μP6321M

Offline AC-DC Primary Side Regulation Switcher

1. Description

The μP6321M is a high performance offline AC-DC switcher for small output current applications, such as shaver chargers.

The μP6321M provides accurate Constant Voltage (CV) and Constant Current (CC) without requiring TL431 and opto-coupler. It also eliminates the need of loop compensation circuitry while maintaining stability.

The μP6321M is equipped with both adjustable line voltage compensation function for perfect CC and adjustable cable drop compensation function to meet various cables with different lengths and gauges.

The μP6321M uses the μPsemi's proprietary VCC forward power supply technology. It can work normally when the output voltage is very low, even 0V, and it can achieve lower standby power, faster startup time with small VCC capacitor.

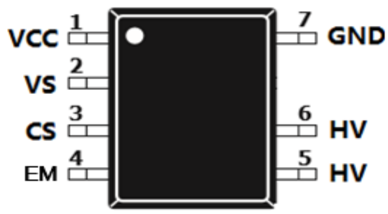
2. Applications

- Shaver Charger
- Small Home Appliance Charger

3. Features

- Built-in BJT
- Less than 75mW Standby Power
- High Precision Constant Voltage and Current Special for Small Output Current Applications Without TL431 and Opto-coupler
- Normal work @ Output Voltage is 0V
- External Adjustable Line Compensation for CC
- External Adjustable Cable Compensation for CV
- No Need for Control Loop Compensation
- Valley Turn-on to Reduce Switching Loss and Improve EMI
- Operating Frequency Jitter Function for Conductive EMI Suppression
- DoE(VI)/CoC tier2 Compliant Efficiency
- Multiple Protections
  - ◆Over Temperature Protection(OTP)
  - ◆Output Over-Voltage Protection(OVP)
  - ◆Line Voltage OVP and VCC OVP
  - ◆IC Single Pin Floating Protection
- Output power: < 2W

4. Pin Assignments



SOP7 package

5. Pin descriptions

Pin number	Pin Name	Pin Functions
1	VCC	The power supply for the IC.
2	VS	Voltage feedback.
3	CS	Current sense of the integrated power BJT.
4	EM	The emitter pin of the integrated power BJT
5,6	HV	The collector pin of the integrated power BJT
7	GND	The ground of the IC

6. Absolute Maximum Ratings (Note 1)

Parameter	Name	Range	Unit
Collector voltage of Power BJT	HV	-0.5 to 800	V
Voltage at VCC to Ground	VCC	-0.5 to 40	V
VS input voltage	VS	-30 to 6	V
Voltage at CS to Ground	CS	-0.5 to 6	V
Collect Current		0.32	A
Maximum junction temperature	T_{JMAX}	150	°C
Lead temperature	T_{LEAD}	260	°C
Storage temperature	T_{STG}	-55 to 150	°C
Thermal resistance (Note2)	θ_{JA}	160	°C/W
Human Body Mode ESD per ANSI/STM5.1-2001	HBM	+/-2000	V
Charged Device Model per JEDEC JESD22-C101F	CDM	+/-1000	V
Latchup test per JEDEC 78D		+/-200	mA

Note1: Stresses over those listed under “Absolute maximum ratings” may cause permanent damages to the device. These are stress ratings only. Functional operation beyond those under “Recommended operating conditions” is not implied.

Note2:The junction-to-ambient thermal resistance under natural convection is obtained in a simulation on a JEDEC-standard, high-K board, as specified in JESD51-7, in an environment described in JESD51-2a

7. Recommended Operating Conditions

Symbol	Parameter	Range	Unit
HV	Power device voltage	0~600	V
VCC	Supply voltage	4~36	V

8. Electrical Parameter

(Ta=25°C, unless otherwise specified)

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Power supply (VCC pin)						
Quiescent current @ no load	I_{CC}	VCC=12V	280	380	480	µA

Startup voltage	V_{ST}		13.6	17.8	22	V
Minimum operating voltage	V_{UVLO}		3.2	3.8	4.4	V
Startup current	I_{ST}	VCC=Vst-1V		0.85	1.5	µA
Constant voltage control (VS pin)						
VS regulation voltage	V_{FB}		-2.91	-2.86	-2.81	V
Maximum discontinuous time	t_{OFF_MAX}			2		ms
Constant current control（CS pin）						
Shutdown voltage (Note 4)	V_{CSMAX}		552	600	648	mV
Leading edge blanking	T_{LEB}		350	480	610	ns
Maximum duty of secondary winding conduction	D_{MAX}	Note 3		0.17		
Drive control (Note 3)						
Over drive current	I_{DRI}	VCC=12V	8.5	14	19.5	mA
Over drive current time	T_{OVD}			260		ns
Pull down resistance	R_{DSON}	OUT=2V		9		Ω
Protection functions						
Shutdown temperature	T_{OTP}	Note 3		160		°C
Temperature hysteresis	T_{HYS}	Note 3		25		°C
VCC over voltage protection	V_{CC_OVP}			36		V
Output over voltage	V_{FB_OVP}			-4		V
Power BJT (HV pin)						
BJT CB leakage current	I_{CBO}	V_{CB}=800V, I_E=0			100	µA

Note 3: These parameters are guaranteed by design and characterization

Note 4: V_{CSMAX} is an equivalent parameter tested in closed loop to ensure the precise constant current.

9. Functional Block Diagram

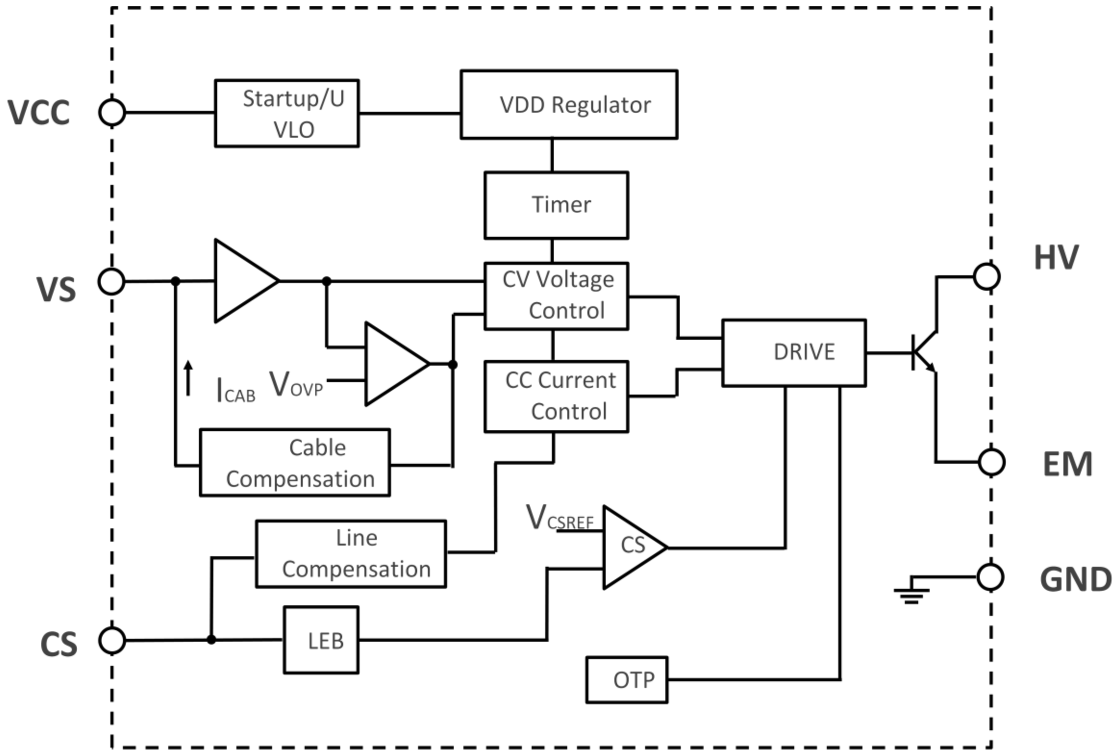


Fig.1, µP6321M Block Diagram

10. Typical Application

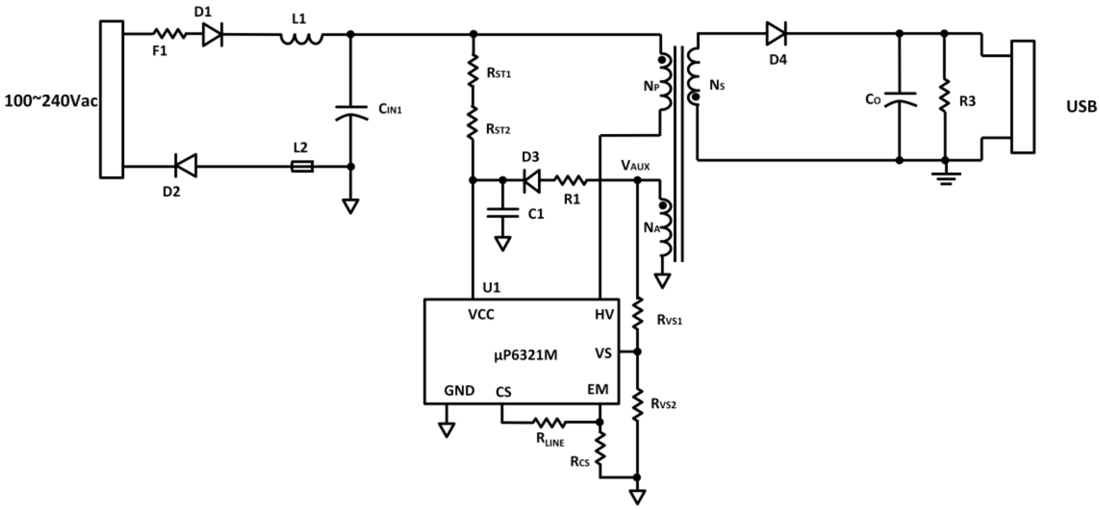


Fig.2, µP6321M schematic

11. Principle of Operation

The typical application circuit of µP6321M is a conventional flyback converter with a 3-winding transformer---primary winding (N_P), secondary winding (N_S) and auxiliary winding (N_A), as shown in typical application. The forward auxiliary winding is used for providing VCC supply voltage for IC and sensing the output voltage feedback signal to VS pin.

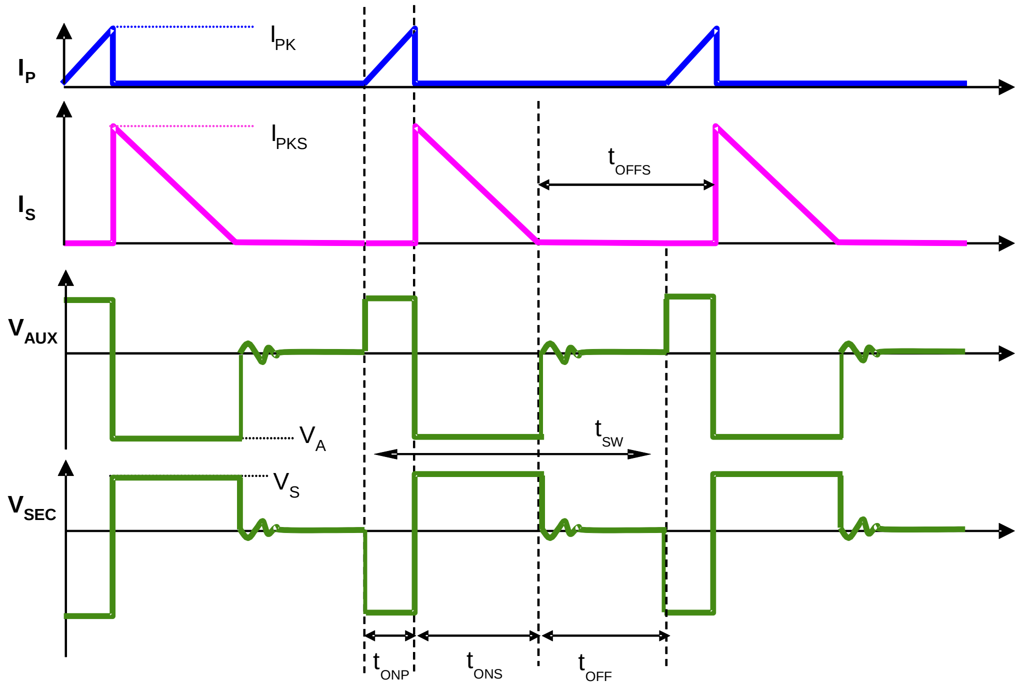


Fig.3 Typical Waveforms

Fig.3 shows the typical waveforms which demonstrate the basic operating principle of µP6321M application. And the parameters are defined as following.

- **I_P**---The primary side current
- **I_S**---The secondary side current
- **I_{PK}**---Peak value of primary side current
- **I_{PKS}**---Peak value of secondary side current
- **V_{SEC}**---The transient voltage at secondary winding
- **V_S**---The stable voltage at secondary winding when rectification diode is in conducting status, which equals the sum of output voltage V_O and the forward voltage drop of diode
- **V_{AUX}**---The transient voltage at auxiliary winding
- **V_A**--- The stable voltage at auxiliary winding when rectification diode is in conducting status, which equals the sum of voltage V_{CC} and the forward voltage drop of auxiliary diode
- **t_{SW}** ---The period of switching frequency
- **t_{ONP}** ---The conduction time when primary side switch is "ON"
- **t_{ONS}** ---The conduction time when secondary side diode is "ON"
- **t_{OFF}** ---The dead time when neither primary side switch nor secondary side diode is "ON"
- **t_{OFFS}** --- The time when secondary side diode is "OFF"

11.1 Proprietary VCC Forward Power Supply

The µP6321M adopts the µPsemi's proprietary VCC forward power supply technology, which the polarity terminal of auxiliary winding is opposite to the commonly used flyback power supply.

In the traditional VCC flyback power supply, the forward voltage of auxiliary winding is $V_O * N_{AS}$. The output voltage is very low when starting, $V_O * N_{AS}$ is less than VCC voltage and can't supply VCC power. At this stage the power consumption on VCC is depending on previous storage, so it is necessary to use the large VCC capacitance in order to maintain normal starting.

In the µPsemi's proprietary VCC forward power supply, as long as the primary side is switched on, the forward voltage of auxiliary winding is $1.414*V_{AC}/N_{PA}$ and can supply VCC power, which is independent of the output voltage. Therefore, the VCC forward power supply can use smaller VCC capacitor (470nf~1uf generally used), and the starting resistance can be about 20Mohm to achieve lower standby power and faster startup time.

Another advantage of VCC forward power supply is that the VCC voltage has no direct relationship with the output voltage. That is, when the output voltage is very low even 0V, the system can still work well. However VCC flyback power supply can't work normally because VCC can't be supplied power.

11.2 Constant Voltage (CV) Operation

Constant voltage operation occurs when the load is between no-load and full-load. Output voltage is sensed at the VS pin, which is connected to the auxiliary winding via resistors R_{VS1} and R_{VS2}. The VS waveform is sampled at t_{SAMPLE} , around 2/3 duration of the secondary winding conduction time(T_{ONS}). The sampled voltage is regulated at V_{VS} by the voltage control loop. The CV output is determined by the resistors R_{VS1}, R_{VS2} and the turn ratio of secondary winding to auxiliary winding (N_S/N_A). The output voltage at cable end is:

$$V_O = |V_{VS}| \times (1 + \frac{R_{VS1}}{R_{VS2}}) \times \frac{N_S}{N_A}$$

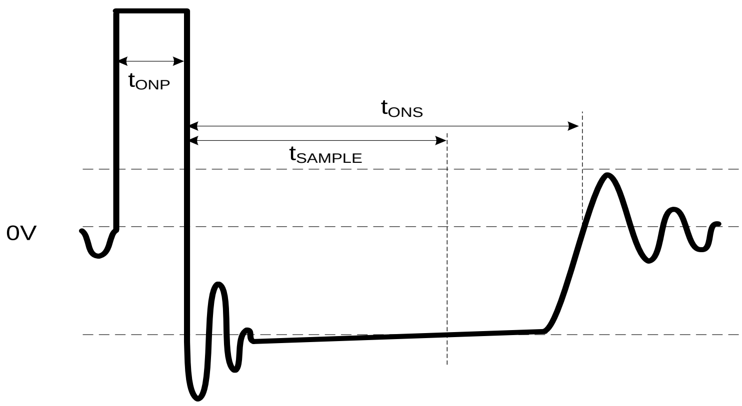


Fig.4 Auxiliary Voltage Waveform

11.3 Constant Current (CC) Operation

The µP6321M can work in constant-current (CC) mode. Figure 3 shows the secondary current waveforms. In CC operation mode, the CC control loop of µP6321M will keep a fixed proportion between D1 on-time t_{ONS} and D1 off-time t_{OFFS}. The fixed proportion is

$$\frac{t_{ONS}}{t_{OFFS}} = \frac{1}{5}$$

The relationship between the output current and secondary peak current I_{PKS} is given by:

$$I_{OUT} = \frac{1}{2} \times I_{PKS} \times \frac{t_{ONS}}{t_{ONS} + t_{OFFS}}$$

As to tight coupled primary and secondary winding, the secondary peak current is

$$I_{PKS} = \frac{N_P}{N_S} \times I_{PK}$$

Thus the output constant-current is given by:

$$I_{OUT} = \frac{1}{2} \times \frac{N_P}{N_S} \times I_{PK} \times \frac{t_{ONS}}{t_{ONS} + t_{OFFS}} = \frac{1}{12} \times \frac{N_P}{N_S} \times I_{PK}$$

11.4 Switching Frequency Control

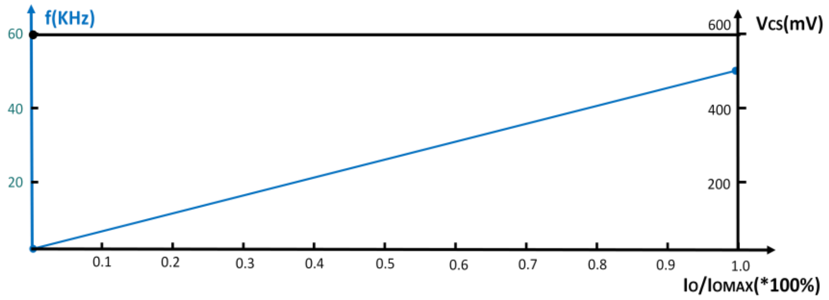


Fig.6, Switching frequency and CS voltage v.s. load current

The µP6321M operates in Pulse Frequency Modulation (PFM) mode to control output voltage and current. As shown in Fig.6, the CS voltage (VCS) at the power transistor turnoff instant is a fixed value (V_{CSMAX}) in the whole load range. Operating frequencies varies from around 600Hz at no load to around 45KHz at full load, in the typical charger design. The power transistor turns on when the resonant ring voltage is down to its valley (Quasi-Resonant switching). This can reduce turn on losses of the power transistor. It can also generate switching period jittering to reduce EMI.

11.5 Adjustable Cable Compensation

To meet the voltage drop of different output cables, the µP6321M can realize the adjustable cable compensation. The VS pin source a current proportional to the load to generate cable compensation voltage. The cable compensation current at max load is I_{CAB}. The cable compensation voltage V_{CAB} can be adjusted by setting the R_{VS1}, R_{VS2} values. Neglecting the forward conduction voltage of second D2, the cable compensation voltage at max load is

$$V_{CAB} = I_{CAB} \times R_{VS1} \times \frac{N_S}{N_A}$$

The output voltage at PCB end is

$$V_{O\_PCB} = V_O + V_{CAB}$$

The cable compensation percentage is approximately

$$\frac{V_{CAB}}{V_O} = I_{CAB} \times R_{VS1} // R_{VS2} / |V_{VS}| - 0.05$$

For 5V1A typical application： R_{VS1} =7.5KΩ， R_{VS2} =10KΩ， $\frac{V_{CAB}}{V_O}$ is about 4%

The -0.05 item in the formula is to compensate load regulation.

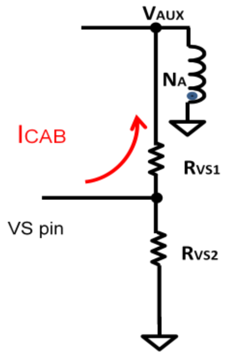


Fig.5. Adjustable Cable Compensation Circuit

11.6 Adjustable Line Compensation

Since there is a constant delay time from the CS pin voltage reaching the given V_{CS} reference to the power BJT turning off, the real primary peak current value always has a gap with the ideal value. The gap value changes with different input line voltage, which is caused by different current rising slope, results in different system constant current value.

In order to eliminate the constant current deviation due to line voltage, the adjustable line compensation is introduced to design. The positive voltage of FB pin which is linear to the line voltage is added up to V_{CS} reference by a certain proportion and create an adjustable compensation voltage to clear up the primary current gap, so that the excellent line regulation of output current will be achieved. The working principle is shown in Fig. 6.

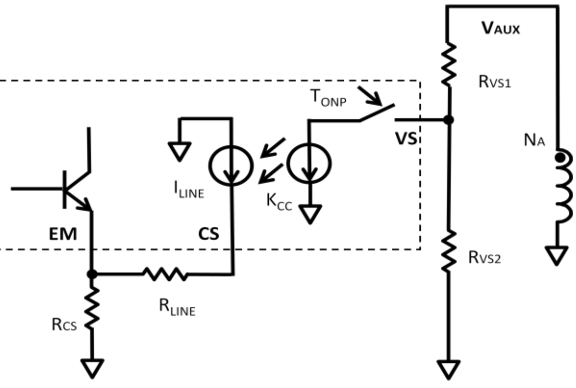


Figure 6. Adjustable Line Compensation Circuit

The positive voltage (V_P) of auxiliary winding (V_{AUX}) reflects input voltage:

$$V_P = \frac{R_{VS2}}{R_{VS1}+R_{VS2}} \cdot V_{AUX} = \frac{R_{VS2}}{R_{VS1}+R_{VS2}} \cdot \frac{N_A}{N_P} \cdot V_{INDC}$$

I_{LINE} is proportional to V_P (K_{CC} is the ratio). So, the reduction of CS pin is proportional to input voltage:

$$V_{CS\_LINE} = R_{LINE} \cdot I_{LINE} = R_{LINE} \cdot Kcc \cdot \frac{R_{VS2}}{R_{VS1}+R_{VS2}} \cdot \frac{N_A}{N_P} \cdot V_{INDC}$$

So, the μP6321M can change the line compensation capability by adjusting the resistor (R_{LINE}) between CS pin and EM pin. Larger resistance means higher line compensation capability.

11.7 Protection

The μP6321M has multiple built-in fault protection functions:

- ◆Line Voltage OVP and VCC OVP
- ◆Output Over-Voltage Protection(OVP)
- ◆Over Temperature Protection(OTP)
- ◆IC Single Pin Floating Protection

11.7.1 AC Line Voltage OVP and VCC OVP

When the system works normally, the forward voltage of V_{AUX} charges the VCC capacitor at the primary turn-on (t_{ONP}) stage. The VCC voltage reflects the AC line voltage. That is to say, VCC over voltage protection can realize AC line voltage over voltage protection.

When the VCC voltage is over the threshold voltage V_{VCC_OVP}, the device will be turned off and enter auto-recovery mode that the IC immediately shuts down and then restarts until the line voltage drops below V_{LINE_OVP} when the VCC voltage restarts to V_{ST}.

$$V_{LINE\_OVP} = 0.707 \times V_{VCC\_OVP} \times \frac{N_P}{N_A}$$

11.7.2 Output Over Voltage Protection

The μP6321M includes output over-voltage protection (OVP). If the voltage at VS pin exceeds V_{VS_OVP} for 3 successive switching cycles, the device immediately shuts down and enters auto-recovery mode.

$$V_{OVP} = \left|V_{VS\_OVP}\right| \times (1+\frac{R_{VS1}}{R_{VS2}}) \times \frac{N_S}{N_A} + I_{CAB} \times R_{VS1} \times \frac{N_S}{N_A}$$

11.7.3 Over Temperature Protection

The μP6321M provides internal over-temperature protection (OTP). If the junction temperature reaches the threshold T_{OTP}, the device enters auto-recovery mode. If the junction temperature decreases by T_{HYS} when the

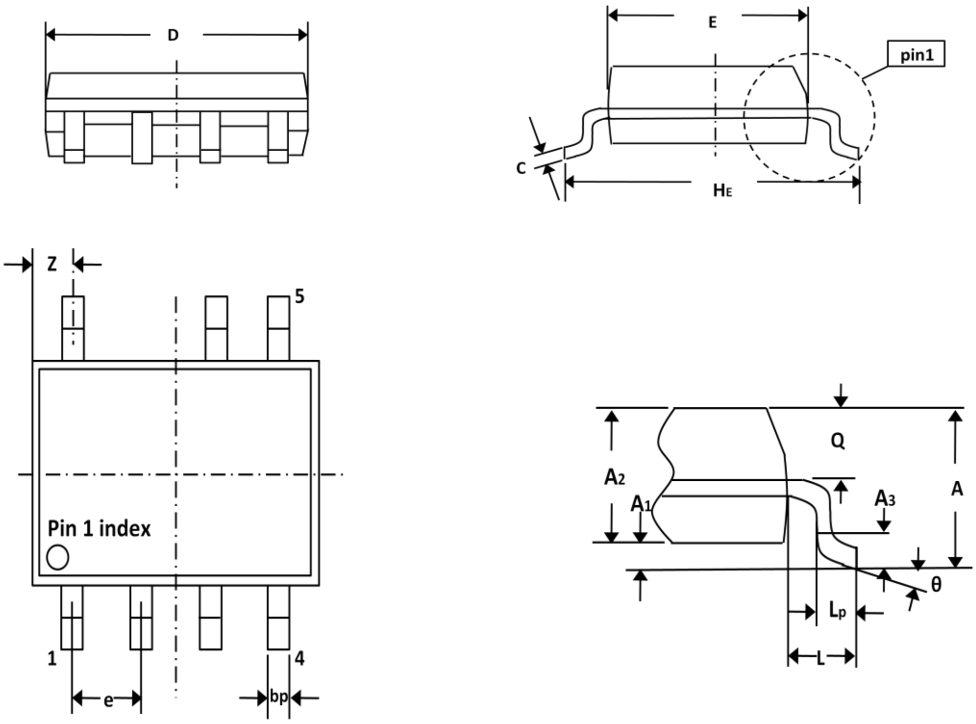
VCC voltage restarts to V_{ST}, the device can recover to normal operation. If not, the power system enters hiccup mode until the junction temperature decreases below T_{OTP} –T_{HYS}.

12. Ordering Information

Part number	Mark ID	Package	Packing
µP6321M	6321M	SOP7	4000/Reel

13. Mechanical dimensions

SOP7



UNIT	A	A1	A2	A3	bp	c	D	E	e	HE	L	Lp	Q	Z	θ
mm	1.75MAX	0.10 0.25	1.25 1.65	0.25	0.31 0.51	0.17 0.25	4.8 5.0	3.8 4.0	1.27	5.8 6.2	1.05	0.4 1.2	0.6 0.7	0.3 0.7	0° 8°