11-Series to 15-Series Li-Lon and Phosphate Cell Battery Monitor

FEATURES

- Internal ADC measures cell voltage, die temperature and operating ambient temperature
- Independent, internal ADC measures battery pack current (coulomb counter)
- Directly Support up to Three Thermistors (103AT)
- Overcurrent in Discharge (OCD), Short-Circuit in Discharge (SCD)
- Overvoltage (OV), Undervoltage (UV)
- Secondary Protector Fault Detection
- I^2C Interface
- Integrated Cell Balancing FETs
- Charge, Discharge Low-Side N-Channel FET Drivers
- Alert Interrupt for Host Microcontroller
- Default 3.3V Output Regulator. Can Provide 2.5V
- High Power Supply Absolute Rating:108V
- Random Cell Connection Tolerance

APPLICATIONS

- Light Electric Vehicle: Electric Bike, Electric Scooter, Pedal Bicycle
- Electric Tool and Garden Tool
- Battery Backup Unit System (BBUS), Energy Storage System (ESS) and Uninterruptible Power Supply (UPS) System
- Wireless Base Station Backup System
- 36-V, 48-V, 54-V Industrial Battery Packs

PRODUCT DESCRIPTION

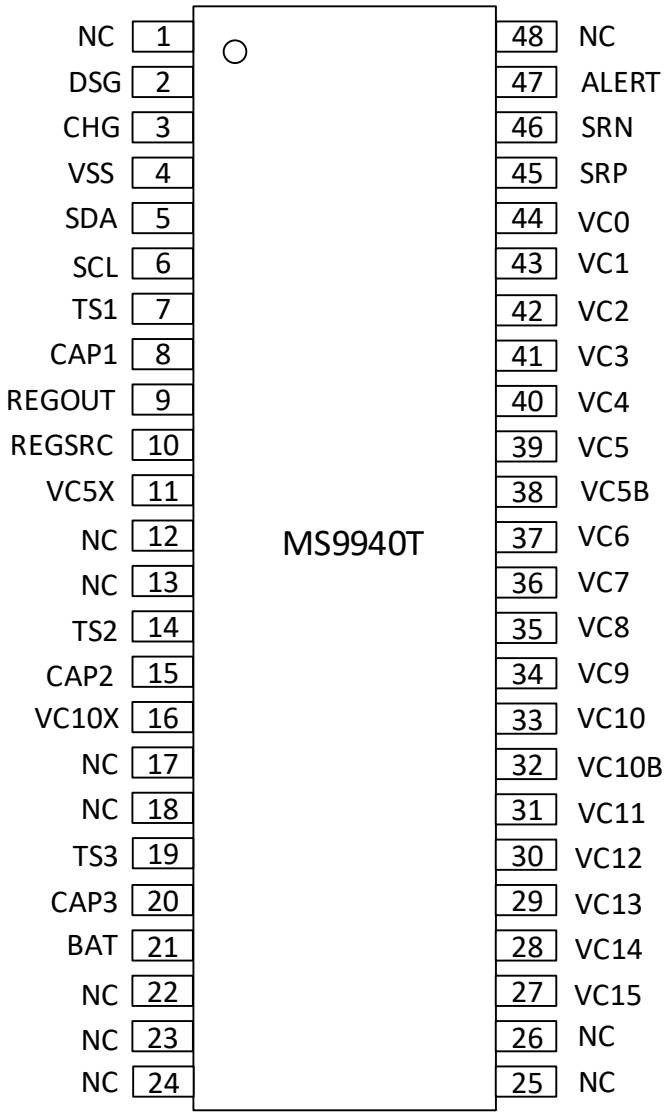
The MS9940T is analog front-end (AFE) device. The MS9940T supports 11-series to 15-series cell. By I^2C, host controller can use the MS9940T to achieve battery pack management functions, such as monitoring (cell voltage, pack current, pack temperature), protection (control charge/discharge FETs) and balancing battery. The MS9940T can be used to manage various battery chemistries, including lithium Ion, lithium iron phosphate. The operating temperature ranges from -40°C to 85°C.

PRODUCT SPECIFICATION

Part Number	Package	RANGE	Cells	I^2C Address(7-bit)	LDO(V)	CRC	Marking
MS9940T	TSSOP48	01	11-15	0x08	2.5	No	MS9940T
		02				Yes	
		03			3.3	No	
		04				Yes	
		05		0x18		Yes	

TABLE of CONTENTS

PIN CONFIGURATION



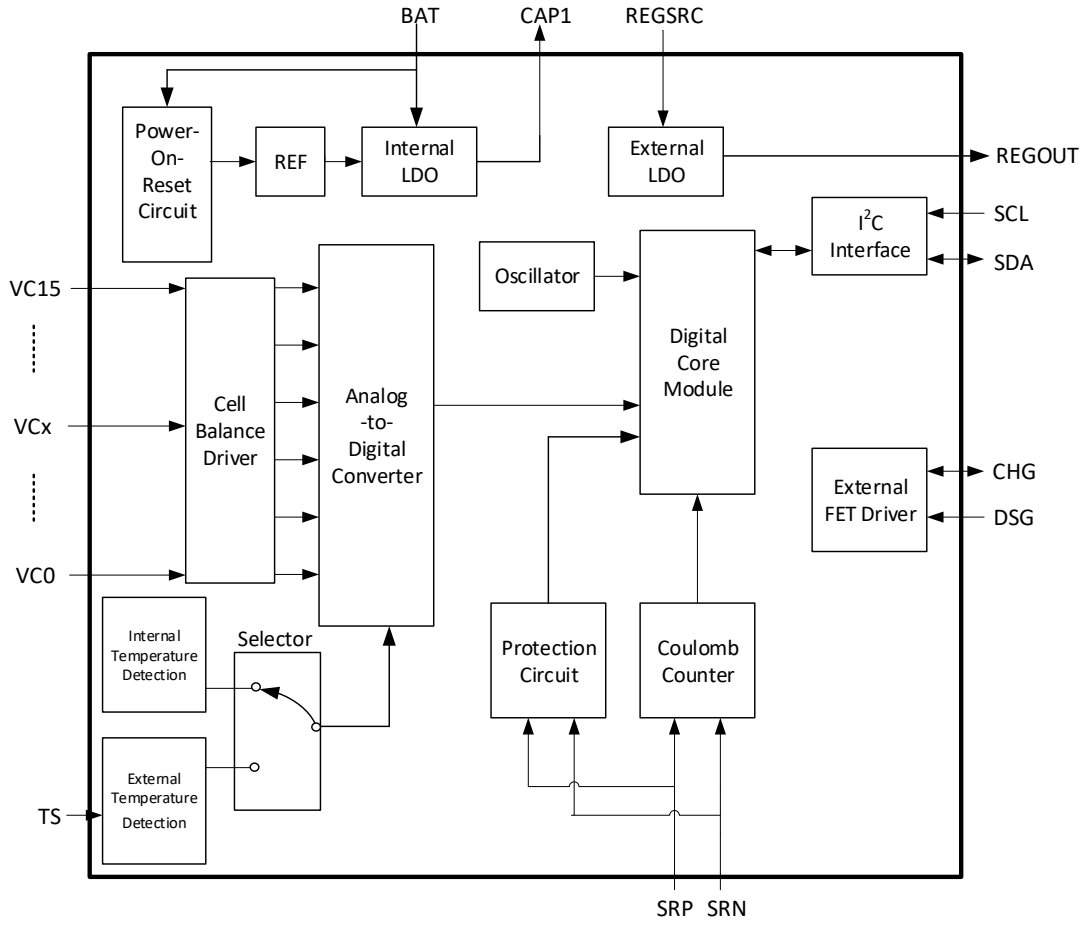
PIN DESCRIPTION

Pin	Name	Type	Description
1	NC	-	Not Connection
2	DSG	O	Discharge FET Driver
3	CHG	O	Charge FET Driver
4	VSS	-	Reference Ground
5	SDA	I/O	I^2C Communicate with Host Controller, Data Pin
6	SCL	I	I^2C Communicate with Host Controller, Clock Pin
7	TS1	I	Thermistor 1 Positive Terminal [1]
8	CAP1	O	3.3V Output, Capacitor to VSS
9	REGOUT	O	Output LDO
10	REGSRC	I	Power Supply for Output LDO
11	VC5X	-	Thermistor 2 Negative Terminal
12	NC	-	Not Connection
13	NC	-	Not Connection
14	TS2	I	Thermistor 2 Positive Terminal [1]
15	CAP2	O	3.3V Output, Capacitor to VC5X
16	VC10X	-	Thermistor 3 Negative Terminal
17	NC	-	Not Connection
18	NC	-	Not Connection
19	TS3	I	Thermistor 3 Positive Terminal [1]
20	CAP3	O	3.3V Output, Capacitor to VC10X
21	BAT	-	Battery (Top-most) Terminal
22	NC	-	Not Connection
23	NC	-	Not Connection
24	NC	-	Not Connection
25	NC	-	Not Connection
26	NC	-	Not Connection
27	VC15	I	Sense Voltage for 15th Cell Positive Terminal
28	VC14	I	Sense Voltage for 14th Cell Positive Terminal
29	VC13	I	Sense Voltage for 13th Cell Positive Terminal
30	VC12	I	Sense Voltage for 12th Cell Positive Terminal
31	VC11	I	Sense Voltage for 11th Cell Positive Terminal
32	VC10B	I	Sense Voltage for 11th Cell Negative Terminal
33	VC10	I	Sense Voltage for 10th Cell Positive Terminal

Pin	Name	Type	Description
34	VC9	I	Sense Voltage for 9th Cell Positive Terminal
35	VC8	I	Sense Voltage for 8th Cell Positive Terminal
36	VC7	I	Sense Voltage for 7th Cell Positive Terminal
37	VC6	I	Sense Voltage for 6th Cell Positive Terminal
38	VC5B	I	Sense Voltage for 6th Cell Negative Terminal
39	VC5	I	Sense Voltage for 5th Cell Positive Terminal
40	VC4	I	Sense Voltage for 4th Cell Positive Terminal
41	VC3	I	Sense Voltage for 3rd Cell Positive Terminal
42	VC2	I	Sense Voltage for 2nd Cell Positive Terminal
43	VC1	I	Sense Voltage for 1st Cell Positive Terminal
44	VC0	I	Sense Voltage for 1st Cell Negative Terminal
45	SRP	I	Negative Current Sense (Close to VSS)
46	SRN	I	Positive Current Sense
47	ALERT	I/O	Alert Output and Fault Detection Input
48	NC	-	Not Connection

Note 1: If not in use, please pull down to VSS with 10kΩ nominal resistor.

BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Any exceeding absolute maximum rating application causes permanent damage to device. Because long-time absolute operation state affects device reliability. Absolute ratings just conclude from a series of extreme tests. It doesn't represent chip can operate normally in these extreme conditions.

Parameter	Symbol	Condition	Ratings	Unit
Power Supply	V_{BAT}		-0.3 ~ +108	V
Input Voltage	REGSRC		-0.3 ~ +45	V
	V_{IN}	VCn-VSS, n=1,2,3...15	-0.3 ~ +n*7.2	V
		VCn-VCn-1, n=1,2,3...10	-0.3 ~ +9	V
Output Voltage	REGOUT,ALERT		-0.3 ~ +3.6	V
	DSG		-0.3 ~ +20	V
	CHG		-0.3 ~ +$V_{CHGCLAMP}$	V
Balance Current for Each Cell	I_{CB}		5	mA
Input Current, DSG Pin	I_{DSG}	Flow into DSG pin when disabled	7	mA
ESD(HBM)	V_{ESD}		±4000	V

RECOMMENDED OPERATING CONDITIONS

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Power Supply	V_{BAT}	(BAT-VC10X),(VC10X-VC5X), (VC5X-VSS)	7.5		25	V
Input Voltage	V_{IN}	VCn-VCn-1,n=1,2,3...15. VCn-VCn-1,n=1,2,3...15. Only for in-use cell	2		5	V
		VCn-VSS,n=1,2,3,4,5. VCn-VC5X,n=6,7,8,9,10. VCn-VC10X,n=11,12,13,4,15	0		5*n	V
		SRP	-10		10	mV
		SRN	-200		200	mV
		VC0-VSS,VC5B-VC5X,VC10B-VC10X	-10		10	mV
		SDA,SCL	0		3.6	V
		TS1-VSS,TS2-VCX5,TS3-VC10X	0		3.6	V
		REGSRC	6		25	V
Output Voltage	V_{OUT}	CHG,DSG	0		16	V
		REGOUT,ALERT	0		3.6	V
		CAP1-VSS,CAP2-VCX5,CAP3-VC10X	0		3.6	V
Balance Current for Each Cell	I_{CB}		0		5	mA
External Cell Input Resistor	R_C		500		1k	Ω
External Cell Input Capacitor	C_C		0.1	1	10	μF

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Power-Filtering Capacitor	C_f		1	10	40	μF
Power-Filtering Resistor	R_f		40	100	1k	Ω
Rsns Filtering Resistor	R_{FILT}		100	1k		Ω
REGOUT Load Capacitor	C_L		1	4.7		μF
Decoupling Capacitor	C_{CAP}	CAP1,CAP2,CAP3,REGSRC	1			μF
External Thermistor	R_{TS}	25°C		10k		Ω
Operating Temperature	T_A		-40		85	°C
Storage Temperature	T_{STG}		-65		150	°C
Lead Temperature (10s)	T_{TOR}			260		°C

ELECTRICAL CHARACTERISTICS

Typical operating conditions are measured at 25°C with VBAT voltage of 48V. The maximum and minimum values are conditions when temperature ranges from -40°C to +85°C. Unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Normal Mode Current						
ADC Off, CC Off	I_{DD}	Sum current of flowing into BAT and REGSRC		38		μA
ADC On, CC Off				66		μA
ADC Off, CC On				124		μA
ADC On, CC On				152		μA
ADC Off	I_{CC_BAT}	Flow into BAT		25		μA
ADC On				52		μA
CC Off	I_{CC_REGSRC}	Flow into REGSRC		14		μA
CC 开				99		μA
SHIP Mode Current						
SHIP Mode Current	I_{SHIP}	Only boot module enabled		0.72		μA
Current Change and Leakage Current						
Normal Mode Current Change	dI_{NOM}	Flow into VC5X and VC10X		13		μA
SHIP Mode Current Change	dI_{SHIP}	Flow into VC5X and VC10X		±0.2		μA
Added Current when ALERT Enabled	dI_{ALERT}	Flow into VC5X or add to BAT		13		μA
Input Current when Cell Measurement	dI_{CELL}	Flow into VC0~VC4, VC6~VC9, VC11-VC14		±0.06		μA
		Flow into VC5, VC10, VC15		±0.1		μA
Input Leakage Current	I_{LKG}			0.6		μA
Internal Power Control (Startup and Shutdown)						
Analog POR Threshold	V_{PORA}	BAT pin		23.5		V
Time Delay after Boot Signal on TS1 before I^2C Communications Allowed	$t_{I2CSTARTUP}$			1		ms
Time Delay between Boot Signal and Complete Startup	$t_{BOOTREADY}$				10	ms
Shutdown Temperature	T_{SHUTD}			100		°C

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Measurement Time						
Measurement Period	t_{VCELL}	From VC1 to VC5, VC6 to VC10, VC11 to VC15		250		ms
Measurement Time for Single Cell	$t_{INDCELL}$	Cell balance off		50		ms
		Cell balance on		12.5		ms
Balance Time before Cell Measurement	t_{CB_RELAX}			37.5		ms
Temperature Measurement Time	t_{TEMP_DEC}			12.5		ms
Pack Voltage Calculation Period	t_{BAT}			250		ms
Temperature Measurement Interval	t_{TEMP}			2		s
14bit ADC used for Cell Voltage Measurement and Temperature Measurement						
ADC Recommended Measurement Range	ADC_{RANGE}	Cell Voltage	2		5	V
		TS1/Temperature measurement	0.3		3	V
ADC LSB	ADC_{LSB}			354		μV
Cell Measurement Accuracy at 25°C	ADC	V_{CELL}=3.6V~4.3V		±10		mV
		V_{CELL}=3.2V~4.6V		±15		mV
		V_{CELL}=2.0V~5.0V		±25		mV
Cell Measurement Accuracy 0~60°C		V_{CELL}=3.6V~4.3V	-40		40	mV
		V_{CELL}=3.2V~4.6V	-40		40	mV
		V_{CELL}=2.0V~5.0V	-50		50	mV
Cell Measurement Accuracy -40°C~85°C		V_{CELL}=3.6V~4.3V	-40		40	mV
		V_{CELL}=3.2V~4.6V	-40		40	mV
		V_{CELL}=2.0V~5.0V	-50		50	mV
Coulomb Counter for Current Measurement CC						
CC Input Voltage	CC_{RANGE}		-200		200	mV
CC Full-scale	CC_{FSR}		-270		270	mV
CC LSB	CC_{LSB}			8.44		μV

Parameter	Symbol	Condition	Min	Typ	Max	Unit
CC Conversion Time	tCC_{READ}			250		ms
Integral Non-linearity INL	CC_{INL}	Within input voltage range		±2	±40	LSB
Offset Error	CC_{OFFSET}			±1	±4	LSB
Gain Error	CC_{GAIN}	Within input voltage range		±0.8%	±1.5%	FSR
Gain Error Drift	$CC_{GAINDRIFT}$	Within input voltage range		20	150	ppm/°C
Valid Input Resistor	CC_{RIN}			2.5	3.5	MΩ

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Thermistor						
Pull-up Resistor	R_{TS}	25°C	9.85	10	10.15	kΩ
Pull-up Resistor Drift	$R_{TSDRIFT}$	-40°C~85°C	9.7		10.3	kΩ
Chip Temperature						
Junction Voltage at 25°C	$V_{DIETEMP}$			1.28		V
Junction Voltage with Chip Temperature	$V_{DIETEMPDRIFT}$			-4.0		mV/°C
Integrated Hardware Protection						
Overvoltage Threshold	OV_{RANGE}		0x2008		0x2FF8	ADC
Undervoltage Threshold	UV_{RANGE}		0x1000		0x1FF0	ADC
Overvoltage and Undervoltage Threshold Step	OV_UV_{STEP}			16		LSB
Minimum Undervoltage Value	$UV_{MINQUAL}$	Below $UV_{MINQUAL}$, cell shorted		0x0518		ADC
Overvoltage Delay Timer Option	OV_{DELAY}	OV delay 1s		1		s
		OV delay 2s		2		s
		OV delay 4s		4		s
		OV delay 8s		8		s
Undervoltage Delay Timer Option	UV_{DELAY}	UV delay 1s		1		s
		UV delay 4s		2		s
		UV delay 8s		4		s
		UV delay 16s		8		s

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Overcurrent Protection Threshold Option	OCD_{RANGE}	Measure SRP-SRN	9		95	mV
Overcurrent Protection Threshold Step	OCD_{STEP}	RSNS=0		2.55		mV
		RSNS=1		5.1		mV
Overcurrent Protection Delay	OCD_{DELAY}		8		1280	ms
Short-circuit Protection Threshold Option	SCD_{RANGE}	Measure SRP-SRN	18.5		181.5	mV
Short-circuit Protection Threshold Step	SCD_{STEP}	RSNS=0		10.2		mV
		RSNS=1		20.4		mV
Short-circuit Protection Delay	SCD_{DELAY}			70		µs
				100		µs
				200		µs
				400		µs
Overcurrent Protection Delay Accuracy	$T_{PROTACC}$		-20%		+20%	
Overcurrent Protection and Short-circuit Protection Voltage Error	OC_{OFFSET}		-5	3.5	+5	mV
Overcurrent Protection and Short-circuit Protection Scale Accuracy	$OC_{SCALEER}$		-20%		+20%	

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Charge and Discharge Driver						
CHG and DSG Open	V_{FETON}	REGSRC≥12V, Load resistor 10MΩ	10	12	13.5	V
CHG and DSG Rise Time	t_{FET_ON}	Load 10nF, 10%~90%		10	100	µs
Fall Time when CHG Pull-down Off	t_{CHG_OFF}	90%~10%		65	200	µs
Fall Time when DSG Pull-down Off	t_{DSG_OFF}	90%~10%		60	90	µs

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Resistor to Ground when CHG Pull-down Off	R_{CHG_OFF}	CHG off and keep on 12V		0.7		MΩ
Resistor to Ground when DSG Pull-down Off	R_{DSG_OFF}	DSG off and keep on12V		2.3		kΩ
Load Detection Threshold	V_{LOAD_DETECT}			1.4		V
CHG Clamp Voltage	V_{CHG_CLAMP}	If CHG pin is pulled up externally, maximum 500μA current flows into CHG pin	20	20.5	21	V
ALERT Pin						
Output High-level	V_{ALERT_OH}	I_{OL}=1mA		REGOUT ×0.98		V
Output Low-level	V_{ALERT_OL}	No load		0		V
Input High-level	V_{ALERT_IH}	When ALERT is driven low internally	1.6	1.75	1.9	V
Pull-down Resistor when ALERT Output Low	R_{ALERT_PD}	ALERT pin to ground		2.0		MΩ
Cell Balance Driver						
Internal Cell Balance Drive Resistor	R_{DSFET}	VCELL=3.6V	2.0	3.5	5.0	Ω
Cell Balance Startup Time Duty Cycle	X_{BAL}	Every 250ms		70%		

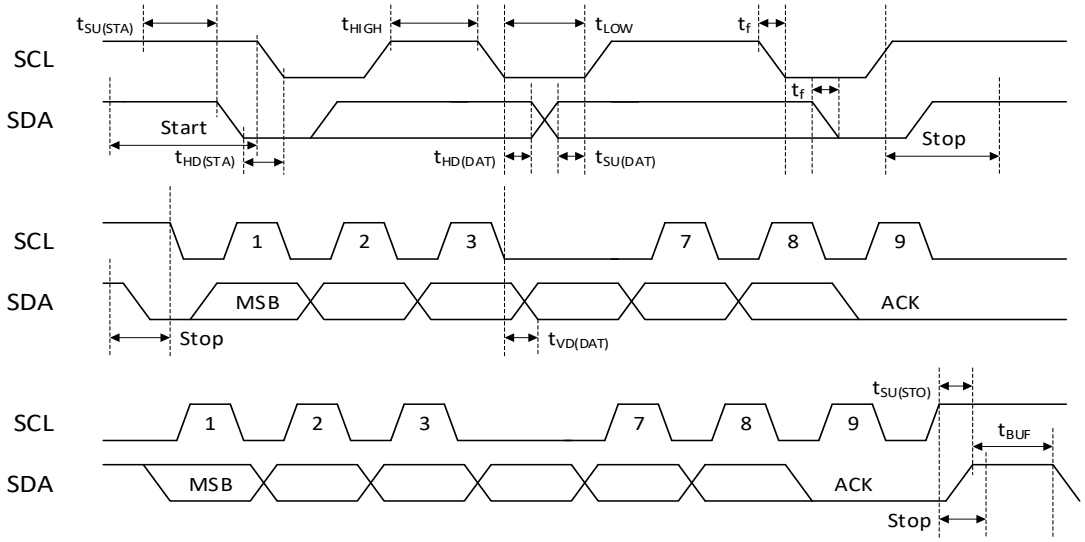
Parameter	Symbol	Condition	Min	Typ	Max	Unit
REGOUT Pin						
External LDO Output Voltage No Load within Total Temperature Range	V_{EXTLDO}	2.5V version	2.45	2.52	2.55	V
		3.3V version	3.2	3.3	3.4	V
Linearity Regulation	V_{EXTLDO_LN}	10mA Load current REGSRC pin increases from 6V to 25V with 100μs		5	100	mV
Load Regulation	V_{EXTLDO_LD}	Load current from 0mA to 10mA	-4%	-1.7%	+4%	

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Minimum Output Voltage with DC Load	V_{EXTLDO_DC}	2.5V version 10mA	2.4	2.44		V
		2.5V version 20mA	2.3	2.4		V
		3.3V version 10mA	3.15	3.21		V
		3.3V version 20mA	3.05	3.13		V
External LDO Current Limit	V_{EXTLDO_LIMIT}	REGOUT=0, REGSRC=18V	32.0	36.0	40.0	mA
Boot Detection						
Boot Threshold Voltage	V_{BOOT}	Measured at TS1 pin. Ensure boot if higher than maximum. Not boot if lower than minimum	300	700	1000	mV
Apply Boot Signal Duration Time	t_{BOOT}	Measured at TS1 pin. Ensure boot if higher than maximum. Not boot if lower than minimum	60	125	2000	µs

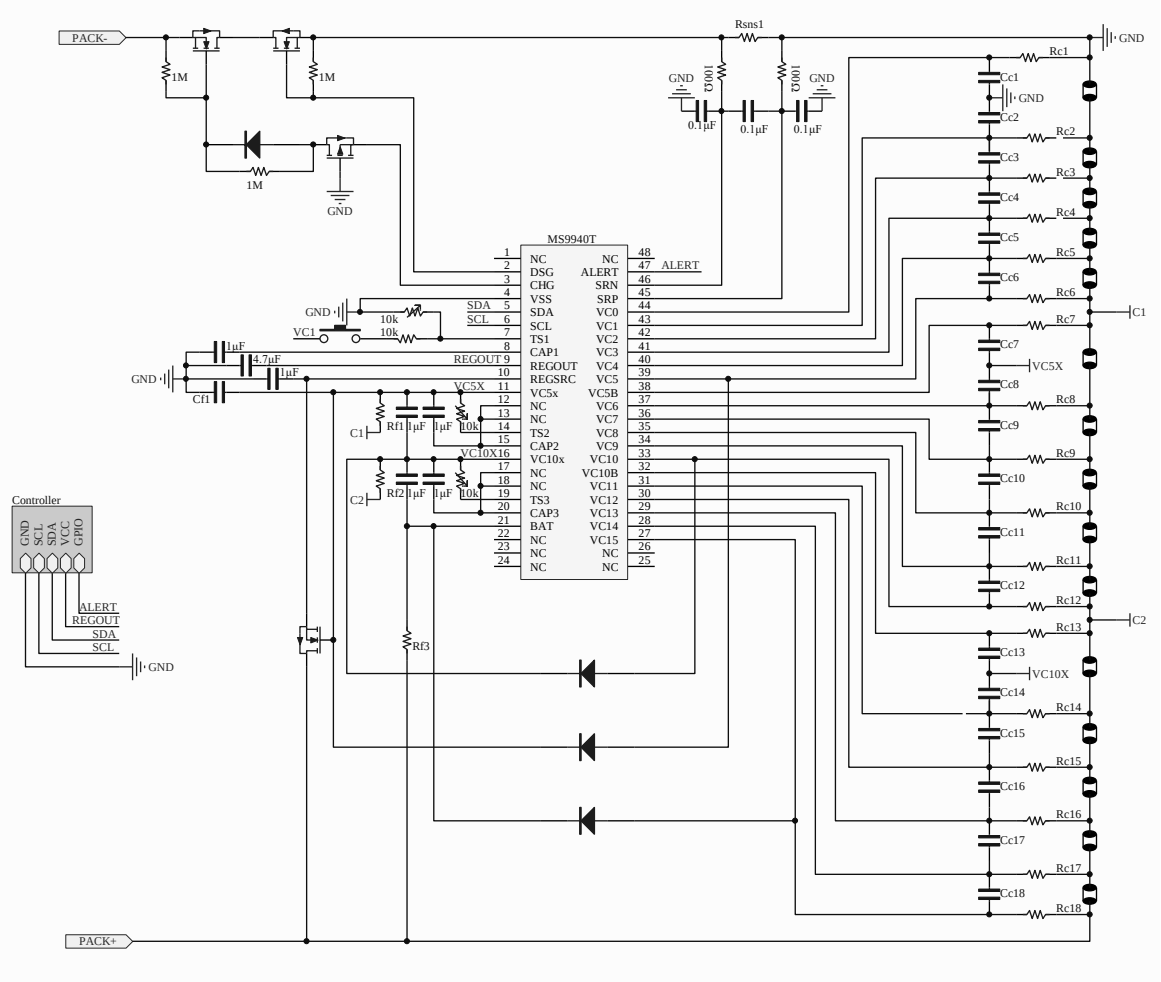
Parameter	Symbol	Condition	Min	Typ	Max	Unit
I^2C Interface						
Input Low-level Voltage	V_{IL}				REGOUT×0.25	V
Input High-level Voltage	V_{IH}		REGOUT×0.75			V
Output Low-level Voltage	V_{OL}			0		V
SCL, SDA Fall Time	t_f			0.4		ns
SCL High-level Pulse Width	t_{HIGH}			1.5		µs
SCL Low-level Pulse Width	t_{LOW}			2.0		µs
Setup Time, Start State	$t_{SU,STA}$			2.0		µs
Hold Time, Start State	$t_{HD,STA}$			1.5		µs
Data Setup Time	$t_{SU,DAT}$			130		ns
Data Hold Time	$t_{HD,DAT}$			26		µs
Setup Time, Stop State	$t_{SU,STO}$			2.5		µs

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Bus Idle Wait Time before New Transmission	t_{BUF}			4.0		μs
Clock Low to Data Output Valid	$t_{VD,DAT}$				900	ns
Clock Frequency	f_{SCL}				100	kHz

Timing Diagram



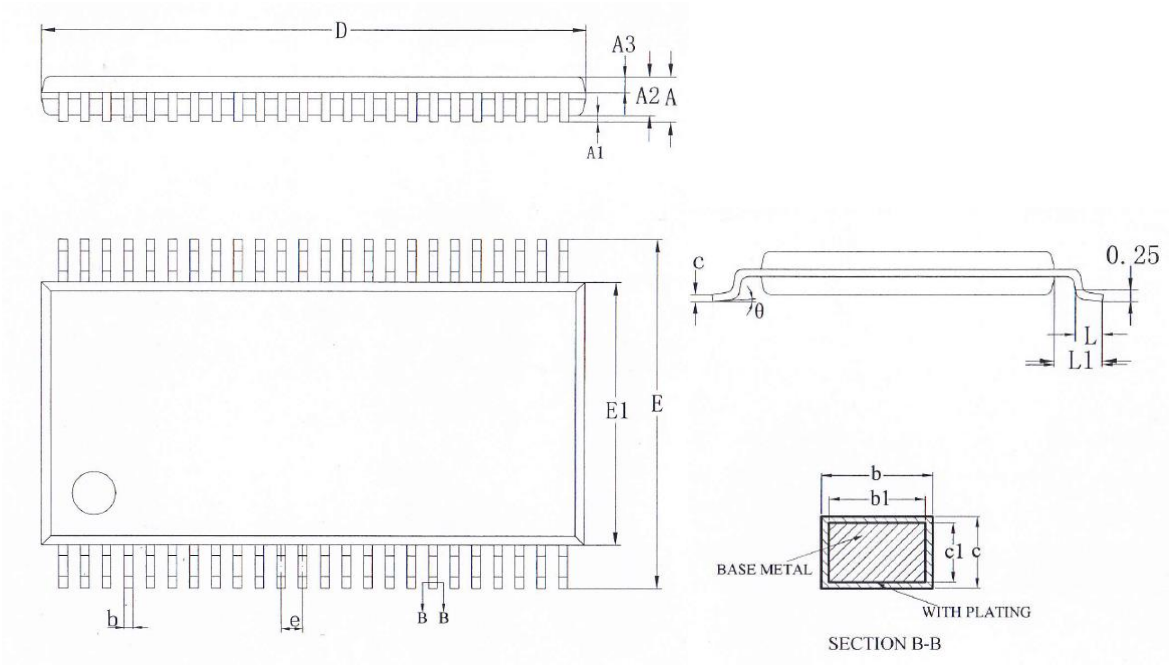
TYPICAL APPLICATION DIAGRAM



MS9940T Application Diagram

PACKAGE OUTLINE DIMENSIONS

TSSOP48



Symbol	Dimensions in Millimeters		
	Min	Typ	Max
A	-	-	1.20
A1	0.05	0.10	0.15
A2	0.85	0.95	1.05
A3	0.35	0.40	0.45
b	0.18	-	0.26
b1	0.17	0.20	0.23
c	0.15	-	0.19
c1	0.14	0.15	0.16
D	12.40	12.50	12.60
E	7.90	8.10	8.30
E1	6.00	6.10	6.20
e	0.50BSC		
L	0.45	-	0.75
L1	1.00REF		
θ	0	-	8°

MARKING and PACKAGING SPECIFICATION

1. Marking Drawing Description

Product Name: MS9940T

Product Code: XXXXXXX

2. Marking Drawing Demand

Laser printing, contents in the middle, font type Arial.

3. Packaging Specification

Device	Package	Piece/Reel	Reel/Box	Piece/Box	Box/Carton	Piece/Carton
MS9940T	TSSOP48	3000	1	3000	8	24000

STATEMENT

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- The process of improving product is endless. And our company would sincerely provide more excellent product for customer.

MOS CIRCUIT OPERATION PRECAUTIONS

Static electricity can be generated in many places. The following precautions can be taken to effectively prevent the damage of MOS circuit caused by electrostatic discharge:

1. The operator shall ground through the anti-static wristband.
2. The equipment shell must be grounded.
3. The tools used in the assembly process must be grounded.
4. Must use conductor packaging or anti-static materials packaging or transportation.

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