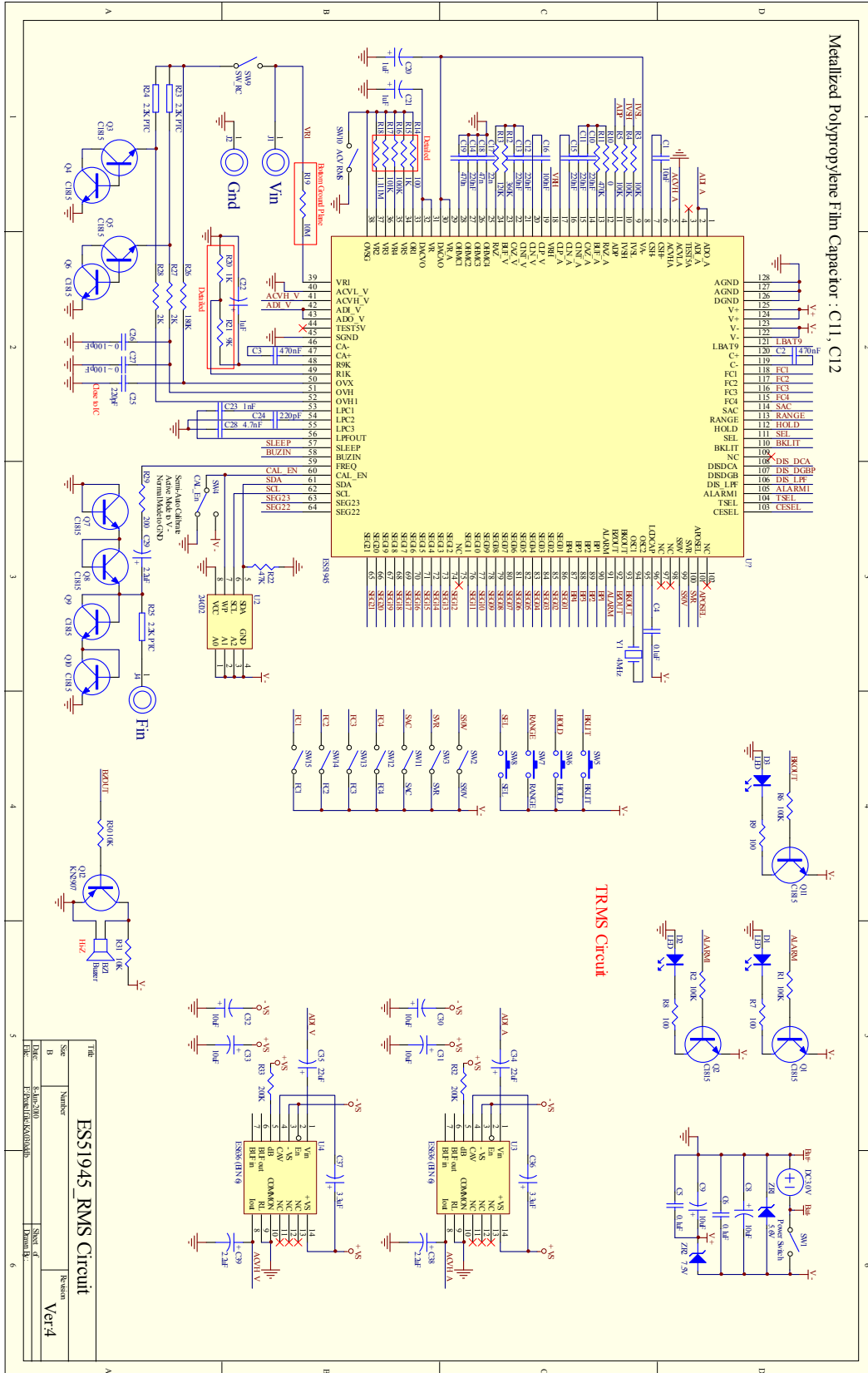
In range 500.0Hz~50MHz, the measurement cycle = 1.05 sec

**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.



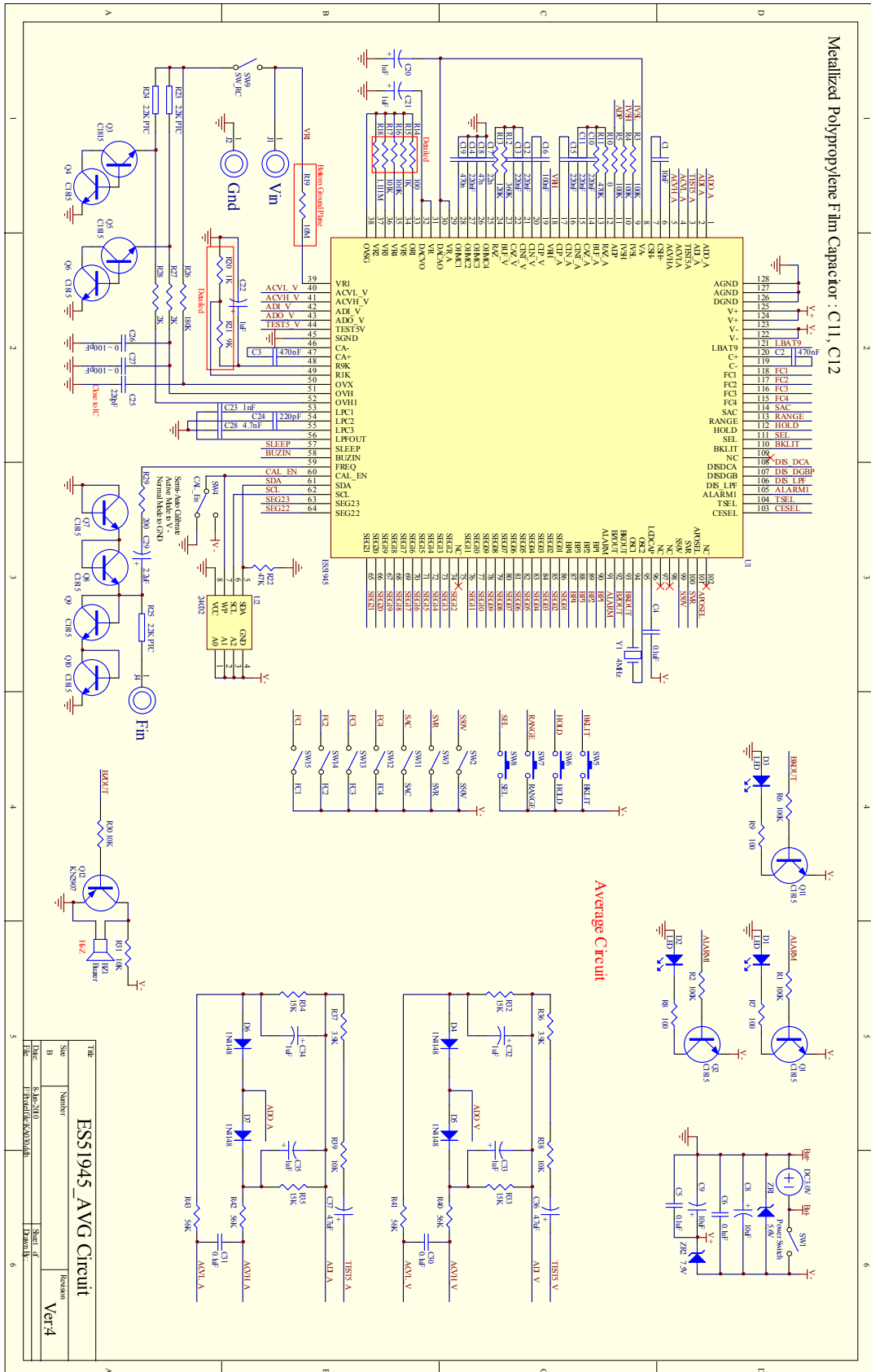
### 4. Application Circuit

#### 4.1 EEPROM is used (AC RMS circuit)



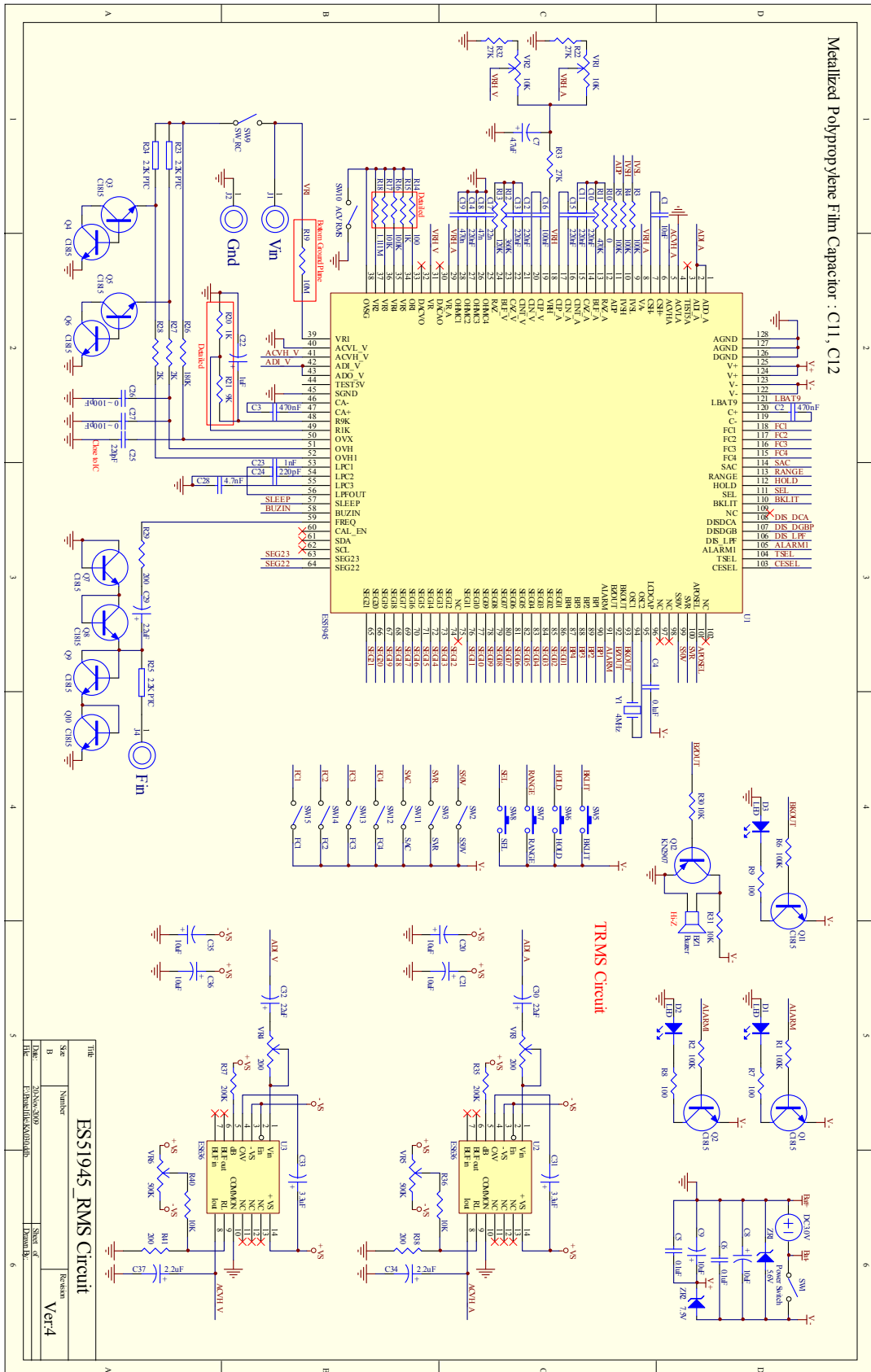


4.2 EEPROM is used (AC AVG circuit)



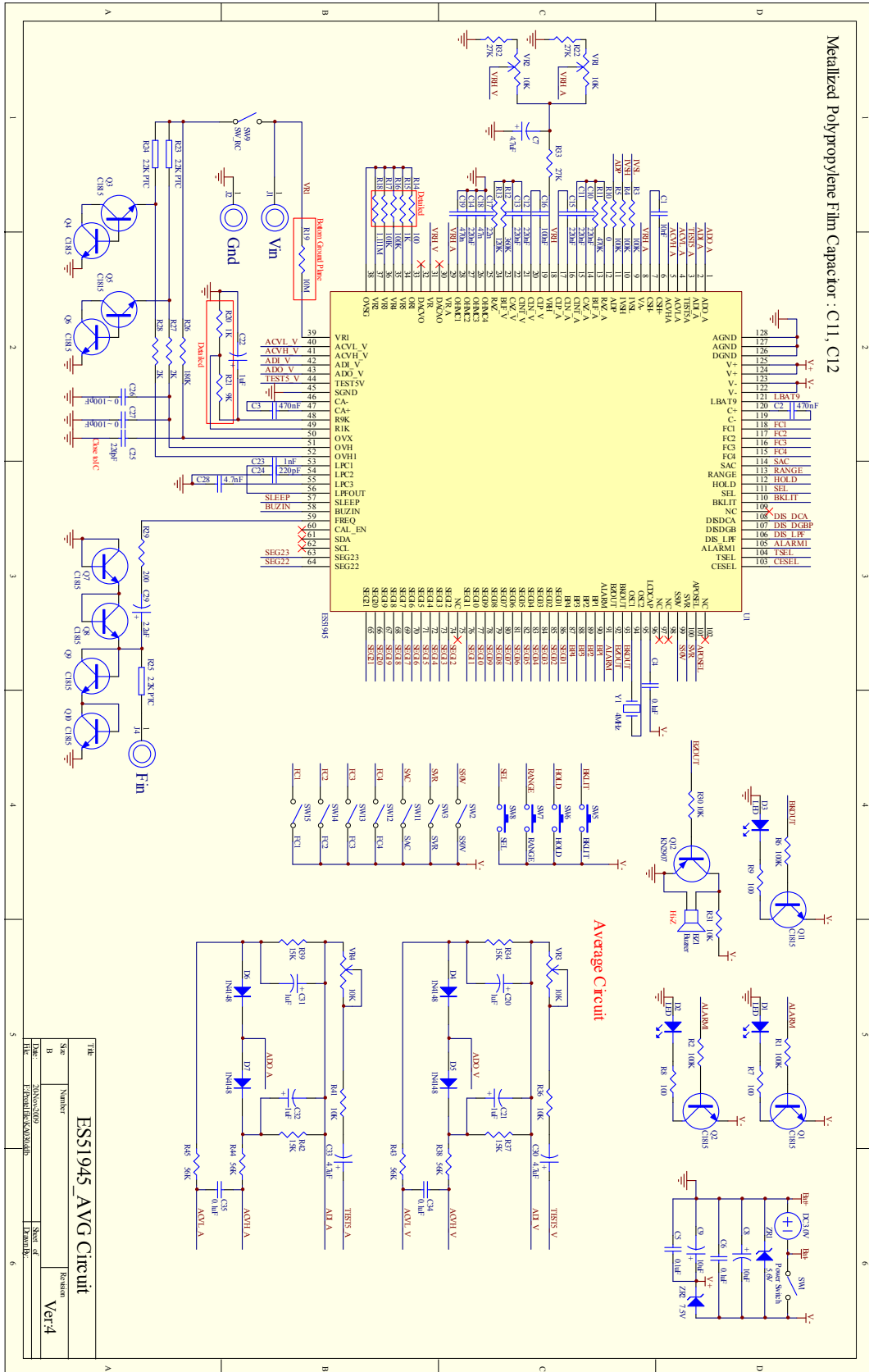


**4.3 EEPROM is not used (AC RMS circuit)**





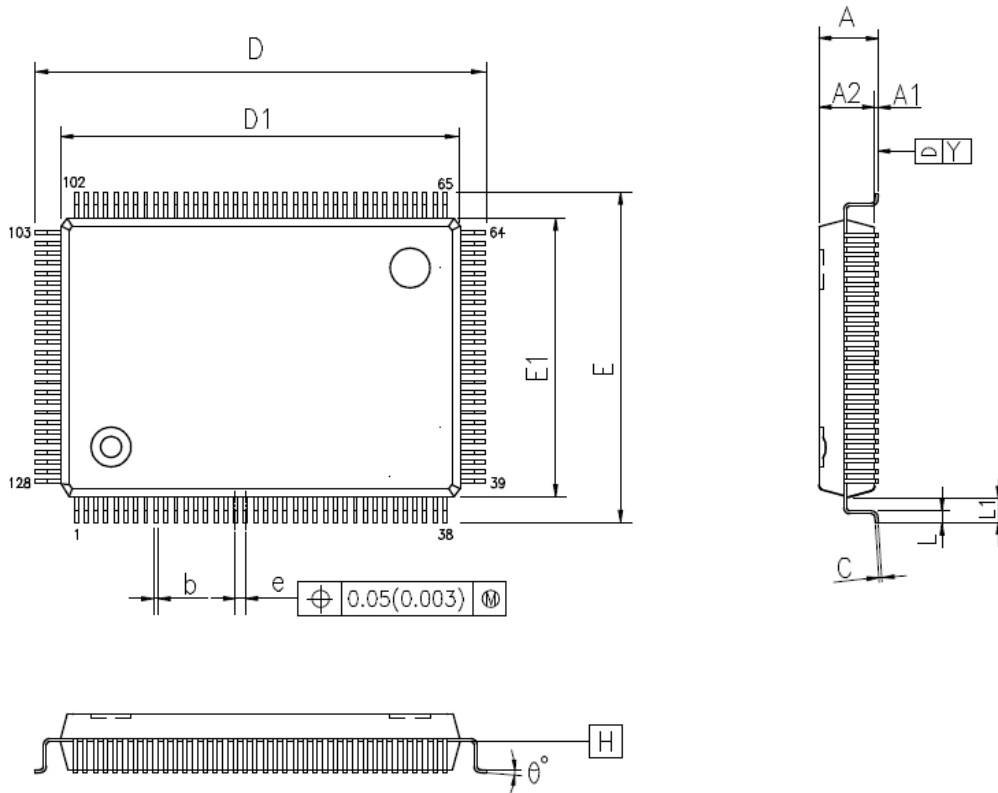
4.4 EEPROM is not used (AC AVG circuit)





## 5. Package Information

### 8.1 128L LQFP Outline drawing



### 8.2 Dimension parameters

SYMBOLS	MIN.	NOM.	MAX.
A	—	—	1.60
A1	0.05	—	0.15
A2	1.35	1.40	1.45
b	0.17	0.22	0.27
C	0.10	0.15	0.20
D1	—	20.00 BSC	—
E1	—	14.00 BSC	—
e	—	0.50 BSC	—
D	—	22.00 BSC	—
E	—	16.00 BSC	—
L	0.45	0.60	0.75
L1	—	1.00 REF	—
Y	—	—	0.08
θ°	0°	3.5°	7°

UNIT : mm

#### NOTES:

1. JEDEC OUTLINE:  
MS-026 BHB;  
MS-026 BHB-HD(THERMALLY ENHANCED VARIATIONS ONLY).
2. DATUM PLANE [H] IS LOCATED AT THE BOTTOM OF THE MOLD PARTING LINE COINCIDENT WITH WHERE THE LEAD EXITS THE BODY.
3. DIMENSIONS E1 AND D1 DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS 0.25 mm PER SIDE. DIMENSIONS E AND E DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE [H].
4. DIMENSION b DOES NOT INCLUDE DAMBAR PROTRUSION.