1T 8051

8-bit Microcontroller

NuMicro® Family
ML51 Series
Product Brief

For additional information or questions, please contact: Nuvoton Technology Corporation.

www.nuvoton.com

1 GENERAL DESCRIPTION

The NuMicro® ML51 series is Flash embedded 1T 8051-based microcontroller. The instruction set of the ML51 is fully compatible with the standard 80C51 with performance enhanced.

The ML51 series runs up to 24 MHz at a wide voltage range from 1.8V to 5.5V, and contains up to 64/32/16 Kbytes Flash called APROM for programming code. The ML51 Flash supports In-Application-Programming (IAP) function, which enables on-chip firmware updates. Partial Flash can be optionally configured as Data Flash programmed by IAP and read by IAP or MOVC instruction. The ML51 includes an additional configurable up to 4/3/2/1 Kbytes Flash area called LDROM, in which the Boot Code normally resides for carrying out the In-System-Programming (ISP).

The ML51 provides rich peripherals including 256 bytes of SRAM, 4/2/1 Kbytes of auxiliary RAM (XRAM), up to 43 general purpose I/O, two 16-bit Timers/Counters 0/1, one 16-bit Timer2 with three-channel input capture module, one Watchdog Timer (WDT), one Self Wake-up Timer (WKT), one 16-bit auto-reload Timer3 for general purpose or baud rate generator, two UARTs with frame error detection and automatic address recognition, two ISO7816 Smartcard interface, two SPI, two I^2C, 12 enhanced PWM output channels with dead zone control, two analog comparators, eight-channel shared pin interrupt for all I/O ports, and one 12-bit ADC at 500 ksps. There are a total of 30 sources with 4-level-priority interrupts capability.

The ML51 is equipped with four clock sources and supports on-the-fly clock switching via software control. The four clock sources include two sets of external crystal inputs (HXT, LXT), 38.4 kHz internal oscillator, and one 24 MHz internal high-precision ±2% oscillator. The ML51 provides additional power monitoring detection such as power-on reset and 7-level brown-out detection, which stabilizes the power-on/off sequence for a high reliability system design.

The ML51 series provides 3 power modes to reduce power consumption —Low power run mode, Low power Idle mode, and Power-down mode. In Low power run mode, the power consumption can be down to 10 uA at 38.4 kHz LIRC. In Low power idle mode, CPU processing is suspended by holding the Program Counter. No program code is fetched and run in low power idle mode if the power consumption does not exceed 6 uA. Power-down mode stops the whole system clock for minimum power consumption with the leakage current less than 1 uA. The system clock of the ML51 can also be slowed down by software clock divider, which allows for flexibility between execution performance and power consumption.

Through the high performance of 1T 8051 core, low power performance of the ML51 and rich well-designed peripherals, the ML51 benefits for low-power, battery powered devices, general purpose, home appliances, or motor control system.

2 FEATURES

- **Operating Characteristics**
  - Wide supply voltage from 1.8 V to 5.5 V.
  - Wide operating frequency up to 24 MHz
  - Industrial temperature grade: -40 ℃ to +105 ℃.
- **CPU**
  - Fully static design 8-bit high performance 1T 8051-based CMOS microcontroller.
  - Instruction set fully compatible with MCS-51.
  - 4-priority-level interrupts capability.
  - Dual Data Pointers (DPTRs).
- **Low power features**
  - Normal run typical power consumption 80μA /MHz + 400 μA (HIRC) or 600μA (HXT)
  - Low power run mode typical power consumption 15 μA
  - Low power Idle mode power consumption does not exceed 13 μA
  - Power-down mode typical power consumption less than 1 μA
  - Wake up time from Power-down mode less than 10 μs (run with HIRC).
- **Memory**
  - Up to 64/32/16 Kbytes of APROM for User Code.
  - 4/3/2/1 Kbytes of Flash for loader (LDROM) configure from APROM for In-System-Programmable (ISP)
  - Flash Memory accumulated with pages of 128 Bytes from APROM by In-Application-Programmable (IAP).
  - Flash Memory 100,000 writing cycle endurance.
  - Code lock for security.
  - 256 Bytes on-chip RAM.
  - Additional 4/2/1 Kbytes on-chip auxiliary RAM (XRAM) accessed by MOVX instruction.
- **PDMA**
  - Three modes: peripheral-to-memory, memory-to-peripheral, and memory-to-memory transfer.
  - Source address and destination address must be word alignment in all modes.
  - Memory-to-memory mode: transfer length must be word alignment.
  - Peripheral-to-memory and memory-to-peripheral mode: transfer length could be byte alignment.
  - Peripheral-to-memory and memory-to-peripheral mode: transfer data width byte alignment.
- **Clock sources**
  - 24 MHz high-speed internal oscillator (HIRC) trimmed to ±1% (accuracy at 25 ℃, 5 V), ±2% in all conditions.
  - 38.4 kHz low-speed internal oscillator (LIRC) calibrating to ±1% by software from high-speed internal oscillator (HIRC) or external crystal (HXT).
  - External 4~24 MHz crystal (HXT) input for precise timing operation.
  - External 32.768 kHz (LXT) crystal input.
  - On-the-fly clock source switch via software.
  - Programmable system clock divider from 1/2, 1/4, 1/6, 1/8…, up to 1/512.
- **Peripherals**
  - Up to 43 general purpose I/O pins. All output pins have individual 2-level slew rate control.
  - 8 channels of GPIO interrupt with variable edge/level detection from all 43 GPIO configure as one of the input source.
  - Two 16-bit Timers/Counters 0 and 1 compatible with standard 8051.
  - One 16-bit Timer 2 with three-channel input capture module.
  - One 16-bit auto-reload Timer 3, which can be the baud rate clock source of UARTs.
  - One programmable Watchdog Timer (WDT) clocked by dedicated 38.4 kHz LIRC.
  - One dedicated Self Wake-up Timer (WKT) for self-timed wake-up for power reduced modes by dedicated 38.4 kHz LIRC or 32.768 kHz LXT.
  - Two full-duplex UART ports with frame error detection and automatic address recognition.
  - Two smart card port supports ISO7816-3 compliant T=0, T=1 and supports full-duplex UART mode .
  - Two SPI port with master and slave modes, up to 6 Mbps when system clock is 24 MHz
  - Two I^2C bus with master and slave modes, up to 400 kbps data rate.
  - 6 pairs, 12 channels of pulse width modulator (PWM) output, up to 16-bit resolution, with different modes and Fault Brake function for motor control. The 16-bit PWM counter individual used as timer with interrupt.

  - Two comparators support hysteresis function.
  - One 12-bit ADC, up to 500 ksps (When V_{DD} > 2.5 V), hardware triggered and conversion result compare facilitating motor control.
- **Power monitor**
  - Brown-out detection (BOD) with low power mode available, 7-level selection, interrupt or reset options.
  - Power-on reset (POR).
  - Low voltage reset (LVR).
- **Strong ESD and EFT immunity**
  - ESD HBM pass 8 kV
  - EFT ± 4.4 kV
  - Latch-up pass 150 mA
- **Development Tools**
  - Nuvoton Nu-Link with KEILTM and IAR development environment.
  - Nuvoton In-Circuit-Programmer (Nu-Link).
  - Nuvoton In-System-Programming (ISP) via UART.
- **96-bit Unique ID (UID)**
- **128-bit Unique Customer ID (UCID)**

3 BLOCK DIAGRAM

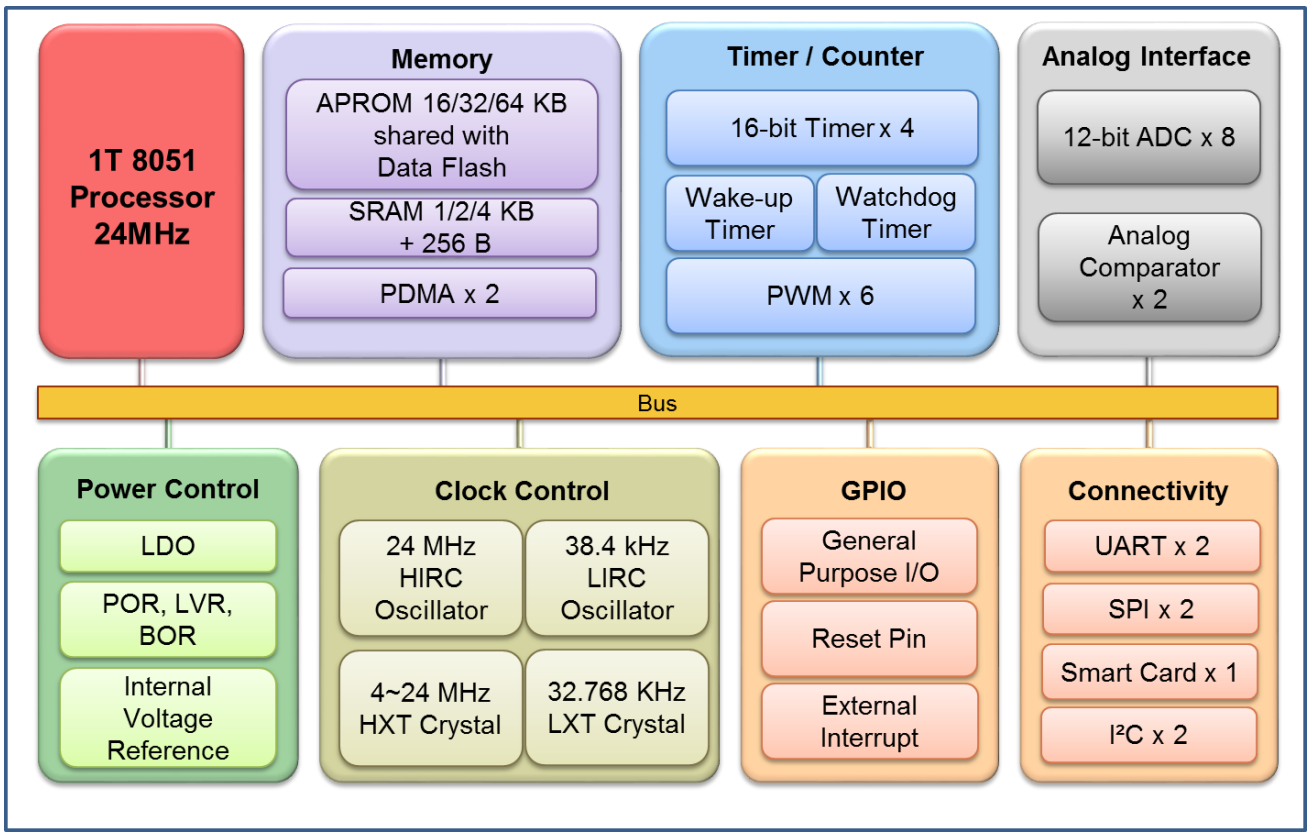


Figure 3-1 NuMicro® ML51 Block Diagram

4 PARTS INFORMATION

4.1 ML51 Series Naming Rule

ML	51	L	D	1	A	E
Core	**Line**	**Package**	**Flash**	**SRAM**	**Reserve**	**Temperature**
1T 8051	51: Base 54: LCD	B: MSOP10 (3x3 mm) D: TSSOP14 (4.4x5.0 mm) F: TSSOP20 (4.4x6.5 mm) E:TSSOP28 (4.4x9.7 mm) U: SOP28 (300 mil) O: SOP20 (300 mil) T: QFN33 (4x4 mm) P: LQFP32 (7x7 mm) L: LQFP48 (7x7 mm) S: LQFP64 (7x7 mm) K: LQFP128 (14x14 mm)	A: 8 KB B: 16 KB C: 32 KB D: 64 KB E: 128 KB G: 256 KB I: 512 KB	0: 2 KB 1: 4 KB 2: 8/12 KB 3: 16 KB 6: 32 KB 8: 64 KB 9: 1 KB A: 96 KB		E:-40°C ~ 105°C

4.2 ML51 Series Selection Guide

Part Number	Flash (KB)	SRAM (KB)	ISP ROM (KB)*	I/O	Timer/	PWM	Analog Comparator	Internal Voltage Reference	PDMA	Connectivity				ADC(12-Bit)	Package
										ISO-7816**	UART	SPI	I²C		
ML51BB9AE	16	1	4*	7	4	5	-	-	-	-	2	-	1	2-ch	MSOP10
ML51DB9AE	16	1	4*	11	4	6	-	-	-	1	2	1	2	3-ch	TSSOP14
ML51FB9AE	16	1	4*	16	4	6	-	-	-	1	2	1	2	6-ch	TSSOP20
ML51OB9AE	16	1	4*	16	4	6	-	-	-	1	2	1	2	6-ch	SOP20
ML51XB9AE	16	1	4*	17	4	6	-	-	-	1	2	1	2	6-ch	QFN20
ML51EB9AE	16	1	4*	24	4	6	-	-	-	1	2	1	2	8-ch	TSSOP28
ML51UB9AE	16	1	4*	24	4	6	-	-	-	1	2	1	2	8-ch	SOP28
ML51PB9AE	16	1	4*	28	4	6	2	Y	2	1	2	2	2	8-ch	LQFP32
ML51TB9AE	16	1	4*	28	4	6	2	Y	2	1	2	2	2	8-ch	QFN33
ML51EC0AE	32	2	4*	24	4	6	2	Y	2	1	2	2	2	8-ch	TSSOP28
ML51UC0AE	32	2	4*	24	4	6	2	Y	2	1	2	2	2	8-ch	SOP28
ML51PC0AE	32	2	4*	28	4	6	2	Y	2	1	2	2	2	8-ch	LQFP32
ML51TC0AE	32	2	4*	28	4	6	2	Y	2	1	2	2	2	8-ch	QFN33
ML51LC1AE	32	4	4*	/	4	12	2	Y	4	2	2	2	2	8-ch	LQFP48
ML51PD1AE	64	4	4*	/	4	12	2	Y	4	2	2	2	2	8-ch	LQFP32
ML51MD1AE	64	4	4*	/	4	12	2	Y	4	2	2	2	2	8-ch	LQFP44
ML51LD1AE	64	4	4*	/	4	12	2	Y	4	2	2	2	2	8-ch	LQFP48
ML51SD1AE	64	4	4*	/	4	12	2	Y	4	2	2	2	2	8-ch	LQFP64

* ISP ROM programmable 1K/2K/3K/4KB Flash for user program loader (LDROM) share from ARPOM.

** ISO-7816 configurable as UART2.

5 PIN CONFIGURATION

5.1 ML51 Series Pin Diagram

5.1.1 ML51 Series QFN33 Pin Diagram

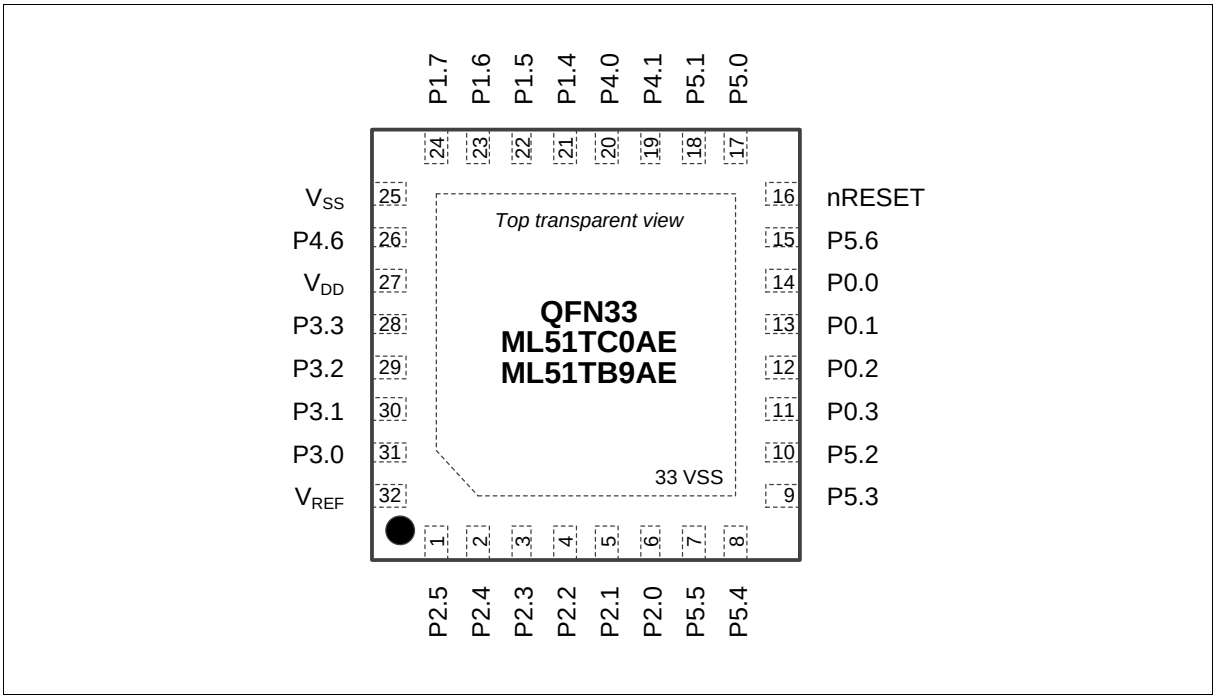


Figure 5-1 ML51 Series QFN33-pin Diagram

5.1.2 ML51 Series LQFP32 Pin Diagram

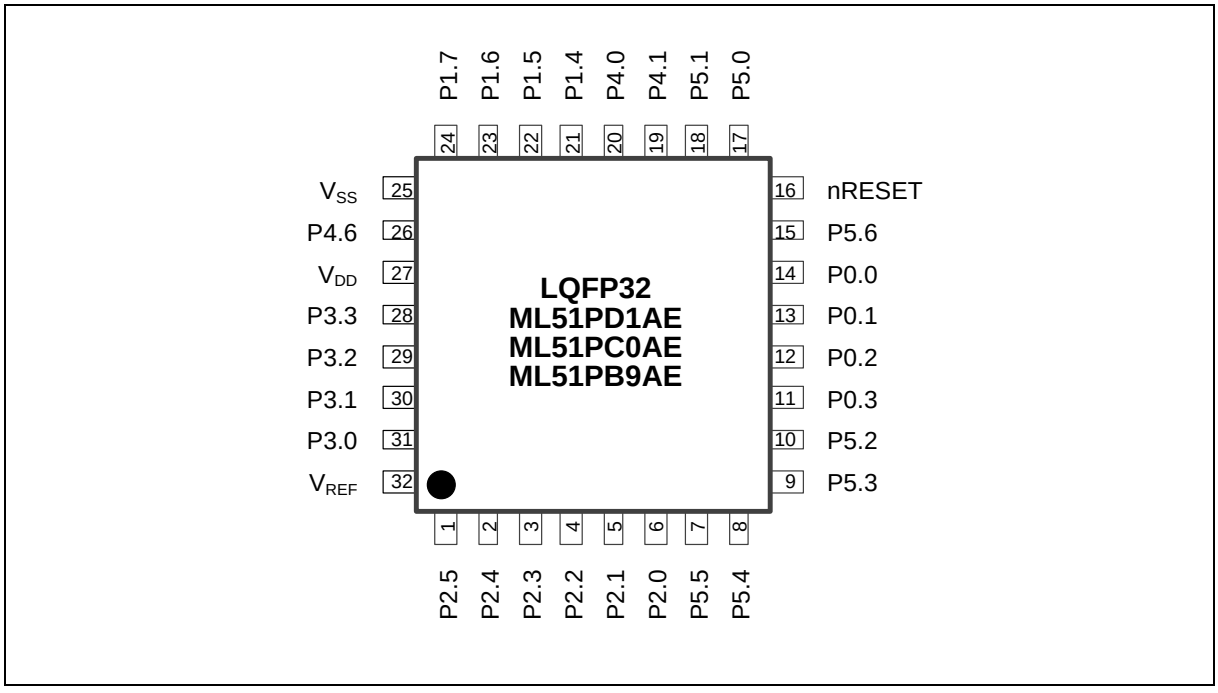


Figure 5-2 ML51 Series LQFP-32 -pin Diagram

5.1.3 ML51 Series TSSOP28 Pin Diagram

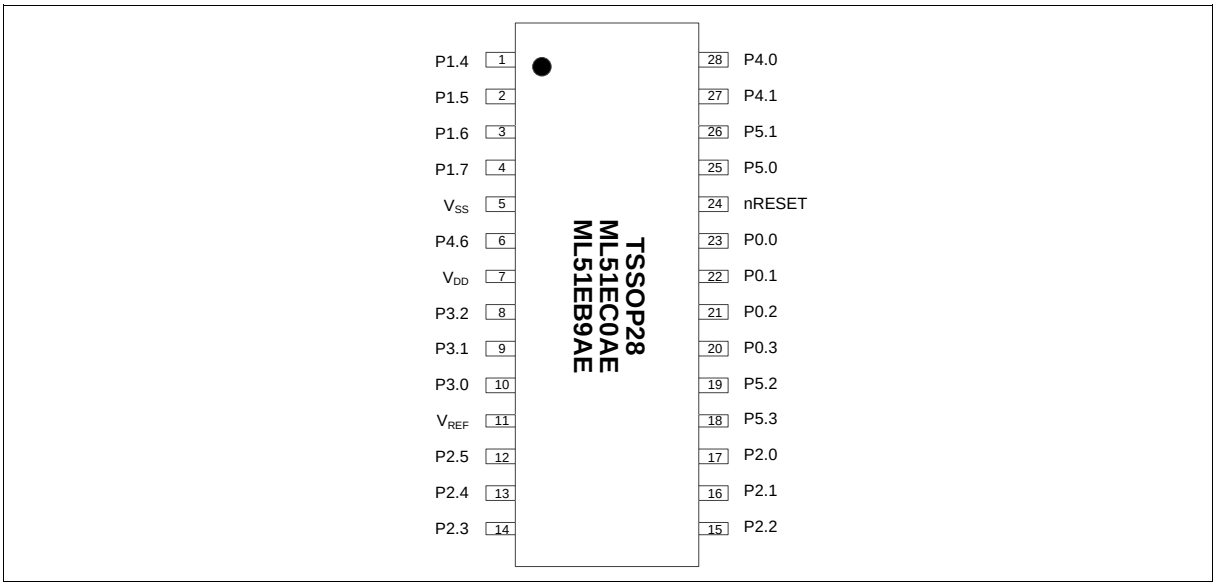


Figure 5-3 ML51 Series TSSOP-28-pin Diagram

5.1.4 ML51 Series SOP28 Pin Diagram

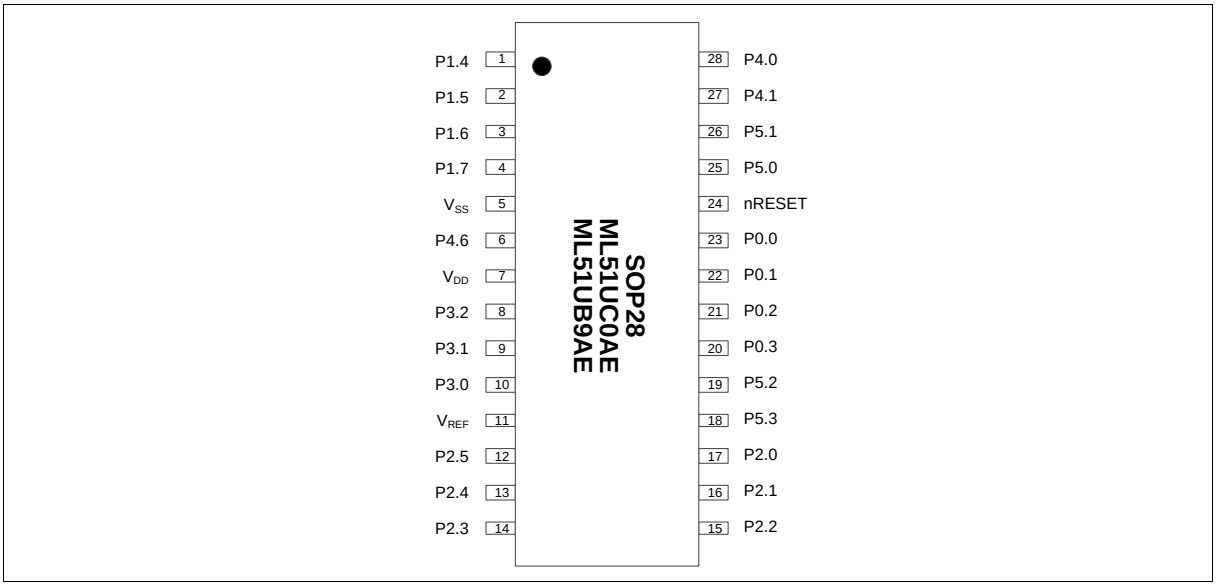


Figure 5-4 ML51 Series SOP-28-pin Diagram

5.1.5 ML51 Series TSSOP20 Pin Diagram

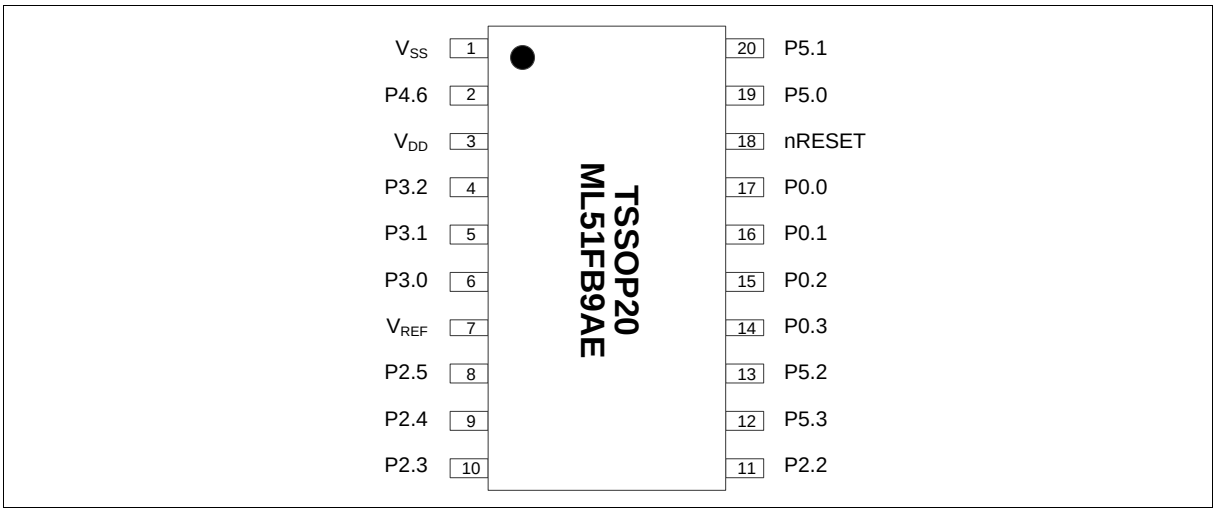


Figure 5-5 ML51 Series TSSOP-20-pin Diagram

5.1.6 ML51 Series SOP20 Pin Diagram

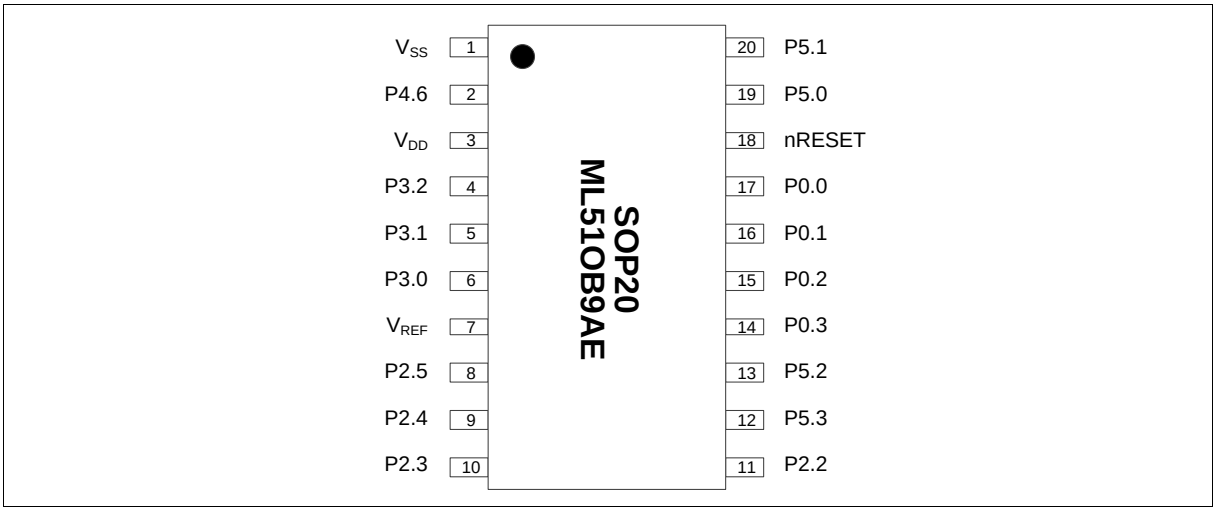


Figure 5-6 ML51 Series SOP-20-pin Diagram

5.1.7 ML51 Series QFN20 Pin Diagram

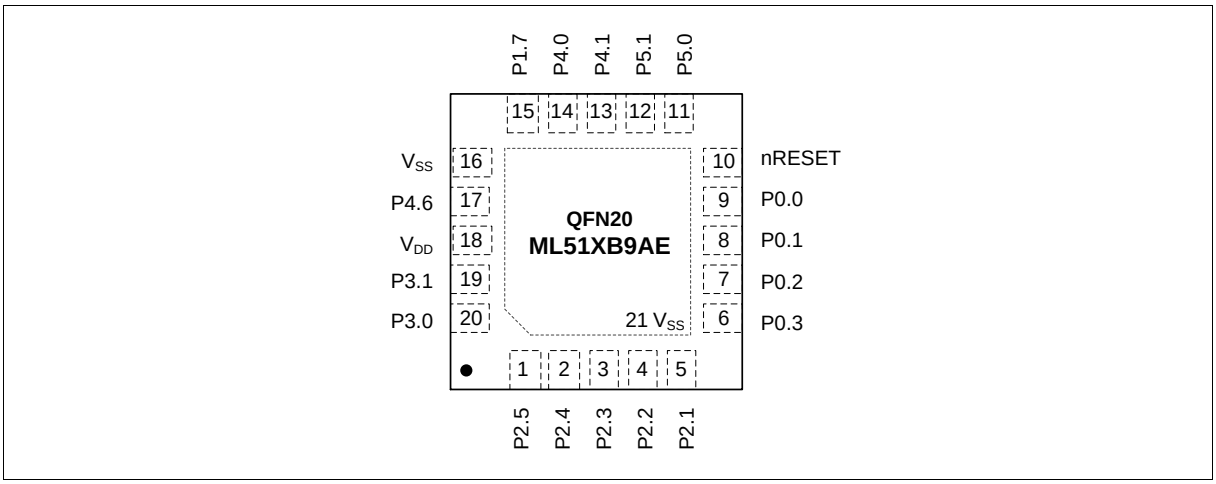


Figure 5-7 ML51 Series QFN-20-pin Diagram

5.1.8 ML51 Series TSSOP14 Pin Diagram

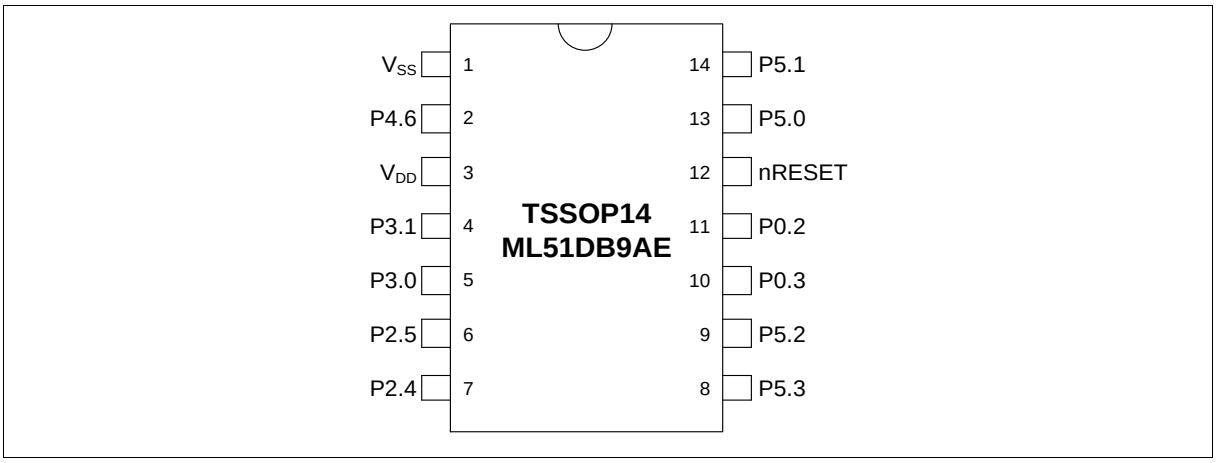


Figure 5-8 ML51 Series TSSOP-14-pin Diagram

5.1.9 ML51 Series MSOP10 Pin Diagram

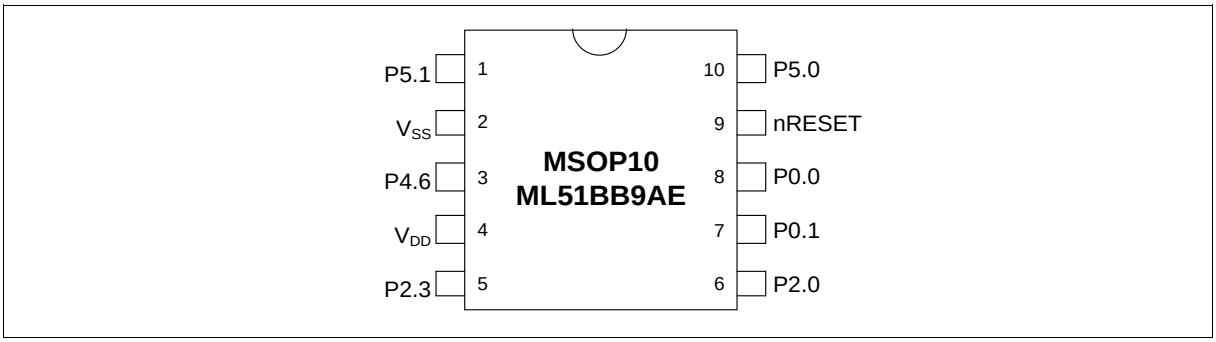


Figure 5-9 ML51 Series MSOP-10-pin Diagram

6 UTILITIES

6.1 Programmer and Debugger

Nu-Link	Basic full speed USB2.0 hardware debugger/programmer
Nu-Link-Pro	Advance hardware debugger/programmer with programming counter
Nu-Link 2.0	Advance high speed USB2.0 hardware debugger/programmer with multi-functions
Nu-Link-Gang	Off-line hardware programmer supports up to four chips programming for mass-production
ISP	In system programming, a software programming tool support UART/USB
ICP	In Chip Programming, a software programming tool support Nu-Link programmer

6.2 Development Environment

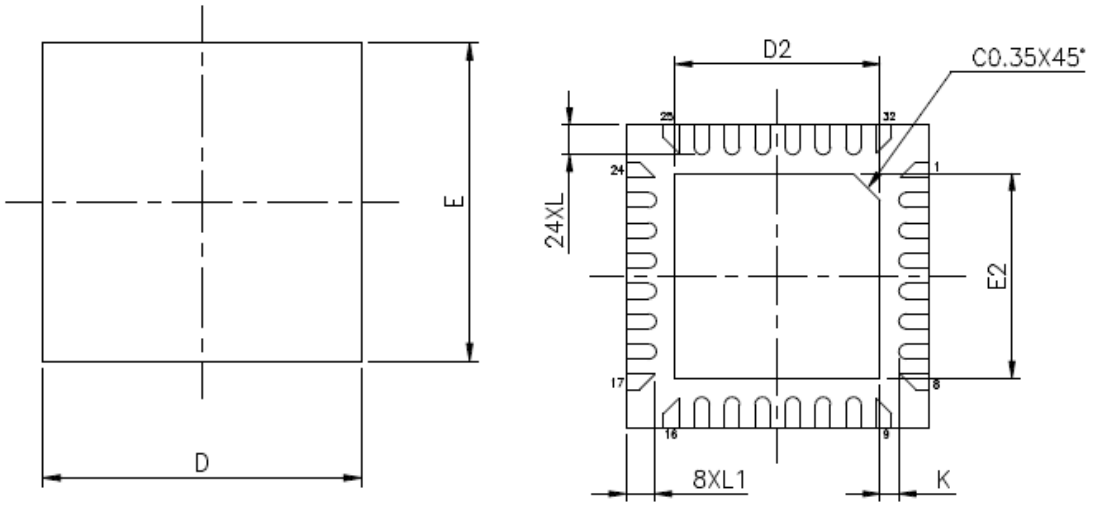
Programming IDE	Keil C-51, IAR EW8051
Software Package	Board Support Package(BSP), Sample Code,
Development IDE	NuTool Pin-View, NuTool-PinView, NuTool-ClockConfig, NuConsole
RTOS	Mbed
Programming IDE	Keil C-51, IAR EW8051

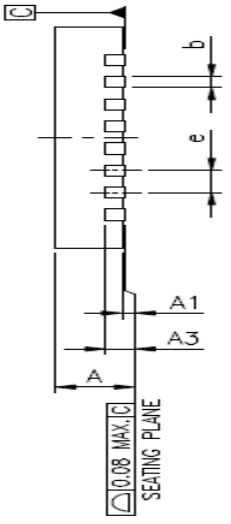
6.3 Development Board

EVB NuMaker	**Part Number**	**Feature**
NK-ML51PC	ML51PB9AE ML51TB9AE ML51EC0AE ML51UC0AE ML51PC0AE ML51TC0AE	Support Expand Connector, Arduino Uno Interface
NT-ML51EB	ML51BB9AE ML51DB9AE ML51FB9AE ML51OB9AE ML51XB9AE ML51EB9AE ML51UB9AE	

7 PACKAGE DIMENSIONS

7.1 QFN 33 (4x4x0.8 mm)

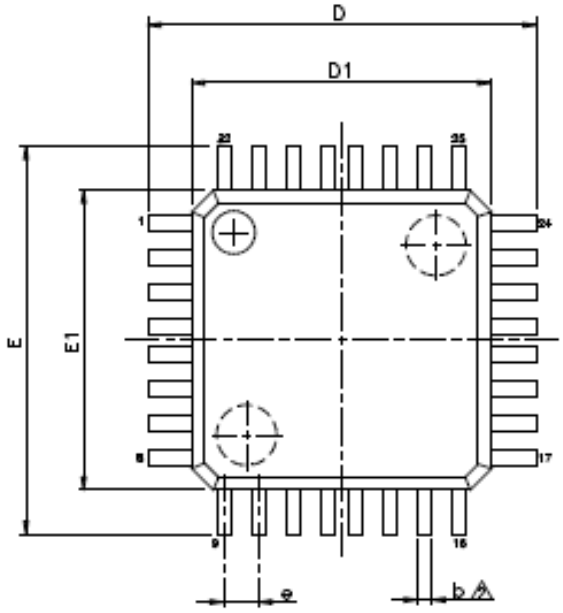


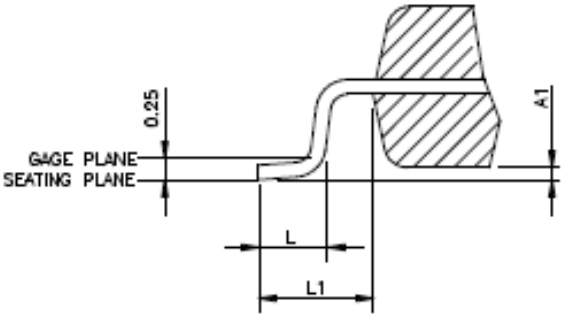


	Symbol	Min	Nom	Max
Total Thickness	A	0.7	0.75	0.8
Stand Off	A1	0.0	0.02	0.05
L/F Thickness	A3		0.2 REF.	
Lead Width	b	0.15	0.20	0.25
Body Size	D		4.00 BSC	
	E		4.00 BSC	
Lead Pitch	e		0.40 BSC	
Lead Length	L	0.35	0.4	0.45
	K	0.2	--	--

Symbol	L/F SIZE	Dimension in mm		
		MIN.	NOR.	MAX.
D2	114X114 mm	2.6	2.7	2.75
E2		2.6	2.7	2.75

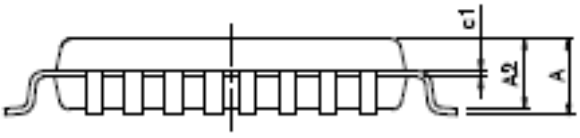
7.2 LQFP 32 (7x7x1.4 mm)



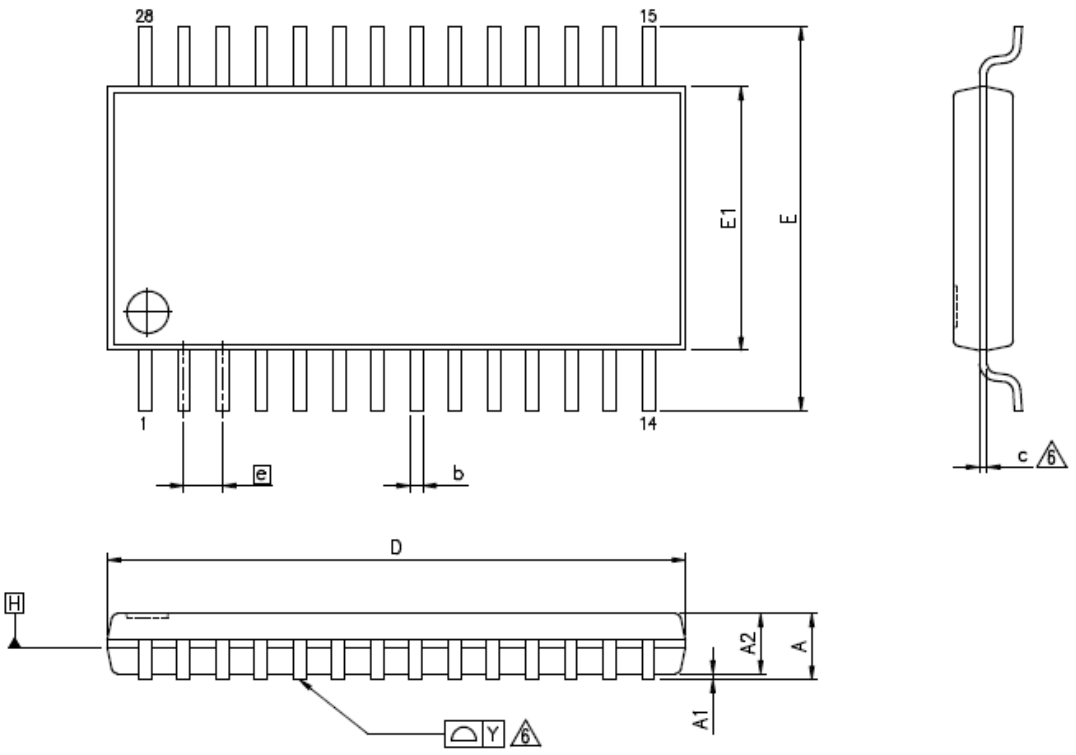


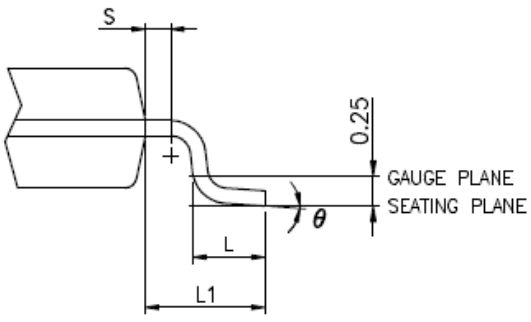
VARIATIONS (ALL DIMENSIONS SHOWN IN MM)

SYMBOLS	MIN.	MAX.
A	--	1.6
A1	0.05	0.15
A2	1.35	1.45
c1	0.09	0.16
D	9.00 BSC	
D1	7.00 BSC	
E	9.00 BSC	
E1	7.00 BSC	
e	0.8 BSC	
b	0.30	0.45
L	0.45	0.75
L1	1 REF	



7.3 TSSOP 28 (4.4x9.7x1.0 mm)

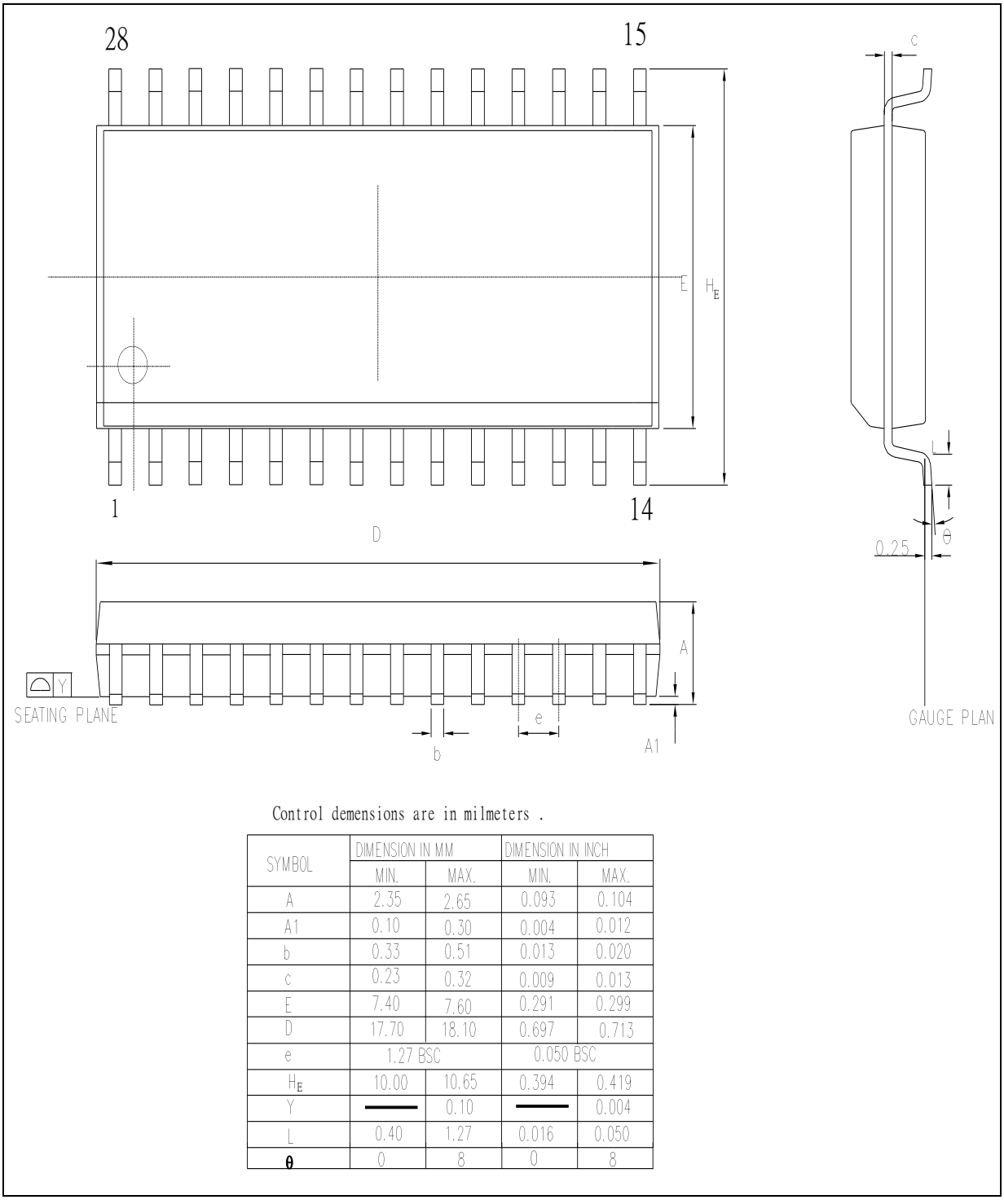




VARIATIONS (ALL DIMENSIONS SHOWN IN MM)

SYMBOLS	MIN.	NOM.	MAX.
A	–	–	1.20
A1	0.00	–	0.15
A2	0.80	1.00	1.05
b	0.19	–	0.30
c	0.09	–	0.20
D	9.60	9.70	9.80
E1	4.30	4.40	4.50
E	6.40 BSC		
e	0.65 BSC		
L1	1.00 REF		
L	0.45	0.60	0.75
S	0.20	–	–
θ	0°	–	8°
Y	0.10		

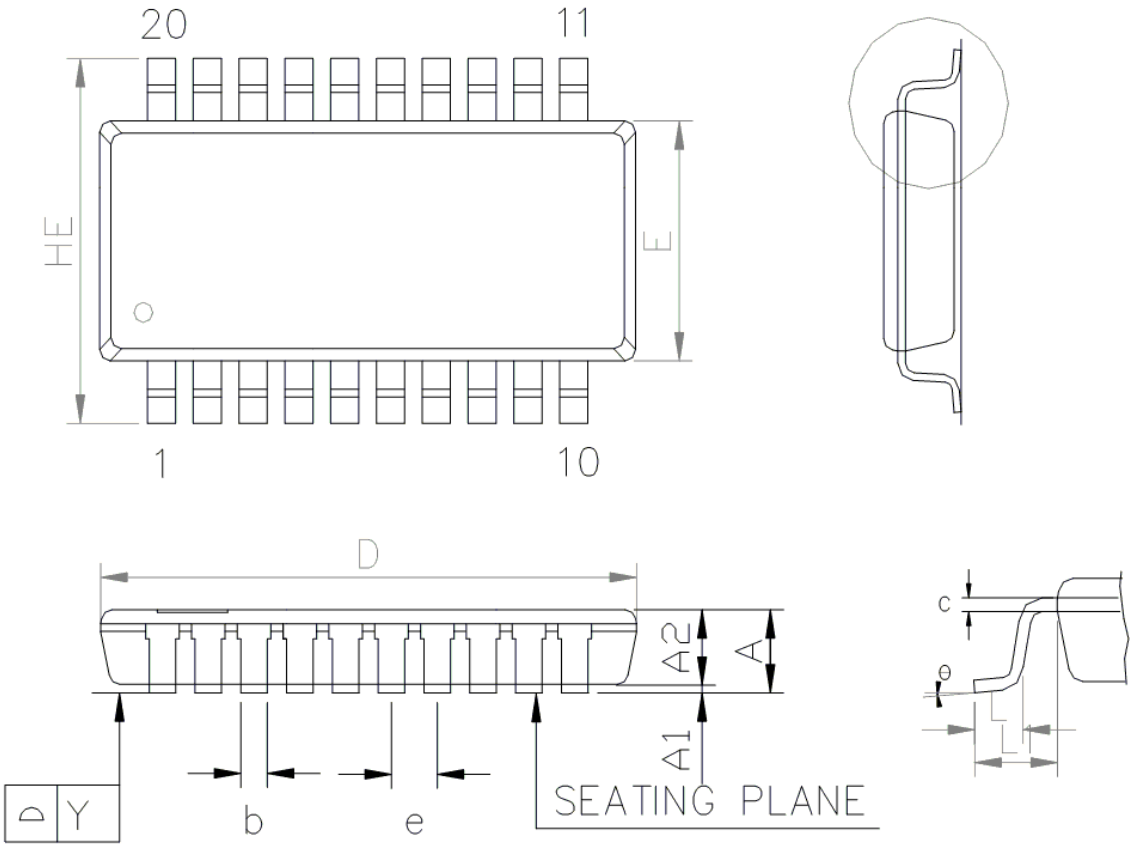
7.4 SOP 28 (300 mil)



Control demensions are in milmeters .

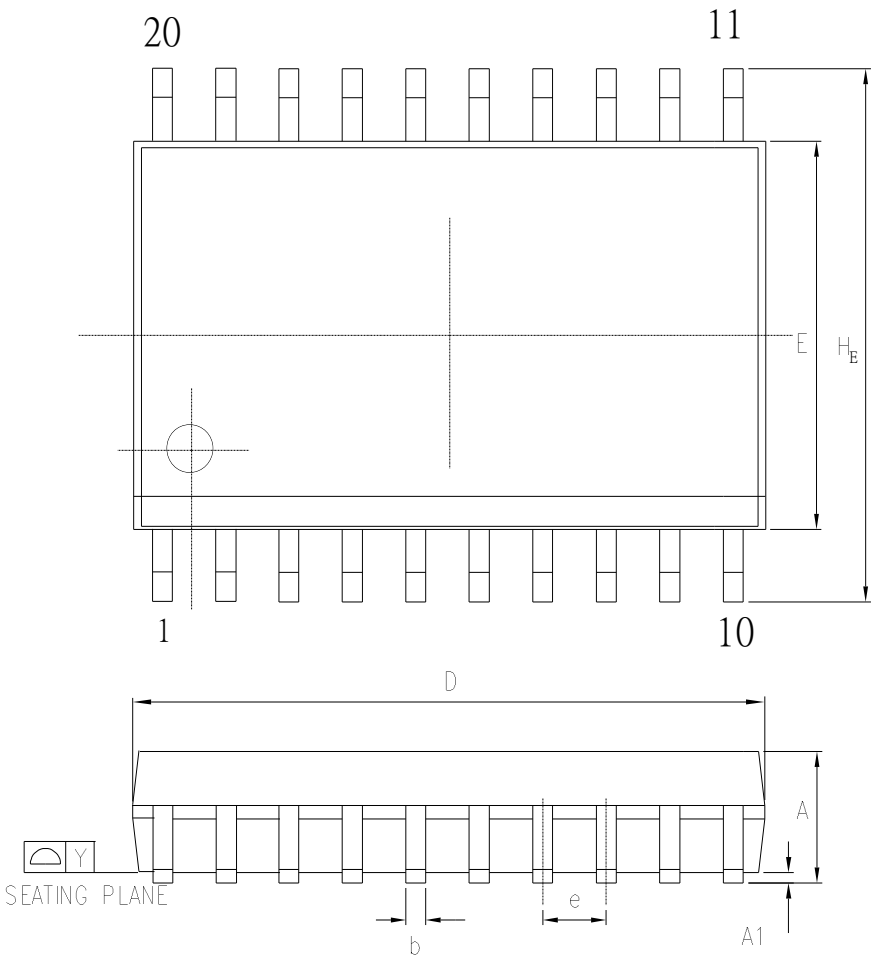
SYMBOL	DIMENSION IN MM		DIMENSION IN INCH	
	MIN.	MAX.	MIN.	MAX.
A	2.35	2.65	0.093	0.104
A1	0.10	0.30	0.004	0.012
b	0.33	0.51	0.013	0.020
c	0.23	0.32	0.009	0.013
E	7.40	7.60	0.291	0.299
D	17.70	18.10	0.697	0.713
e	1.27 BSC		0.050 BSC	
H_E	10.00	10.65	0.394	0.419
Y	—	0.10	—	0.004
L	0.40	1.27	0.016	0.050
θ	0	8	0	8

7.5 TSSOP 20 (4.4X6.5 mm)



SYMBOL	DIMENSION (MM)			DIMENSION (INCH)		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	-	-	1,20	-	-	0.047
A1	0,05	-	0,15	0.002	-	0.006
A2	0.80	0.90	1,05	0.031	0.035	0.041
E	4.30	4.40	4.50	0.169	0.173	0.177
HE	6.40 BSC			0.252 BSC		
D	6.40	6.50	6.60	0.252	0.256	0.260
L	0.50	0.60	0.75	0.020	0.024	0.030
L1	1.00 REF			0.039 REF		
b	0.19	-	0.30	0.007	-	0.012
e	0.65 BSC			0.026 BSC		
c	0.09	-	0.20	0.004	-	0.008
θ	0°	-	8°	0°	-	8°
Y	0.10 BASIC			0.004 BASIC		

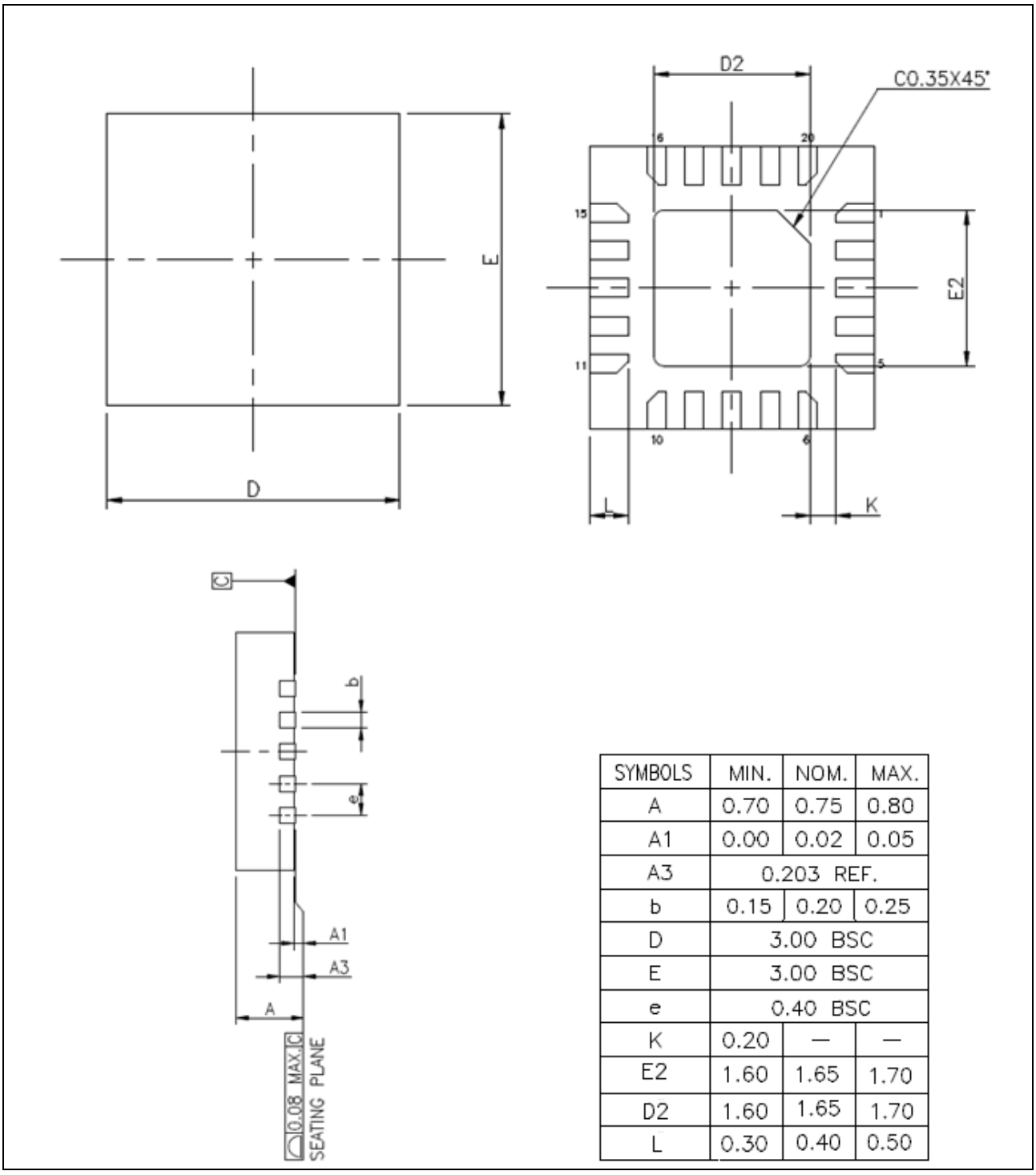
7.6 SOP 20 (300 mil)



Control demensions are in milmeters .

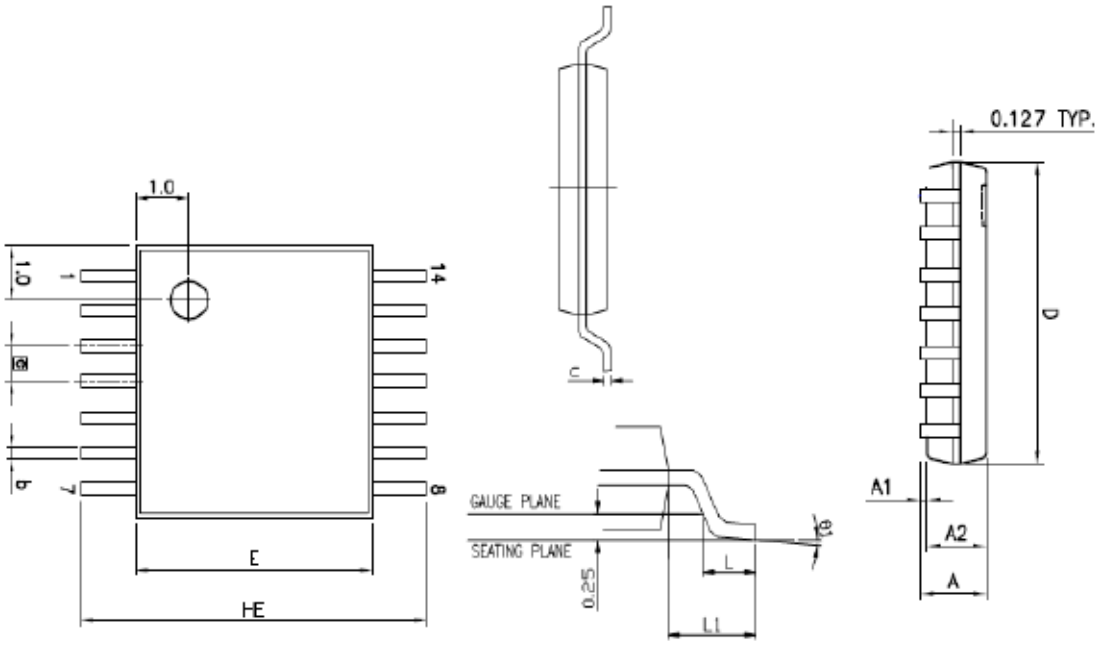
SYMBOL	DIMENSION IN MM		DIMENSION IN INCH	
	MIN.	MAX.	MIN.	MAX.
A	2.35	2.65	0.093	0.104
A1	0.10	0.30	0.004	0.012
b	0.33	0.51	0.013	0.020
c	0.23	0.32	0.009	0.013
E	7.40	7.60	0.291	0.299
D	12.60	13.00	0.496	0.512
e	1.27 BSC		0.050 BSC	
H_E	10.00	10.65	0.394	0.419
Y	—	0.10	—	0.004
L	0.40	1.27	0.016	0.050
θ	0	8	0	8

7.7 QFN 20 (3.0 X 3.0 mm)



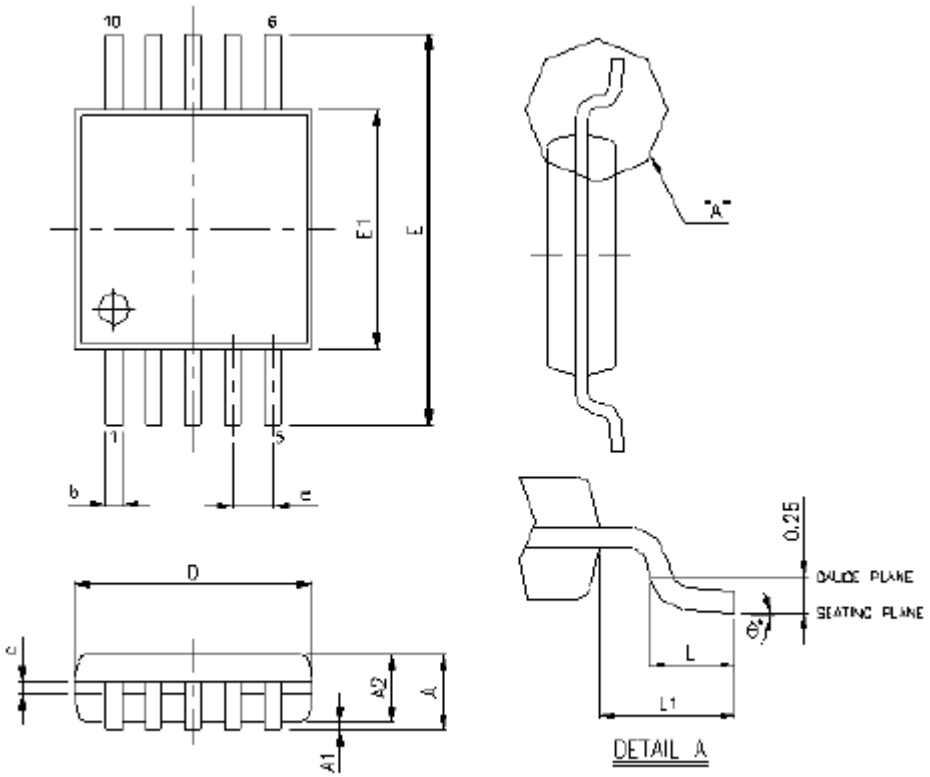
SYMBOLS	MIN.	NOM.	MAX.
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
A3		0.203 REF.	
b	0.15	0.20	0.25
D		3.00 BSC	
E		3.00 BSC	
e		0.40 BSC	
K	0.20	—	—
E2	1.60	1.65	1.70
D2	1.60	1.65	1.70
L	0.30	0.40	0.50

7.8 TSSOP 14 (4.4 X 5.0 mm)



CONTROLLING DIMENSION: MILLMETERS						
SYMBOL	DIMENSION IN MM			DIMENSION IN INCH		
	MIN.	NOM	MAX.	MIN.	NOM	MAX.
A	---	---	1.20	---	---	0.043
A1	0.05	---	0.15	0.02	---	0.006
A2	0.80	0.90	1.05	0.031	0.035	0.041
L	0.50	0.60	0.75	0.020	0.024	0.030
HE	6.40 BSC.			0.252 BSC.		
E	4.30	4.40	4.50	0.169	0.173	0.177
D	4.90	5.00	5.10	0.193	0.197	0.201
b	0.19	---	0.30	0.007	---	0.012
c	0.09	---	0.20	0.004	---	0.008
L1	1.0 REF.			0.039 REF.		
e	0.65 BSC.			0.026 BSC.		
θ1	0	---	8	0	---	8

7.9 MSOP 10 (3 x 3 mm)



SYMBOLS	MIN.	NOM.	MAX.
A	–	–	1.10
A1	0.00	–	0.15
A2	0.75	0.85	0.95
b	0.17	–	0.27
c	0.08	–	0.23
D	3.00 BSC		
E	4.90 BSC		
E1	3.00 BSC		
e	0.50 BSC		
L	0.40	0.60	0.80
L1	0.95 REF		
θ°	0	–	8

UNIT : MM

8 REVISION HISTORY

Date	Revision	Description
2019.01.05	1.00	Initial version.

Important Notice

Nuvoton Products are neither intended nor warranted for usage in systems or equipment, any malfunction or failure of which may cause loss of human life, bodily injury or severe property damage. Such applications are deemed, "Insecure Usage".

Insecure usage includes, but is not limited to: equipment for surgical implementation, atomic energy control instruments, airplane or spaceship instruments, the control or operation of dynamic, brake or safety systems designed for vehicular use, traffic signal instruments, all types of safety devices, and other applications intended to support or sustain life.

All Insecure Usage shall be made at customer's risk, and in the event that third parties lay claims to Nuvoton as a result of customer's Insecure Usage, customer shall indemnify the damages and liabilities thus incurred by Nuvoton.