User's Guide

DX81C01 DX81C02
DX81C04 DX81C08
DX81C16 DX81C32
DX81C64 DX81C128
DX81C256

I2C/SPI Serial
Security EEPROM
With SHA1
Anti-Clone Authentication

Revision 2.3

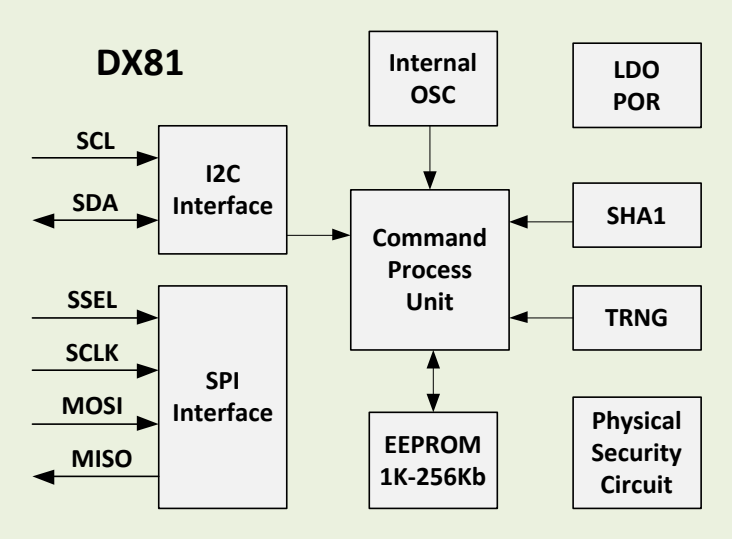
Features

- A family of 9 devices with Security User EEPROM Memory from 1Kbits to 256Kbits
  --- DX81C01: 1Kbits DX81C02: 2Kbits
  --- DX81C04: 4Kbits DX81C08: 8Kbits
  --- DX81C16: 16Kbits DX81C32: 32Kbits
  --- DX81C64: 64Kbits DX81C128: 128Kbits
  --- DX81C256: 256Kbits
- Secure authentication and validation device
- I2C Interface
  --- 1.0 MHz Compatibility for Fast Operation
  --- Same Pinout as 2-wire (24 Series) Serial EEPROM's
- SPI Interface
  --- Compatibility for SPI Standard Protocol (Mode0 and 3)
  --- Max Speed up to 10MHz
  --- Same Pinout as 4-wire (25 Series) EEPROM's
- Configuration Memory
  --- Guaranteed Unique 64bits Serial Number in wafer manufacture
  --- 7-bytes OTP Area for User definable ID
  --- 64 bits User PIN authentication for memory configured
- EEPROM User Memory
  --- Divided into 4 -- 16 User Zones
  --- Read only mode can be individually set for each zone
  --- PGO (program only) mode can be individually set for each zone
  --- Programmable Access Mode for each zone read/write
    Normal mode
    Authentication mode
    Encryption mode
  --- 4 -- 16 individual 128 bits length Keys for each zone
  --- Individual bi-directional authentication for accessing each zone
  --- Single-Byte, Multiple-Byte or Page-Write Modes
  --- Self-timed Write Cycles
- Host Anti-Clone Authentication
  --- Superior SHA1 Hash Algorithm with MAC and HMAC options
  --- 128 bits Key length for authentication
  --- Each time random response even for the same challenge
- High security features in hardware
  --- Stream Encryption and CRC checking for Data transmission on Data Line
    Avoid capturing the real data on Data Line
  --- EEPROM Physical address Scramble with SN involved
  --- EEPROM Physical Data Encryption with SN involved
  Storing the same data in each device has different physical address and data.

Prevent EEPROM Data from physically copying between devices.
--- Internal and High-quality True Random Number Generator
--- Internal POR and High-accuracy Oscillator
--- Voltage Monitor

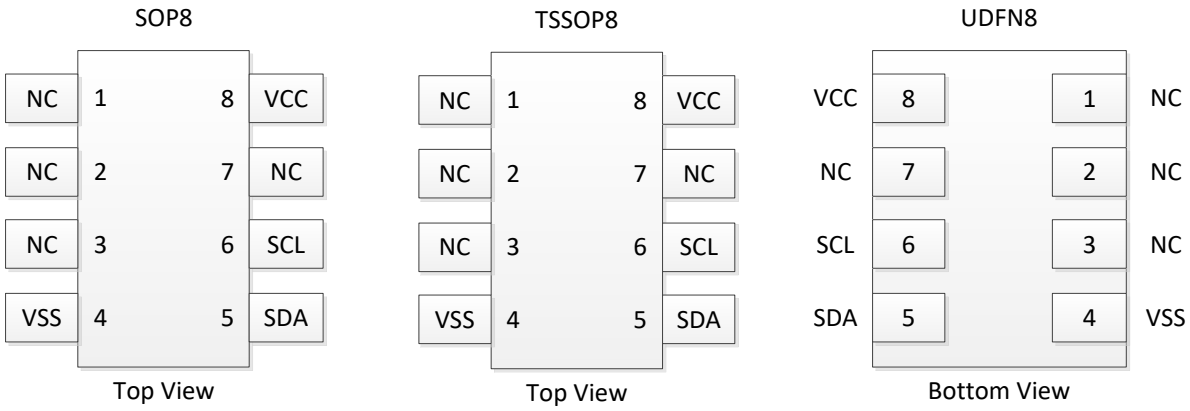
- High reliability
  --- Endurance: >1M Cycles
  --- Data Retention: >10 years
  --- ESD Protection: >4KV
- Operating Voltage: 2.0V—5.5V
- Temperature: -40^{0}C --- +85^{0}C
- < 2uA Sleep current
- Package: SOP8, TSSOP8, UDFN8, SOT23-5, SOT23-6
- Development Kits
  --- Evaluation Board Kits
  --- Customized Library and SDK for Android and iOS
  --- Secure Personalization device and software
- Applications
  --- Anti-Clone protection for accessories, peripherals and consumables
  --- Electronic device management of OEM/Post-sale Service/Authorization
  --- Secure parameter/data storing
  --- User Password Checking
  --- Software anti-piracy
  --- PCB ID and Authentication
  --- Print-Cartridge ID
  --- Medical Consumable ID
  --- STB, GPS, web camera system

Diagram

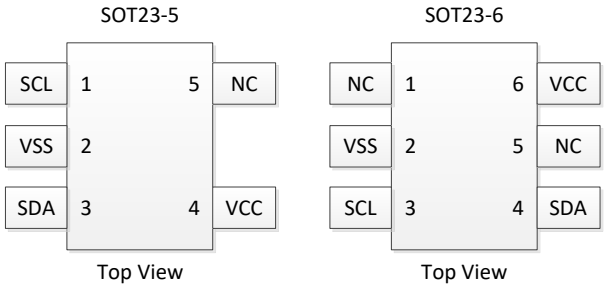


Package and PINs

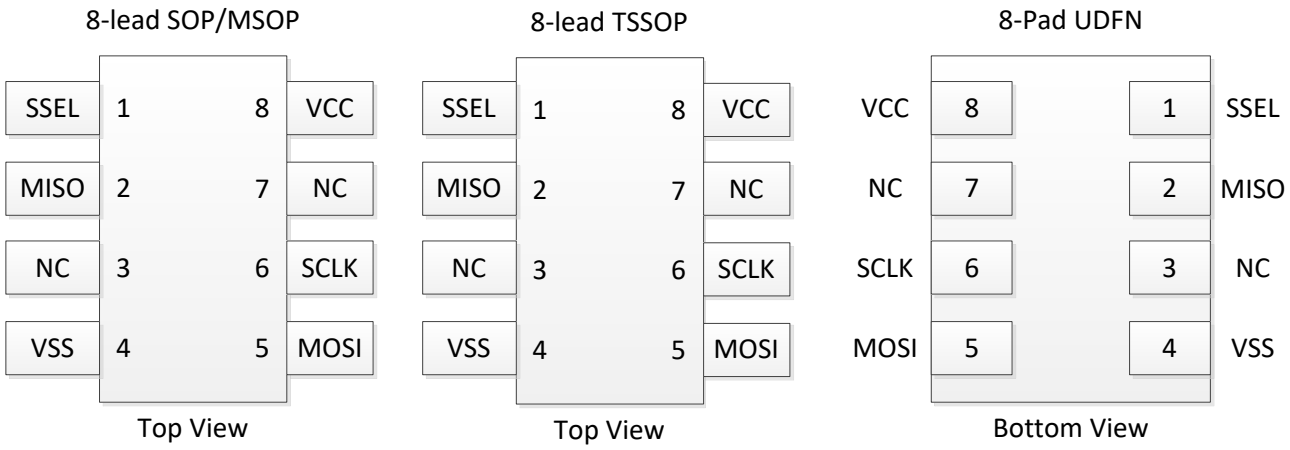
I2C Interface



Signal	IO	Description
VCC	I	Power supply 2.0V – 5.5V
VSS	G	Ground
SCL	I	I2C Interface Clock Line
SDA	I/O	I2C Interface Data Line



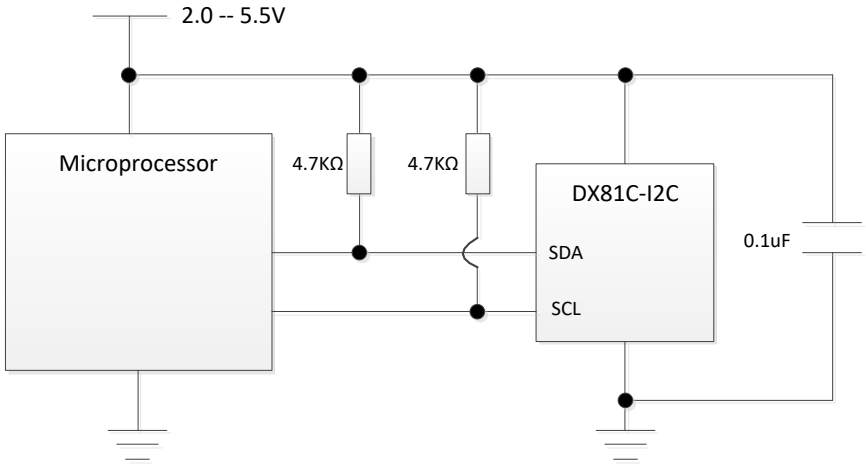
SPI Interface

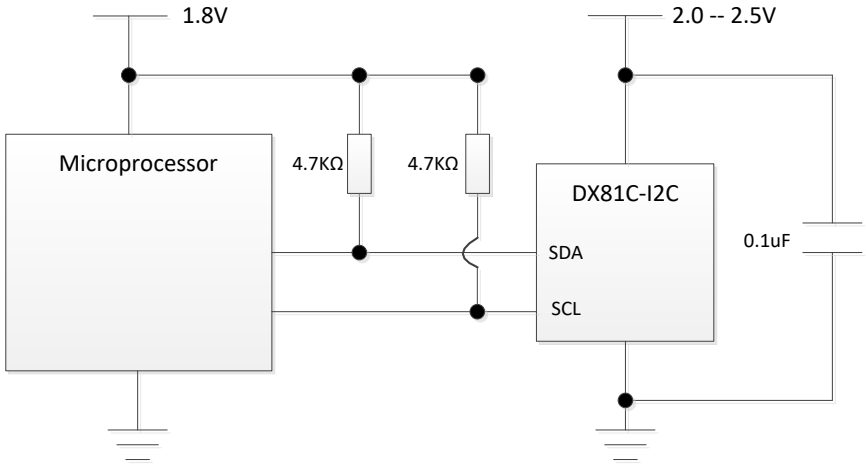


Signal	IO	Description
VCC	I	Power supply 2.0V – 5.5V
VSS	G	Ground
SSEL	I	Chip Select, Active Low
SCLK	I	SPI Clock Line
MOSI	I	Input data Line
MISO	O	Output data Line

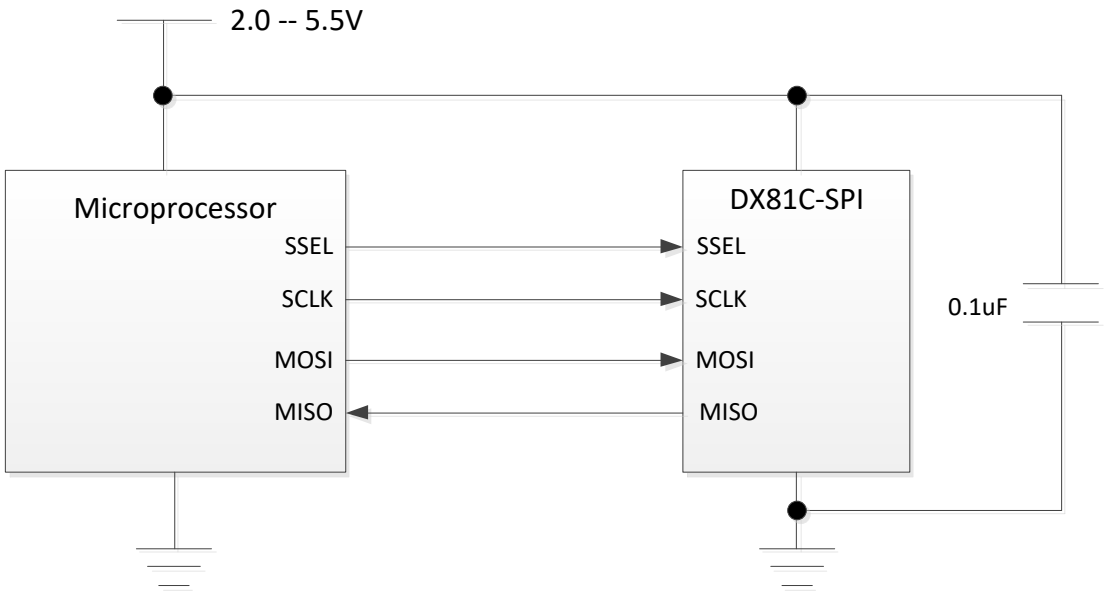
Typical Operation Circuit

I2C Interface





SPI Interface



Order Information

Part	EEPROM	User Zones	Zone Size	Interface	Package Type
DX81C01-C	1K bits	4	32 Bytes	I2C	SOP8/TSSOP8/UDFN8/SOT23-5/SOT23-6
DX81C01-S				SPI	SOP8/TSSOP8/UDFN8
DX81C02-C	2K bits	4	64 Bytes	I2C	SOP8/TSSOP8/UDFN8/SOT23-5/SOT23-6
DX81C02-S				SPI	SOP8/TSSOP8/UDFN8
DX81C04-C	4K bits	4	128 Bytes	I2C	SOP8/TSSOP8/UDFN8/SOT23-5/SOT23-6
DX81C04-S				SPI	SOP8/TSSOP8/UDFN8
DX81C08-C	8K bits	8	128 Bytes	I2C	SOP8/TSSOP8/UDFN8
DX81C08-S				SPI	SOP8/TSSOP8/UDFN8
DX81C16-C	16K bits	16	128 Bytes	I2C	SOP8/TSSOP8/UDFN8
DX81C16-S				SPI	SOP8/TSSOP8/UDFN8
DX81C32-C	32K bits	16	256 Bytes	I2C	SOP8/TSSOP8/UDFN8
DX81C32-S				SPI	SOP8/TSSOP8/UDFN8
DX81C64-C	64K bits	16	512 Bytes	I2C	SOP8/TSSOP8/UDFN8
DX81C64-S				SPI	SOP8/TSSOP8/UDFN8
DX81C128-C	128K bits	16	1K Bytes	I2C	SOP8/TSSOP8/UDFN8
DX81C128-S				SPI	SOP8/TSSOP8/UDFN8
DX81C256-C	256K bits	16	2K Bytes	I2C	SOP8/TSSOP8/UDFN8
DX81C256-S				SPI	SOP8/TSSOP8/UDFN8

Introduction

DX81 family is a secure EEPROM memory with high-security hardware authentication devices. It has a simple and flexible command set that allows use for many applications. DX81 family devices mainly have the following functions:

- **Host anti-clone authentication**
  Validate that a removable, replaceable, or consumable Client is authentic. Example Clients could be printer ink tanks, electronic daughter cards, or other spare parts. It can also be used to validate a software/firmware module or memory storage element.
- **Password checking and verify authentication**
  Validate user entered passwords without letting the expected value become known, authenticate the access privilege for security memory.
- **Secure User EEPROM memory**
  Device can store small quantities of data necessary for configuration, calibration, sensitive value, consumption data, or other secrets. It has programmable protection through encrypted/authenticated mode to read and write. Also you can permanently lock data prevented from modification.

All DX81 family devices include an EEPROM array that can be used for storage keys, miscellaneous read/write, read-only or secret data, consumption logging and security configuration. Access to the various zones of memory can be restricted in a programmable security accessing mode and the configuration then locked or prevented changes. Access to the device is through a standard I2C interface at speeds up to 1Mbps or SPI interface speeds up to 10Mbps, compatible with I2C/SPI interface specifications.

Each DX81 device ships with a guaranteed unique 8-bytes serial number, additional 7-bytes User ID can be set for the third party. Using the cryptographic protocols supported by the device, a Host system or remote server can prove that the SN and UID are both authentic and is not a copy. The unique ROM SN and User defined UID are used as a fundamental input parameter for cryptographic operations. Also each DX81 device ships with an initial PIN code, which can be used for DX81 configuration. Only the PIN authenticated, then you can personalize the DX81 device.

DX81 family devices can generate high-quality random numbers and employ them for any purpose, including as part of the crypto protocols of this device. And there are 128 bits key length KEYA for host anti-clone authentication and 4-16 Zone Keys for user memory accessing authentication or user password checking.

DX81 combines crypto-strong bidirectional secure challenge-and-responses authentication functional with an implementation using the industry-standard SHA-1 secure hash algorithm. A bidirectional security model enables tow-way authentication between a host system and slave-embedded DX81. Slave-to-host authentication is used by a host system to securely validate that attached or embedded DX81 is authentic. Host-to-slave authentication is used to protect DX81

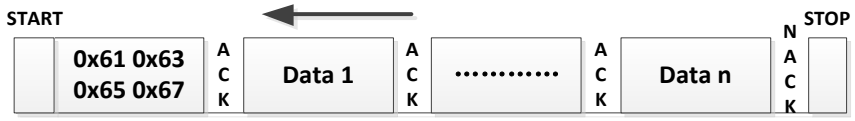
user memory from being modified by a non-authentic host.

Device Interface Protocol

I2C Command Format

I2C RESET

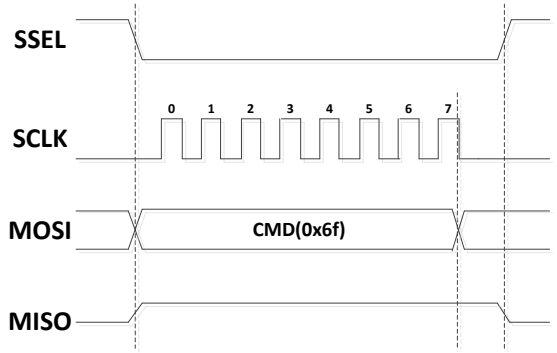
I2C_READ



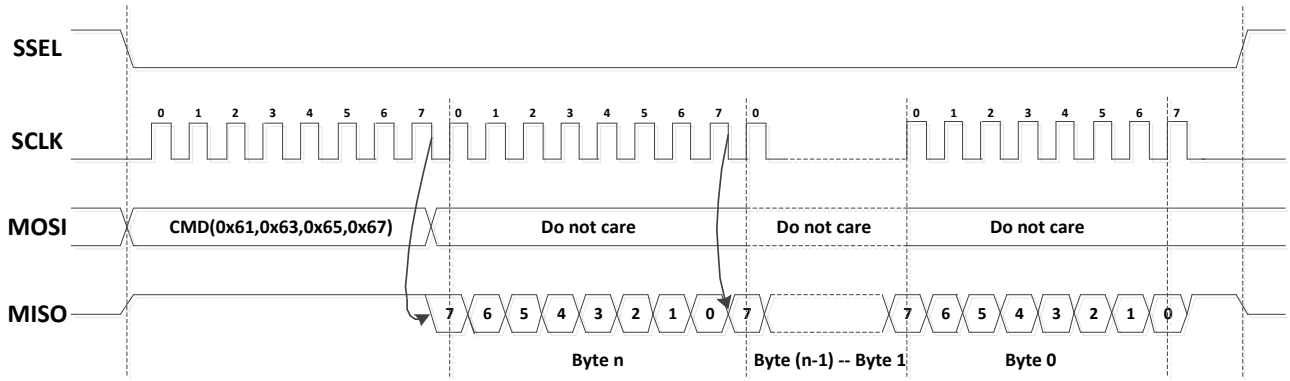
I2C_WRITE

SPI Command Format

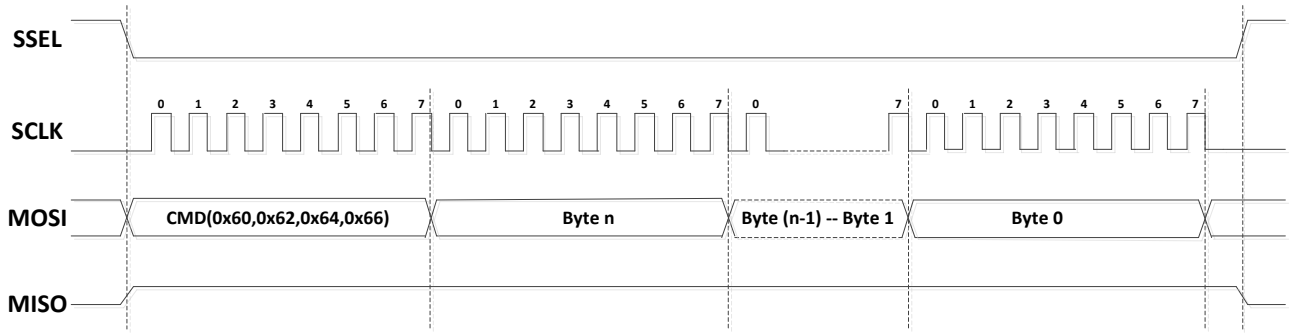
SPI_RESET



SPI_READ



SPI_WRITE



Device Memory

User Memory (DX81C01/02/04)

Address	DX81C01 (1K bits)	DX81C02 (2K bits)	DX81C04 (4K bits)
0x000—0x01f	Zone 0 (32 B)	Zone 0 (64 B)	Zone 0 (128 B)
0x020—0x03f	Zone 1 (32 B)		
0x040---0x05f	Zone 2 (32 B)	Zone 1 (64 B)	
0x060---0x07f	Zone 3 (32 B)		
0x080—0x09f	RSV	Zone 2 (64 B)	Zone 1 (128 B)
0x0a0—0x0bf			
0x0c0—0x0df		Zone 3 (64 B)	
0x0e0—0x0ff			
0x100—0x11f		RSV	Zone 2 (128 B)
0x120—0x13f			
0x140---0x15f			
0x160---0x17f			
0x180---0x19f			Zone 3 (128 B)
0x1a0---0x1bf			
0x1c0---0x1df			
0x1e0---0x1ff			

Page Size: 16 bytes

User Memory (DX81C08/16/32/64)

<table>
<tr><th>Address</th><th>DX81C08
(8K bits)</th><th>DX81C16
(16K bits)</th><th>DX81C32
(32K bits)</th><th>DX81C64
(64K bits)</th></tr>
<tr><td>0x000-0x07f</td><td>Zone 0 (128 B)</td><td>Zone 0 (128 B)</td><td rowspan="2">Zone 0 (256 B)</td><td rowspan="4">Zone 0(512B)</td></tr>
<tr><td>0x080-0x0ff</td><td>Zone 1 (128 B)</td><td>Zone 1 (128 B)</td></tr>
<tr><td>0x100-0x17f</td><td>Zone 2 (128 B)</td><td>Zone 2 (128 B)</td><td rowspan="2">Zone 1 (256 B)</td></tr>
<tr><td>0x180-0x1ff</td><td>Zone 3 (128 B)</td><td>Zone 3 (128 B)</td></tr>
<tr><td>0x200-0x27f</td><td>Zone 4 (128 B)</td><td>Zone 4 (128 B)</td><td rowspan="2">Zone 2 (256 B)</td><td rowspan="4">Zone 1(512B)</td></tr>
<tr><td>0x280-0x2ff</td><td>Zone 5 (128 B)</td><td>Zone 5 (128 B)</td></tr>
<tr><td>0x300-0x37f</td><td>Zone 6 (128 B)</td><td>Zone 6 (128 B)</td><td rowspan="2">Zone 3 (256 B)</td></tr>
<tr><td>0x380-0x3ff</td><td>Zone 7 (128 B)</td><td>Zone 7 (128 B)</td></tr>
<tr><td>0x400-0x47f</td><td rowspan="24">RSV</td><td>Zone 8 (128 B)</td><td rowspan="2">Zone 4 (256 B)</td><td rowspan="4">Zone 2(512B)</td></tr>
<tr><td>0x480-0x4ff</td><td>Zone 9 (128 B)</td></tr>
<tr><td>0x500-0x57f</td><td>Zone 10 (128 B)</td><td rowspan="2">Zone 5 (256 B)</td></tr>
<tr><td>0x580-0x5ff</td><td>Zone 11 (128 B)</td></tr>
<tr><td>0x600-0x67f</td><td>Zone 12 (128 B)</td><td rowspan="2">Zone 6 (256 B)</td><td rowspan="4">Zone 3(512B)</td></tr>
<tr><td>0x680-0x6ff</td><td>Zone 13 (128 B)</td></tr>
<tr><td>0x700-0x77f</td><td>Zone 14 (128 B)</td><td rowspan="2">Zone 7 (256 B)</td></tr>
<tr><td>0x780-0x7ff</td><td>Zone 15 (128 B)</td></tr>
<tr><td>-----</td><td rowspan="16">RSV</td><td>------</td><td rowspan="2">--------</td></tr>
<tr><td>-----</td><td>-------</td></tr>
<tr><td>-----</td><td rowspan="8">RSV</td><td rowspan="2">Zone 14 (256 B)</td><td rowspan="4">Zone 7(512B)</td></tr>
<tr><td>-----</td></tr>
<tr><td>0xe00-0xe7f</td><td rowspan="2">Zone 15 (256 B)</td></tr>
<tr><td>0xe80-0xeff</td></tr>
<tr><td>0xf00-0xf7f</td><td rowspan="8">RSV</td><td rowspan="4">--------</td></tr>
<tr><td>0xf80-0xfff</td></tr>
<tr><td>-----</td></tr>
<tr><td>-----</td></tr>
<tr><td>-----</td><td rowspan="4">Zone 15(512B)</td></tr>
<tr><td>-----</td></tr>
<tr><td>0x1e00-0x1e7f</td></tr>
<tr><td>0x1e80-0x1eff</td></tr>
<tr><td>0x1f00-0x1f7f</td></tr>
<tr><td>0x1f80-0x1fff</td></tr>
</table>

Page Size: 32 bytes

User Memory (DX81C128/256)

Address	DX81C128 (128K bits)	DX81C256 (256K bits)
0x0000-0x03ff	Zone 0 (1K B)	Zone 0 (2K B)
0x0400-0x07ff	Zone 1 (1K B)	
0x0800-0x0bff	Zone 2 (1K B)	Zone 1 (2K B)
0x0c00-0x0fff	Zone 3 (1K B)	
0x1000-0x13ff	Zone 4 (1K B)	Zone 2 (2K B)
0x1400-0x17ff	Zone 5 (1K B)	
0x1800-0x1bff	Zone 6 (1K B)	Zone 3 (2K B)
0x1c00-0x1fff	Zone 7 (1K B)	
0x2000-0x23ff	Zone 8 (1K B)	Zone 4 (2K B)
0x2400-0x27ff	Zone 9 (1K B)	
0x2800-0x2bff	Zone 10 (1K B)	Zone 5 (2K B)
0x2c00-0x2fff	Zone 11 (1K B)	
0x3000-0x33ff	Zone 12 (1K B)	Zone 6 (2K B)
0x3400-0x37ff	Zone 13 (1K B)	
0x3800-0x3bff	Zone 14 (1K B)	Zone 7 (2K B)
0x3c00-0x3fff	Zone 15 (1K B)	
0x4000-0x43ff	RSV	Zone 8 (2K B)
0x4400-0x47ff		
0x4800-0x4bff		Zone 9 (2K B)
0x4c00-0x4fff		
0x5000-0x53ff		Zone 10 (2K B)
0x5400-0x57ff		
0x5800-0x5bff		Zone 11 (2K B)
0x5c00-0x5fff		
0x6000-0x63ff		Zone 12 (2K B)
0x6400-0x67ff		
0x6800-0x6bff		Zone 13 (2K B)
0x6c00-0x6fff		
0x7000-0x73ff		Zone 14 (2K B)
0x7400-0x77ff		
0x7800-0x7bff		Zone 15 (2K B)
0x7c00-0x7fff		

Page Size: 64 bytes

Configuration Memory

Address	$0	$1	$2	$3	$4	$5	$6	$7	Description
$00	Serial Number								ROM SN, Read Only
$08	FUSE	UID							FUSE and User ID
$10	Manufacture Code						ZKEYST		Read Only
$18	ZAMFE	ZAMDC	ZAMBA	ZAM98	ZAM76	ZAM54	ZAM32	ZAM10	Zone Access Mode
$20	KEYA								Host Anti-Clone Authorization Key
$28									
$30	RSV								Reserved
$38	PIN								User PIN

ROM SN (0x00--0x07)

The device's 64-bits Serial Number of ROM SN in wafer manufacture guarantees unique identification and can be used to electronically identify the equipment in which it is used. In addition to its important use as a unique data value participates in cryptographic computations.

FUSE (0x08)

FUSE byte is PGO (Program Only) lock byte, only can be programed from "1" to "0". If one FUSE bit changed to 0, it cannot be changed to 1 forever. Configuration bytes of UID, ZAM, KEYA and PIN, after blowing corresponding FUSE bit to zero, will be locked permanently and cannot be modified forever.

- Bit 7-5: Reserved
- Bit 4: UID: Modify UID(0x09—0x0f) enable, Active High
- Bit 3: ZAM: Modify ZAM(0x18—0x1f) enable, Active High
- Bit 2: KEYA: Modify KEYA(0x20—0x2f) enable, Active High
- Bit 1: Reserved
- Bit 0: PIN: Modify PIN(0x38—0x3f) enable, Active High

ZKEYST (0x16--0x17)

ZKEYST bits always read only, indicates the setting status of each zone key. Setting one zone key successfully, after POR (Power On Reset) or RESET command, ZKEYST corresponding bit will be changed from 1 to 0 automatically. Once ZKEYST bit changed to zero, it indicates that the related zone key has been set and cannot be modified forever.

- Bit 15 -- 0: Zone 15 -- 0 Key setting flag

UID (0x09--0x0f)

It is 56 bits User identification which user defined during personalization. It is recommended that a unique identification number be assigned to each device, for example, QQ number or Telephone number, etc. This UID participates in cryptographic computation of authentication and encryption, will be locked after blowing FUSE.4 to zero.

ZAM (0x18—0x1F)

8 bytes ZAM (Zone Access Mode) control the access manner of 16 user zones' reading and writing. All ZAM bits are PGO (program only) bit, only can be programed from "1" to "0" and irreversible from "0" to "1". Also all ZAM bits will be locked after blowing FUSE.3 to zero.

Address	Bits	Zone Index	Zone Access Mode
ZAMFE(0x18)	Bit[7:4]	15	{MDF, PGO, ENC, AUTH}
	Bit[3:0]	14	{MDF, PGO, ENC, AUTH}
ZAMDC(0x19)	Bit[7:4]	13	{MDF, PGO, ENC, AUTH}
	Bit[3:0]	12	{MDF, PGO, ENC, AUTH}
ZAMBA(0x1a)	Bit[7:4]	11	{MDF, PGO, ENC, AUTH}
	Bit[3:0]	10	{MDF, PGO, ENC, AUTH}
ZAM98(0x1b)	Bit[7:4]	9	{MDF, PGO, ENC, AUTH}
	Bit[3:0]	8	{MDF, PGO, ENC, AUTH}
ZAM76(0x1c)	Bit[7:4]	7	{MDF, PGO, ENC, AUTH}
	Bit[3:0]	6	{MDF, PGO, ENC, AUTH}
ZAM54(0x1d)	Bit[7:4]	5	{MDF, PGO, ENC, AUTH}
	Bit[3:0]	4	{MDF, PGO, ENC, AUTH}
ZAM32(0x1e)	Bit[7:4]	3	{MDF, PGO, ENC, AUTH}
	Bit[3:0]	2	{MDF, PGO, ENC, AUTH}
ZAM10(0x1f)	Bit[7:4]	1	{MDF, PGO, ENC, AUTH}
	Bit[3:0]	0	{MDF, PGO, ENC, AUTH}

- MDF: Modify forbidden, Active Low
- PGO: Program Only, Active Low
- {ENC, AUTH}: 11: normal mode 10: authentication mode 0X: encryption mode

KEYA (0x20—0x2f)

Host anti-clone authentication key, always cannot be read. Modifying KEYA is forbidden after blowing FUSE.2 to zero.

PIN (0x38—0x3f)

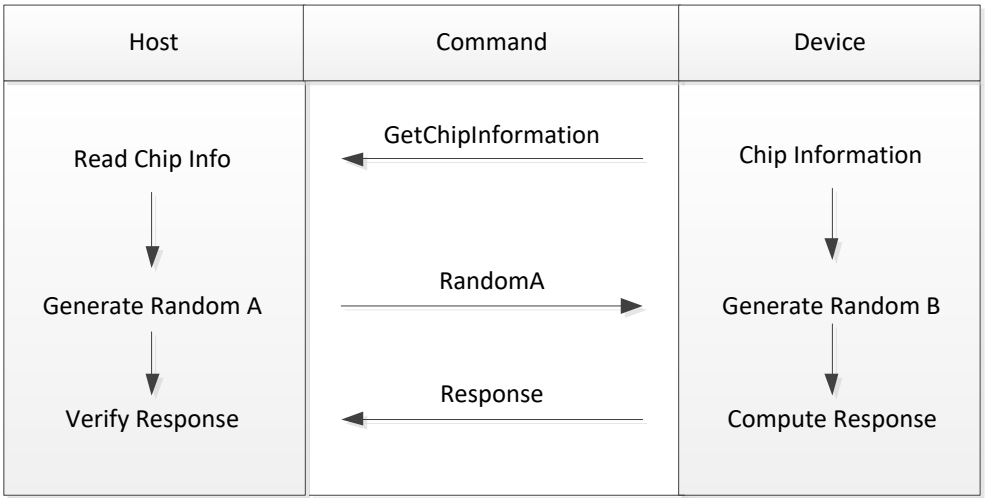
User PIN, for authentication of writing configurations and zone keys. It also can be used to user password for checking. User PIN always cannot be read and modifying is forbidden after blowing FUSE.0 to zero.

Functional Description

Host anti-clone authentication

Host anti-clone authentication of DX81 supports a standard challenge-response protocol to simplify programing. At its most basic, the Host system sends a challenge of Random A to the device in the Client, then device will internally generates a true Random B and combines Random A/B, parts of Chip Information with a secret KEYA to calculate the response, after which the host gets the response from device.

The device uses a cryptographic hash algorithm for the combination, which prevents an observer on the bus from deriving the value of the secret KEYA, and allows the recipient to verify that the response is correct by performing the same calculation (combining the same parameters) with a stored copy of the secret KEYA.



Above authentication flow, The Random B of device generated is also combined for cryptographic hash calculation, at the same time parts of Random B sent to the host together with response. After the host got the random response, device firstly recovers the session key with parts of Random B, and then computes the correct response with the same manner as device. So the response host gets from DX81 is dynamic randomized at any time even if the same challenge, which can effectively prevent hacker from capturing the fixed bus data and simulating the response wave directly with

external general MCU to replace DX81 cryptographic calculation.

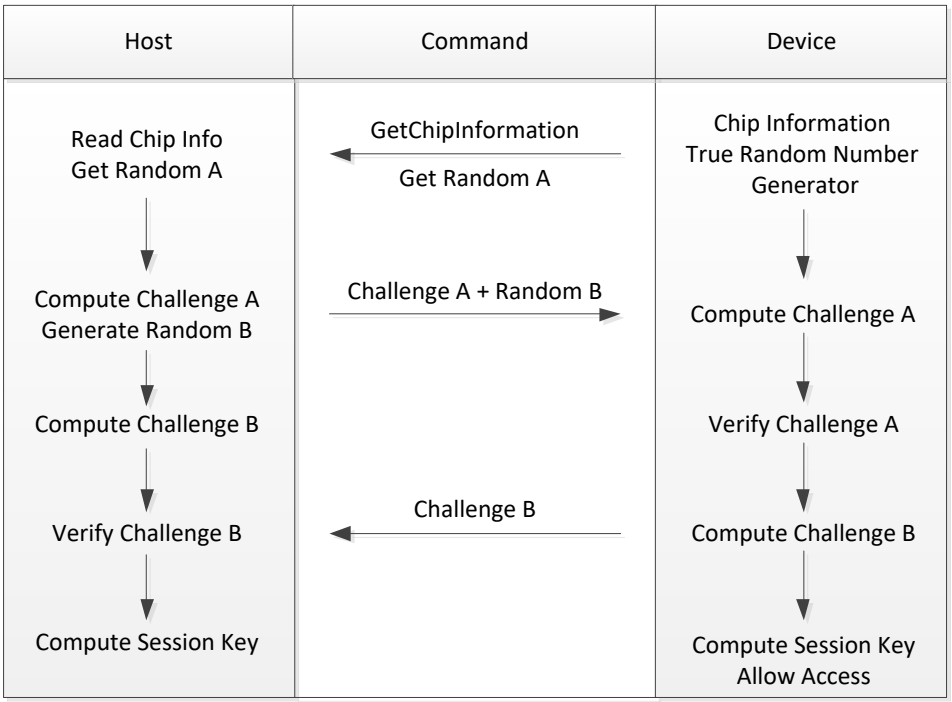
Password checking and Verify Authentication

Each device includes 5 --17 passwords for authentication, one User PIN and 4 --16 Zone Keys, each user zone has an independent zone key. Only the User PIN authentication passed, configuration memory can be written, and only the Zone Key authentication passed, corresponding user zone can open the window to be accessed.

Firstly the host issues command to get random A, at the same time device temporarily stored the random A. Following random A command, the host must firstly compute the challenge A combined Random A with the stored copy of User PIN or Zone Key, and then send the challenge A together with host generating Random B to device.

Secondly when received challenge A and Random B, device will compute the challenge A at the same manner as host, and then compare with the receiving challenge A. If passed device will continuously compute challenge B and session key, or terminate command and refresh the Status Register.

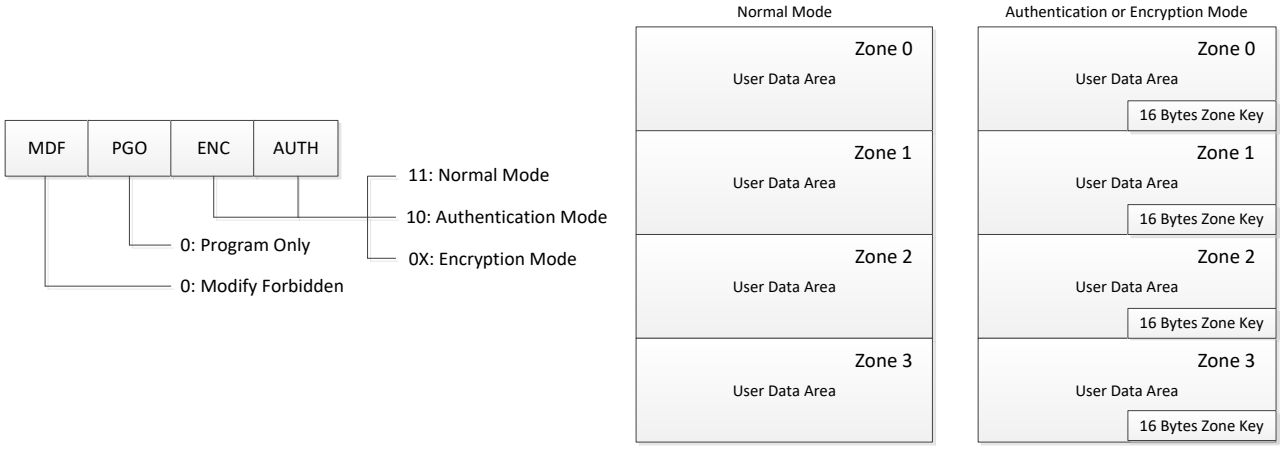
Thirdly host gets challenge B from device, and then compares the response with own software calculation. If passed host will compute the session key for the following encrypt data transmission.



Verifying authentication realizes not only host authenticates device, but also device to host. Only passed the verification both host and device, the next operation is permitted and authorized.

User Memory Zone Access

DX81 family devices have 4--16 user zones and each zone access is controlled by 4 bits (MDF, PGO, ENC, AUTH) . Following is access mode definition of each zone.



Writing and reading user zone must abide by the user zone access mode about ZAM's setting.

MDF

If one user zone's MDF set to zero, this zone will read only and cannot be written.

PGO

If one user zone's PGO set to zero, all bits of this zone will be PGO (Program Only) which only can be changed from 1 to 0, writing from 0 to 1 is no effect.

Before configuring one user zone to PGO (Program Only) mode, firstly you must guarantee all bytes of this zone are 0xff, or the AND logic in PGO mode will result in not your expected value.

ENC and AUTH

All user zones are default normal mode, and all bytes of one user zone are used to user data area, can be read and written freely. But once one user zone configured authentication or encryption mode, after POR or RESET command, this user zone will be divided into two parts, the last 16 bytes are Zone Key area and the other following rest bytes are user data area.

If one user zone configured authentication or encryption mode, Zone Key Area cannot be read forever. User Data Area, after this zone authenticated successfully, then can be read and written.

Electrical Characteristics

Absolute Maximum Ratings

Parameter	Min	Max	Unit
Supply Voltage	2.0	5.5	V
Operating Temperature	-45	+85	°C
DC Output Current	5		mA
Voltage on Any Pin	-0.5	V_{CC}+0.5	V

Note: Stress greater than those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other condition outside those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

Reliability

Parameter	Min	Typical	Max	Units
Write Endurance (each byte at 25^0C)	1M			Write Cycles
Data Retention (at 55^0C)	10			Years

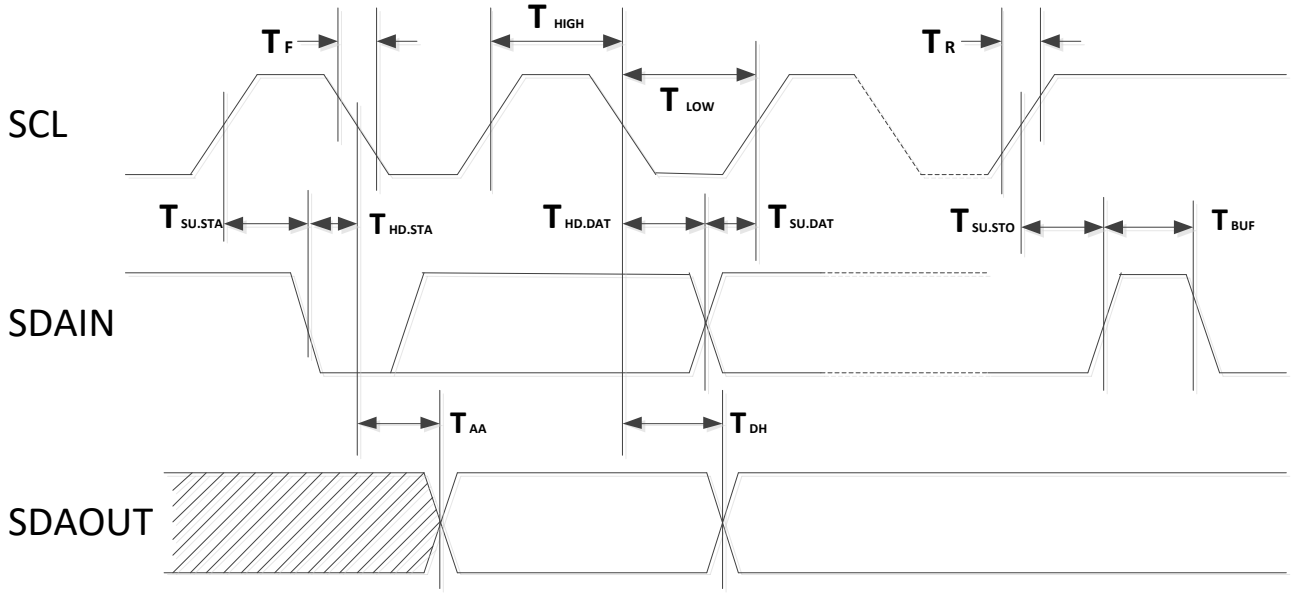
DC Electrical Characteristic

Symbol	Parameter[1]	Min.	Typ	Max.	Unit	Notes
T_O	Operating Temperature	-45		85	°C	
V_{CC}	Supply Voltage	2.0	3.3	5.5	V	
I_{CC}	Supply Current			3	mA	V_{CC} = 3.3V, T_A= 25°C
I_{SB}	Standby Current			2	uA	Device in Sleep mode **I2C Interface:** SCL and SDA to V_{CC} **SPI Interface:** SSEL to V_{CC}, SCLK, MOSI to GND V_{CC} = 2.0V, T_A = 25°C
V_{OL}	Output Low Voltage			0.4	V	V_{CC} = 3.3V I_{OL}=2.1mA
V_{OH}	Output High Voltage	V_{CC}-0.5			V	I_{OH}=400uA
V_{IH}	Input High Voltage	0.7 * V_{CC}		VCC+0.5	V	
V_{IL}	Input Low Voltage	-0.7		0.3 * V_{CC}	V	

[1] The parameters are characterized but not 100% tested.

AC Electrical Characteristic

I2C Timing



Industrial: T_A = - 40°C to + 85°C, V_{CC} = 2.0 ~ 5.5V

Symbol	Parameter[1] [2]	Min.	Max.	Unit
F_{SCL}	SCL Clock Frequency		1	MHz
T_{LOW}	SCL Clock Low Period	400	--	ns
T_{HIGH}	SCL Clock High Period	400	--	ns
$T_{SU:STA}$	Start Condition Setup Time	250	--	ns
$T_{HD:STA}$	Start Condition Hold Time	250		ns
$T_{SU:STO}$	Stop Condition Setup Time	250	--	ns
$T_{SU:DAT}$	Data In Setup Time	100		ns
$T_{HD:DAT}$	Data In Hold Time	10		ns
T_R	Rise Time (SCL and SDA)	--	300	ns
T_F	Fall Time (SCL and SDA)	--	100	ns
T_{AA}	SCL Clock Low to SDA Data Out Valid Time	50	400	ns
T_{DH}	Data Out Hold Time	50		ns
T_{WR}	Write Cycle Time		4	ms
T_{BUF}	Bus Free Time Before New Transmission Start	500		ns

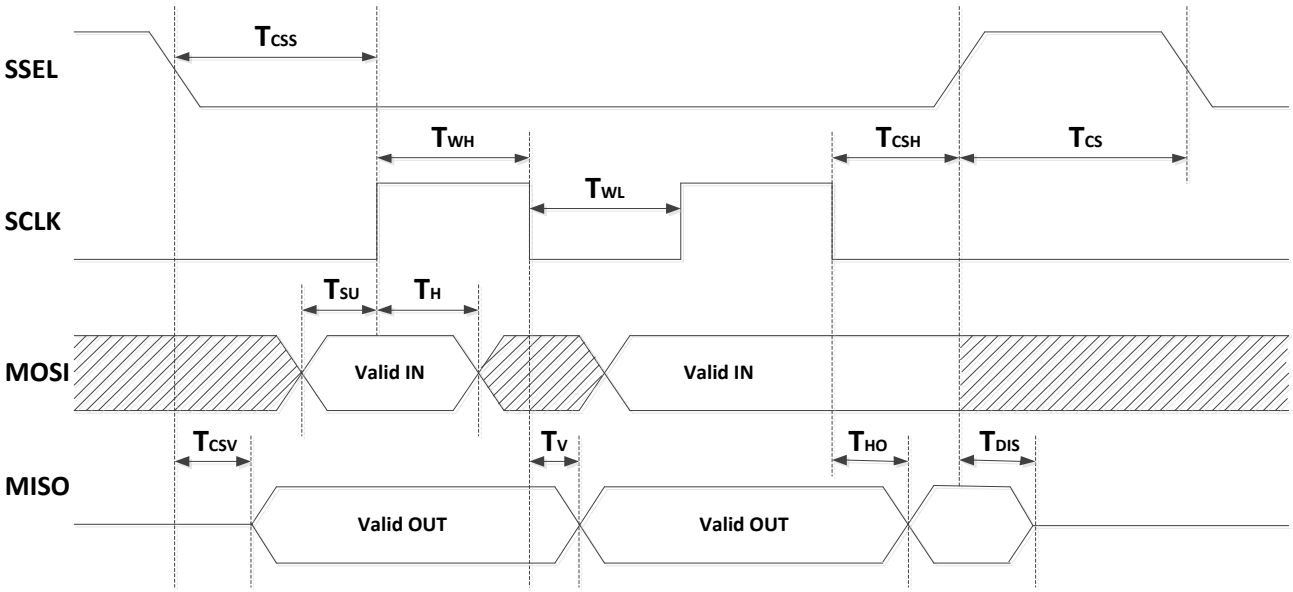
[1] The parameters are characterized but not 100% tested.

[2] AC measurement conditions:

RL (connects to VCC): 1.3kΩ (2.0V--5.0V); Input pulse voltages: 0.3*V_{CC} to 0.7*V_{CC};

Input rise and fall times: ≤ 50 ns; Timing reference voltages: half V_{CC} level;

SPI Timing



Industrial: T_A = - 40°C to + 85°C, V_{CC} = 2.0 ~ 5.5V

Symbol	Parameter[1] [2]	Min.	Max.	Unit
F_{SCLK}	SCLK Clock Frequency		10	MHz
	SCLK Clock Duty Cycle	35	65	Percent
T_{WH}	SCLK Clock HIGH Time	12	--	ns
T_{WL}	SCLK Clock LOW Time	12	--	ns
T_{CS}	SSEL HIGH Time	50	--	ns
T_{CSS}	SSEL to SCLK Rising Setup Time	20		ns
T_{CSH}	SSEL to SCLK Falling Hold Time	20		
T_{CSV}	SSEL to MISO Valid Time	10	--	ns
T_{SU}	Data In to SCLK Rising Setup Time	8		ns
T_H	Data In to SCLK Rising Hold Time	8		ns
T_{RI}	Input Rise Time	--	1	us
T_{FI}	Input Fall Time	--	1	us
T_V	SCLK falling to MISO valid Time	0	10	ns
T_{HO}	MISO to SSEL HIGH Hold Time	0		ns
T_{DIS}	MISO Output Disable Time		20	ns

[1] The parameters are characterized but not 100% tested.

[2] AC measurement conditions:

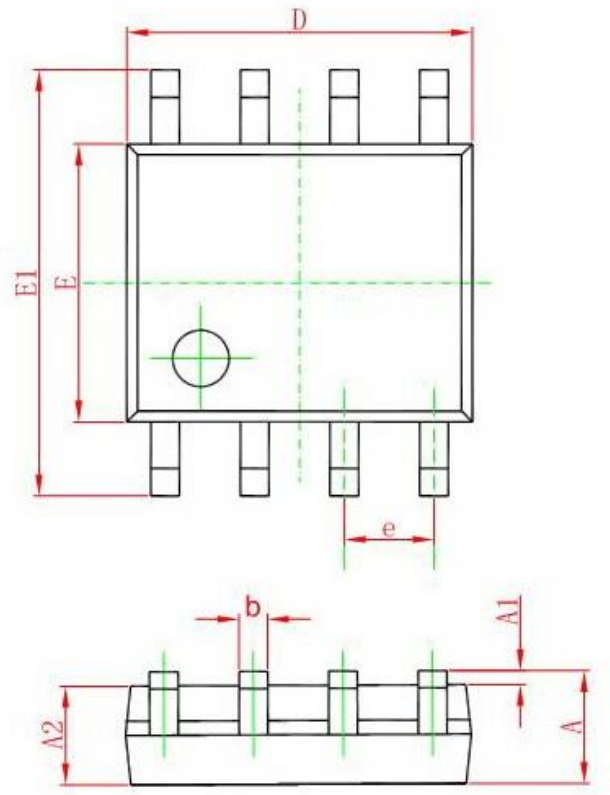
RL (connects to VCC): 1.3kΩ (2.0V--5.0V); Input pulse voltages: 0.3*V_{CC} to 0.7*V_{CC};

Input rise and fall times: ≤ 50 ns; Timing reference voltages: half V_{CC} level;

Package Drawing

SOP8

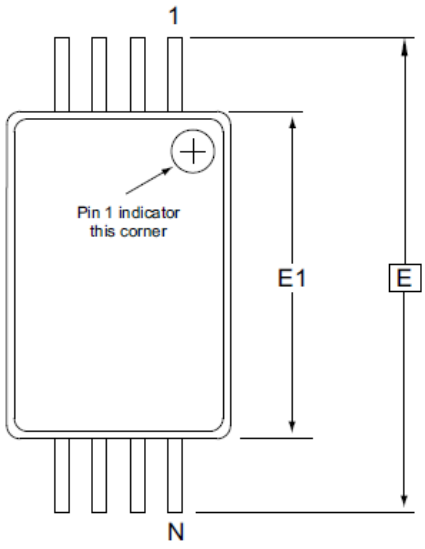
SOP8 PACKAGE OUTLINE DIMENSIONS

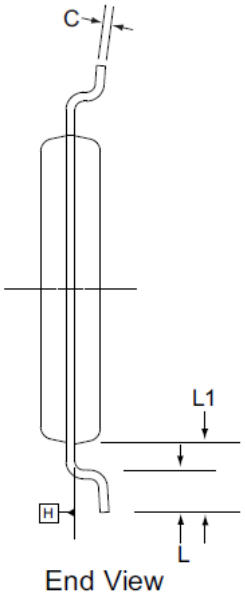


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.270 (BSC)		0.050 (BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

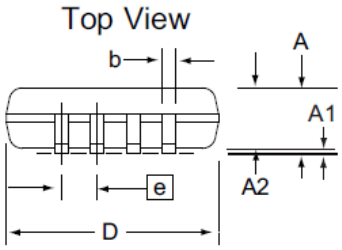
TSSOP8

TSSOP8 PACKAGE OUTLINE DIMENSIONS





End View



Side View

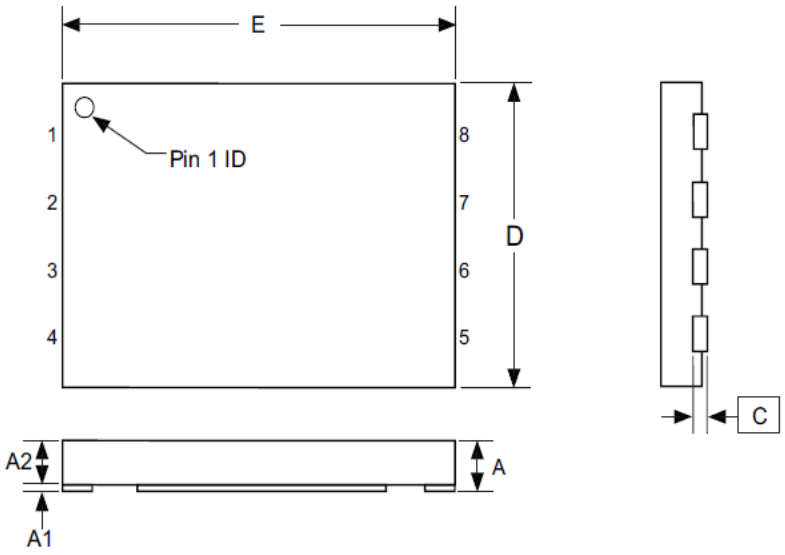
Notes:
1. This drawing is for general information only. Refer to JEDEC Drawing MO-153, Variation AA, for proper dimensions, tolerances, datums, etc.
2. Dimension D does not include mold Flash, protrusions or gate burrs. Mold Flash, protrusions and gate burrs shall not exceed 0.15mm (0.006in) per side.
3. Dimension E1 does not include inter-lead Flash or protrusions. Inter-lead Flash and protrusions shall not exceed 0.25mm (0.010in) per side.
4. Dimension b does not include Dambar protrusion. Allowable Dambar protrusion shall be 0.08mm total in excess of the b dimension at maximum material condition. Dambar cannot be located on the lower radius of the foot. Minimum space between protrusion and adjacent lead is 0.07mm.
5. Dimension D and E1 to be determined at Datum Plane H.

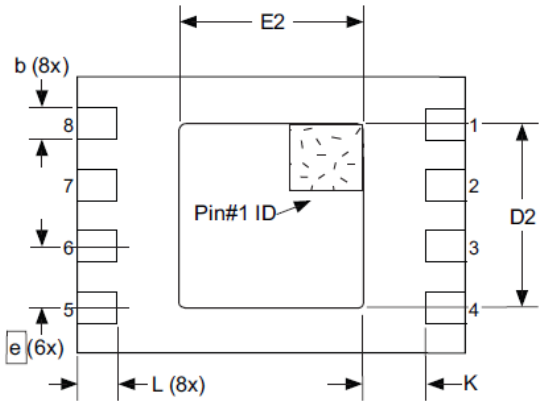
COMMON DIMENSIONS
(Unit of Measure = mm)

SYMBOL	MIN	NOM	MAX	NOTE
A	-	-	1.20	
A1	0.05	-	0.15	
A2	0.80	1.00	1.05	
D	2.90	3.00	3.10	2, 5
E		6.40 BSC		
E1	4.30	4.40	4.50	3, 5
b	0.19	–	0.30	4
e		0.65 BSC		
L	0.45	0.60	0.75	
L1		1.00 REF		
C	0.09	-	0.20	

UDFN8

UDFN8 PACKAGE OUTLINE DIMENSIONS





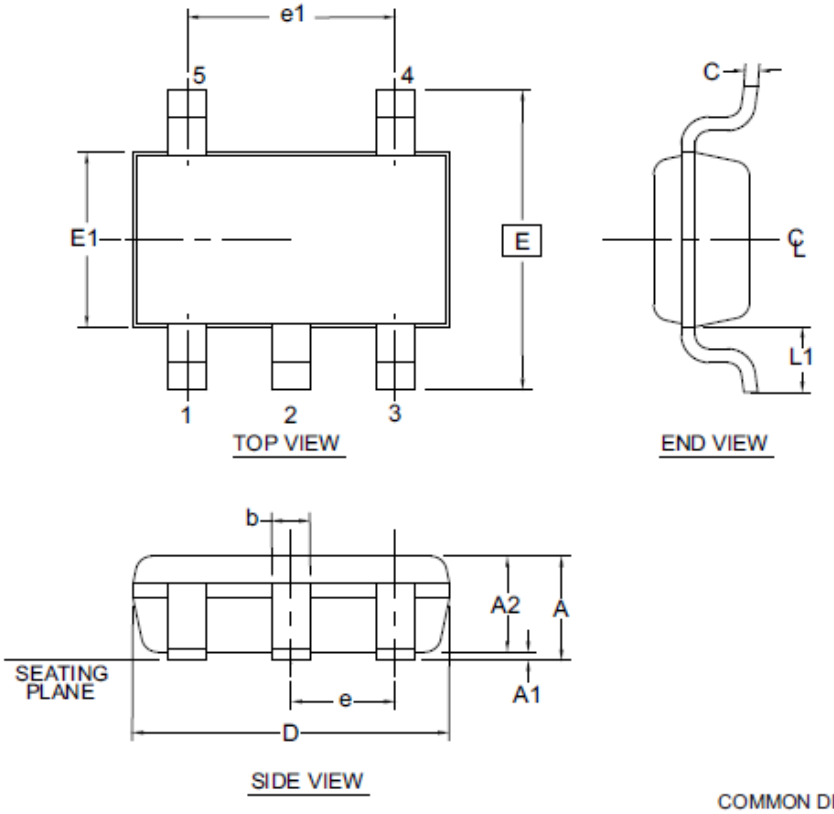
COMMON DIMENSIONS
(Unit of Measure = mm)

SYMBOL	MIN	NOM	MAX	NOTE
D	1.90	2.00	2.10	
E	2.90	3.00	3.10	
D2	1.40	1.50	1.60	
E2	1.20	1.30	1.40	
A	0.50	0.55	0.60	
A1	0.0	0.02	0.05	
A2	–	–	0.55	
C	0.152 REF			
L	0.30	0.35	0.40	
e	0.50 BSC			
b	0.18	0.25	0.30	3
K	0.20	–	–	

Notes: 1. This drawing is for general information only. Refer to JEDEC Drawing MO-229, for proper dimensions, tolerances, datums, etc.
2. The terminal #1 ID is a laser-marked feature.
3. Dimension b applies to metallized terminal and is measured between 0.15 mm and 0.30 mm from the terminal tip. If the terminal has the optional radius on the other end of the terminal, the dimension should not be measured in that radius area.

SOT23-5

SOT23-5L PACKAGE OUTLINE DIMENSIONS



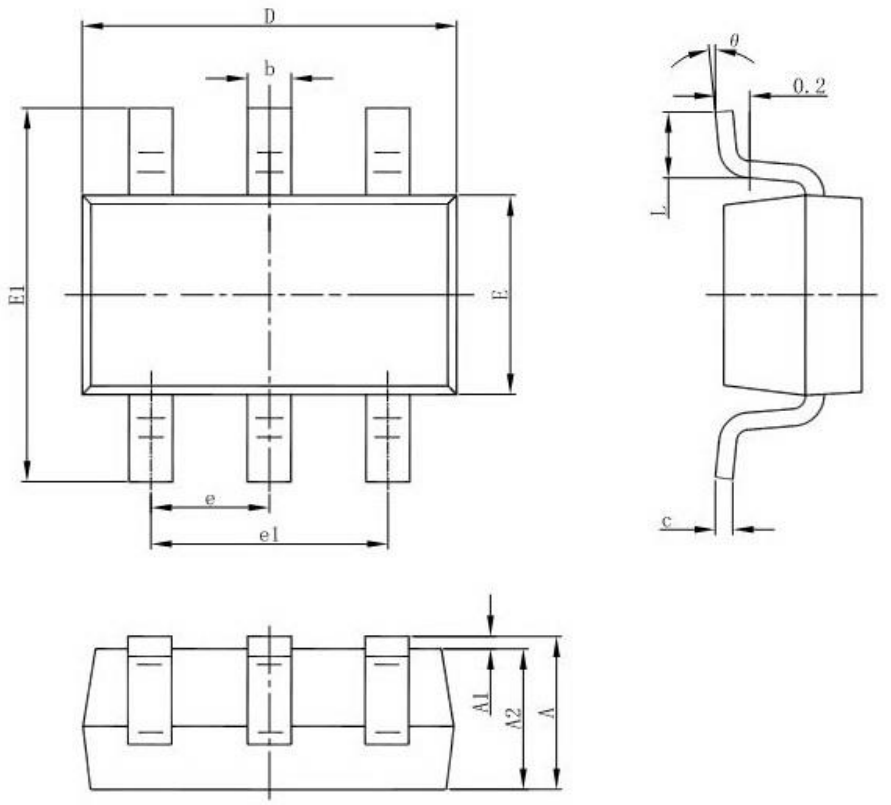
1. Dimension D does not include mold flash, protrusions or gate burrs. Mold flash, protrusions or gate burrs shall not exceed 0.15 mm per end. Dimension E1 does not include interlead flash or protrusion. Interlead flash or protrusion shall not exceed 0.15 mm per side.
2. The package top may be smaller than the package bottom. Dimensions D and E1 are determined at the outermost extremes of the plastic body exclusive of mold flash, tie bar burrs, gate burrs and interlead flash, but including any mismatch between the top and bottom of the plastic body.
3. These dimensions apply to the flat section of the lead between 0.08 mm and 0.15 mm from the lead tip.
4. Dimension "b" does not include dambar protrusion. Allowable dambar protrusion shall be 0.08 mm total in excess of the "b" dimension at maximum material condition. The dambar cannot be located on the lower radius of the foot. Minimum space between protrusion and an adjacent lead shall not be less than 0.07 mm.

COMMON DIMENSIONS
(Unit of Measure = mm)

SYMBOL	MIN	NOM	MAX	NOTE
A	-	-	1.00	
A1	0.00	-	0.10	
A2	0.70	0.90	1.00	
c	0.08	-	0.20	3
D	2.90 BSC			1,2
E	2.80 BSC			1,2
E1	1.60 BSC			1,2
L1	0.60 REF			
e	0.95 BSC			
e1	1.90 BSC			
b	0.30	-	0.50	3,4

SOT23-6

SOT-23-6L PACKAGE OUTLINE DIMENSIONS



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950(BSC)		0.037(BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°