



# MC33PT2001

Programmable solenoid controller

Rev. 7 — 5 November 2019

Product short data sheet

## 1 General description

The PT2001 is a SMARTMOS programmable gate driver IC for solenoid control in automotive application. The typical application is engine control. A wide range of system configurations is also supported.

The general architecture comprises the combination of a set of programmable microcores, integrated high-side (x5), and low-side (x7) predrivers for discrete logic level MOSFETs, end of injection detection and means for diagnostics and protection against external faults. Both battery voltage and booster voltage level high-side configurations are supported. The chip communicates with the main controller through an SPI bus and a flexible set of direct interface signals.

The main characteristics of this component are:

- The programmable architecture: the four dedicated microprocessor cores optimized to control power MOSFETs with small latency time. Thus a high level of flexibility during design and at runtime can be achieved.
- The high level of integration: all interfaces are designed to use as few external components as possible.

## 2 Features and benefits

- Programmable integrated End-of-Injection (EOI) measurement function
- Outputs configurable into 2-bank operation
- Five high-side / seven low-side predrivers:
  - PWM frequency: 100 kHz
  - Four programmable slew rates: 12.5 V/μs to 300 V/μs
- Flexible current profile management through four programmable microcores running at 6 MHz
- Automatic freewheeling control
- Programmable integrated diagnostics:
  - openload
  - undervoltage
  - overvoltage
  - overcurrent
  - overtemperature
- Independent DRVEN pin for safety
- ISO 26262 compliant development
- Embedded encryption for microcode protection
- 16-bit SPI control with IRQB plus three interrupt flags
- 36 V tolerant digital IOs



### 3 Simplified application diagram

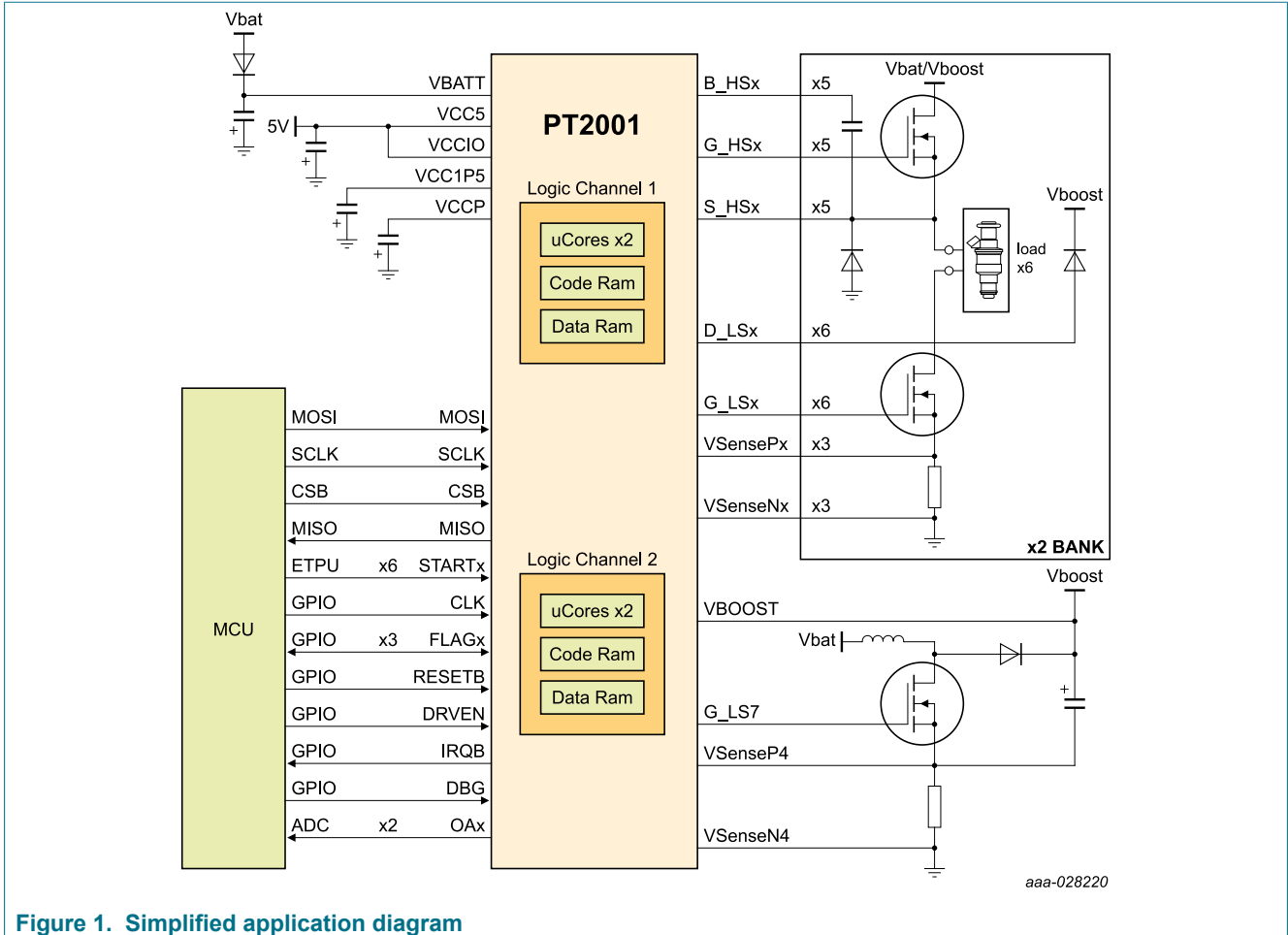


Figure 1. Simplified application diagram

### 4 Applications

- Automotive (12 V), truck and industrial (24 V) powertrain
- Gasoline Direct Injection (GDI)
- Diesel Direct Injection (DDI)
- CNG / LNG engines
- Variable Valve Actuators (VVA)
- Active suspension systems
- Transmission solenoid drivers (CVT, DCT, AT)

## 5 Ordering information

**Table 1. Ordering information**

Type number <sup>[1]</sup>	Part description	Package		
		Name	Description	Version
MC33PT2001AE	Programmable solenoid controller	HLQFP64	HLQFP64, plastic, thermal enhanced low profile quad flat package; 64 terminals; 0.5 mm pitch; 10 mm x 10 mm x 1.4 mm body; 4.9 mm x 4.9 mm exposed pad	SOT1510-1
MC33PT2001MAE	Programmable solenoid controller with measurement function			

[1] To order parts in tape and reel, add the R2 suffix to the part number.

Valid orderable part numbers are provided on the web. To determine the orderable part numbers for this device, go to <http://www.nxp.com> and perform a part number search.

6 Internal block diagram

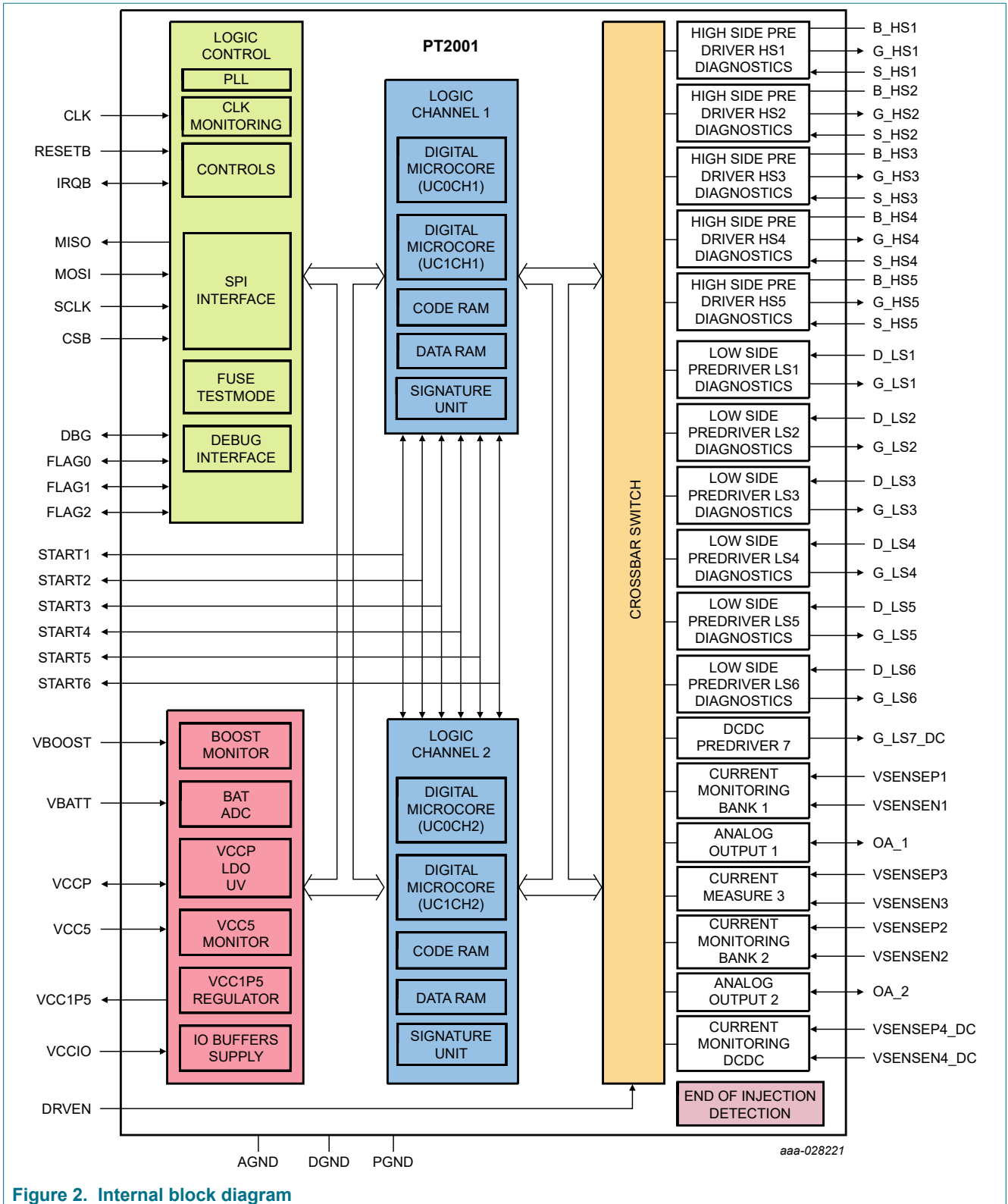


Figure 2. Internal block diagram

## 7 Pinning information

### 7.1 Pinning

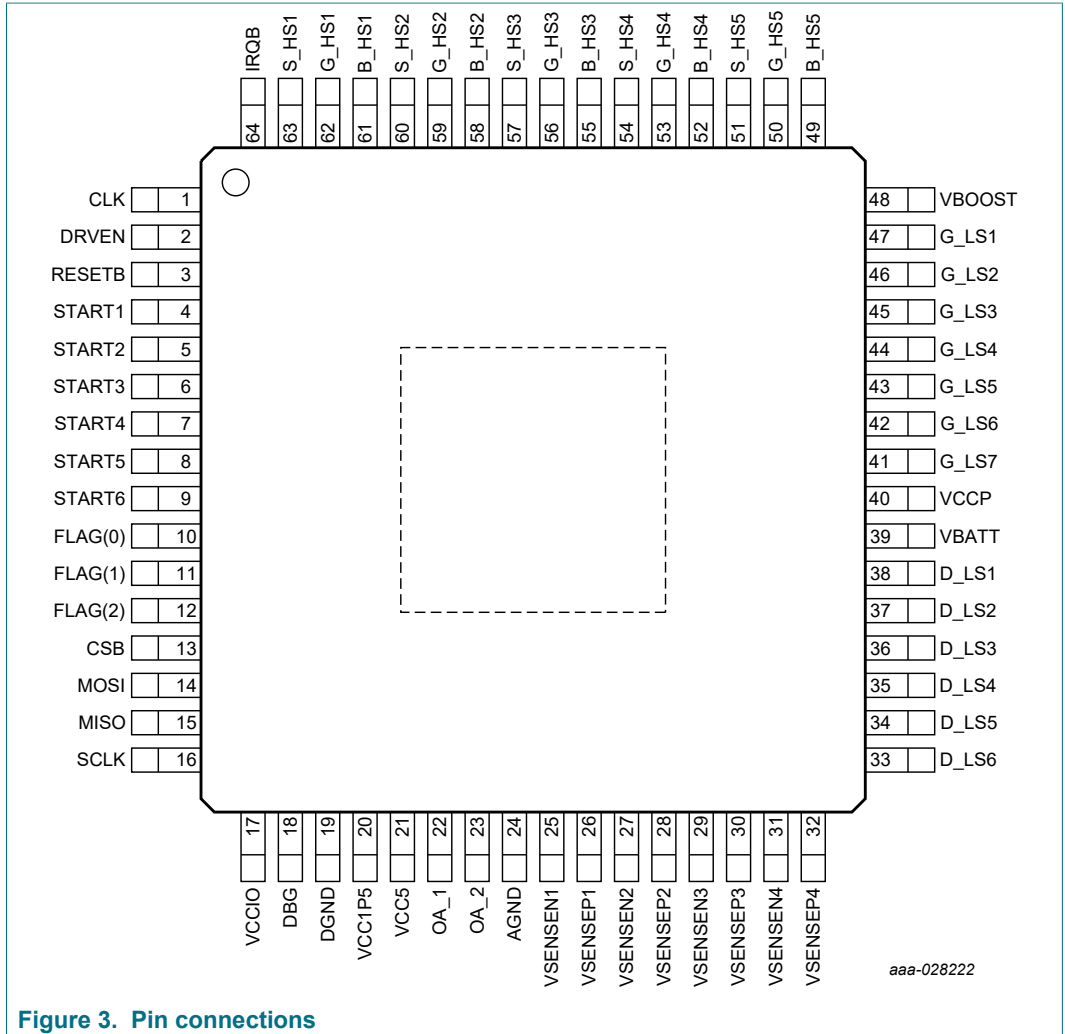


Figure 3. Pin connections

### 7.2 Pin description

Table 2. Pin definitions

Pin number	Pin name <sup>[1][2][3]</sup>	Pin function	Definition	Pull-up/pull-down	Reset
1	Clk	In	Clock pin (low frequency reference for internal PLL)	Weak PU <sup>[4]</sup>	Input
2	DrvEn	In	Driver enable input	Weak PD <sup>[5]</sup>	Input
3	ResetB	In	Reset pin	Weak PU	Input
4	Start1	In/Out	Trigger pin actuator 1 / Flag_bus(3)	PU/PD <sup>[6][7]</sup>	Input
5	Start2	In/Out	Trigger pin actuator 2 / Flag_bus(4)	PU/PD	Input
6	Start3	In/Out	Trigger pin actuator 3 / Flag_bus(5)	PU/PD	Input

Pin number	Pin name <sup>[1][2][3]</sup>	Pin function	Definition	Pull-up/pull-down	Reset
7	Start4	In/Out	Trigger pin actuator 4 / Flag_bus(6)	PU/PD	Input
8	Start5	In/Out	Trigger pin actuator 5 / Flag_bus(7)	PU/PD	Input
9	Start6	In/Out	Trigger pin actuator 6 / Flag_bus(8)	PU/PD	Input
10	Flag(0)	In/Out	Flag_bus(0) (general-purpose I/O)	Weak PD	Input
11	Flag(1)	In/Out	Flag_bus(1) (general-purpose I/O)	Weak PD	Input
12	Flag(2)	In/Out	Flag_bus(2) (general-purpose I/O)	Weak PD	Input
13	Csb	In	SPI chip select	PU	Input
14	Mosi	In	SPI slave input	Weak PU	Input
15	Miso	Out	SPI slave output	—	Output: hi-Z
16	Sclk	In	SPI clock	Weak PU	Input
17	VccIO	—	I/O voltage supply 3.3 V or 5.0 V	—	—
18	Dbg	In/Out	Debug port / Flag_bus(12)	Weak PU	Input
19	Dgnd	—	Digital ground	—	—
20	Vcc1p5	—	1.5 V voltage regulator decoupling	—	Regulator off
21	Vcc5	In	Power supply 5.0 V	—	—
22	OA_1	In/Out	Opamp output current sense 1 / Flag_bus(10)	Weak PD	Input
23	OA_2	In/Out	Opamp output current sense 2 / Flag_bus(11)	Weak PD	Input
24	Agnd	—	Analog ground	—	—
25	VsenseN1	In	Current sense 1 –	—	—
26	VsenseP1	In	Current sense 1 +	—	—
27	VsenseN2	In	Current sense 2 –	—	—
28	VsenseP2	In	Current sense 2 +	—	—
29	VsenseN3	In	Current sense 3	—	—
30	VsenseP3	In	Current sense 3	—	—
31	VsenseN4	In	Current sense 4	—	—
32	VsenseP4	In	Current sense 4	—	—
33	D_Is6	In	Drain pin low-side MOSFET actuator 6	—	—
34	D_Is5	In	Drain pin low-side MOSFET actuator 5	—	—
35	D_Is4	In	Drain pin low-side MOSFET actuator 4	—	—
36	D_Is3	In	Drain pin low-side MOSFET actuator 3	—	—
37	D_Is2	In	Drain pin low-side MOSFET actuator 2	—	—
38	D_Is1	In	Drain pin low-side MOSFET actuator 1	—	—
39	Vbatt	In	Battery voltage and drain pin for high-side predrivers	—	—

Pin number	Pin name <sup>[1][2][3]</sup>	Pin function	Definition	Pull-up/pull-down	Reset
40	VccP	—	7.0 V voltage regulator decoupling	—	Regulator off
41	G_Is7	Out	Gate pin low-side MOSFET for DC/DC converter	—	Output: low
42	G_Is6	Out	Gate pin low-side MOSFET actuator 6	—	Output: low
43	G_Is5	Out	Gate pin low-side MOSFET actuator 5	—	Output: low
44	G_Is4	Out	Gate pin low-side MOSFET actuator 4	—	Output: low
45	G_Is3	Out	Gate pin low-side MOSFET actuator 3	—	Output: low
46	G_Is2	Out	Gate pin low-side MOSFET actuator 2	—	Output: low
47	G_Is1	Out	Gate pin low-side MOSFET actuator 1	—	Output: low
48	Vboost	In	Boost voltage and drain pin for boost predrivers	—	—
49	B_hs5	—	Bootstrap pin high-side MOSFET	—	—
50	G_hs5	Out	Gate pin high-side MOSFET HP	—	Output: low
51	S_hs5	In	Source pin high side MOSFET	—	—
52	B_hs4	—	Bootstrap pin Boost MOSFET	—	—
53	G_hs4	Out	Gate pin Boost MOSFET	—	Output: low
54	S_hs4	In	Source pin Boost MOSFET	—	—
55	B_hs3	—	Bootstrap pin high-side MOSFET	—	—
56	G_hs3	Out	Gate pin high-side MOSFET	—	Output: low
57	S_hs3	In	Source pin high-side MOSFET	—	—
58	B_hs2	—	Bootstrap pin Boost MOSFET	—	—
59	G_hs2	Out	Gate pin Boost MOSFET	—	Output: low
60	S_hs2	In	Source pin Boost MOSFET	—	—
61	B_hs1	—	Bootstrap pin high-side MOSFET	—	—
62	G_hs1	Out	Gate pin high-side MOSFET	—	Output: low
63	S_hs1	In	Source pin high-side MOSFET	—	—
64	IrqB	In/Out	Interrupt (output) / Flag_bus(9)	Weak PD	Input
ePAD	Pgnd	—	Power ground		

[1] External 7.0 V is required in case the typical battery voltage is 24 V.

[2] Except for supply and ground, it is guaranteed by design unused pins can be kept open without any impact on the device.

[3] Unused VSENSEPx and VSENSEnx pins can both be connected to GND.

[4] Weak pull-up to VCCIO (nominal value: 480 kΩ)

[5] Weak pull-down to AGND (nominal value: 480 kΩ)

[6] PU: Pull-up to VCCIO (nominal value: 120 kΩ)

[7] PD: Pull-down to AGND (nominal value: 120 kΩ)

## 8 Functional description

### 8.1 Introduction

The PT2001 is a mixed signal IC for any solenoid control but more particularly to engine injector and electrical valve control. It provides a cost effective, flexible, and smart, high-side and low-side MOSFET gate driver. The device includes both individual charge pump outputs for each high-side predriver and high-voltage DC-to-DC converter predriver. Gate drive, diagnostics, and protection against external faults, are managed through four independent and concurrent digital microcores. Each of the two logic channels including two microcores and their own code RAM and data RAM.

The internal microcode is protected against theft via encryption and corruption via check sums. Those microcores are optimized to control power MOSFET with a small latency time, they also enable moving the computation from MCU to PT2001 and using the MCU for other critical tasks. The PT2001 can control two banks of two/three injectors each.

1. At power-up, MCU programs CRAM in PT2001 using SPI, this defines a particular state machine inside the core to generate a specific current shape. Once done PT2001 can control solenoid current by itself.
2. The solenoid turn ON/OFF is still controlled by the MCU most of the time from eTPU or GTM but also from a GPIO, which simply sends a pulse to the STARTx pin of PT2001. Then PT2001 controls gate HS and gate LS according to the current waveform needed.

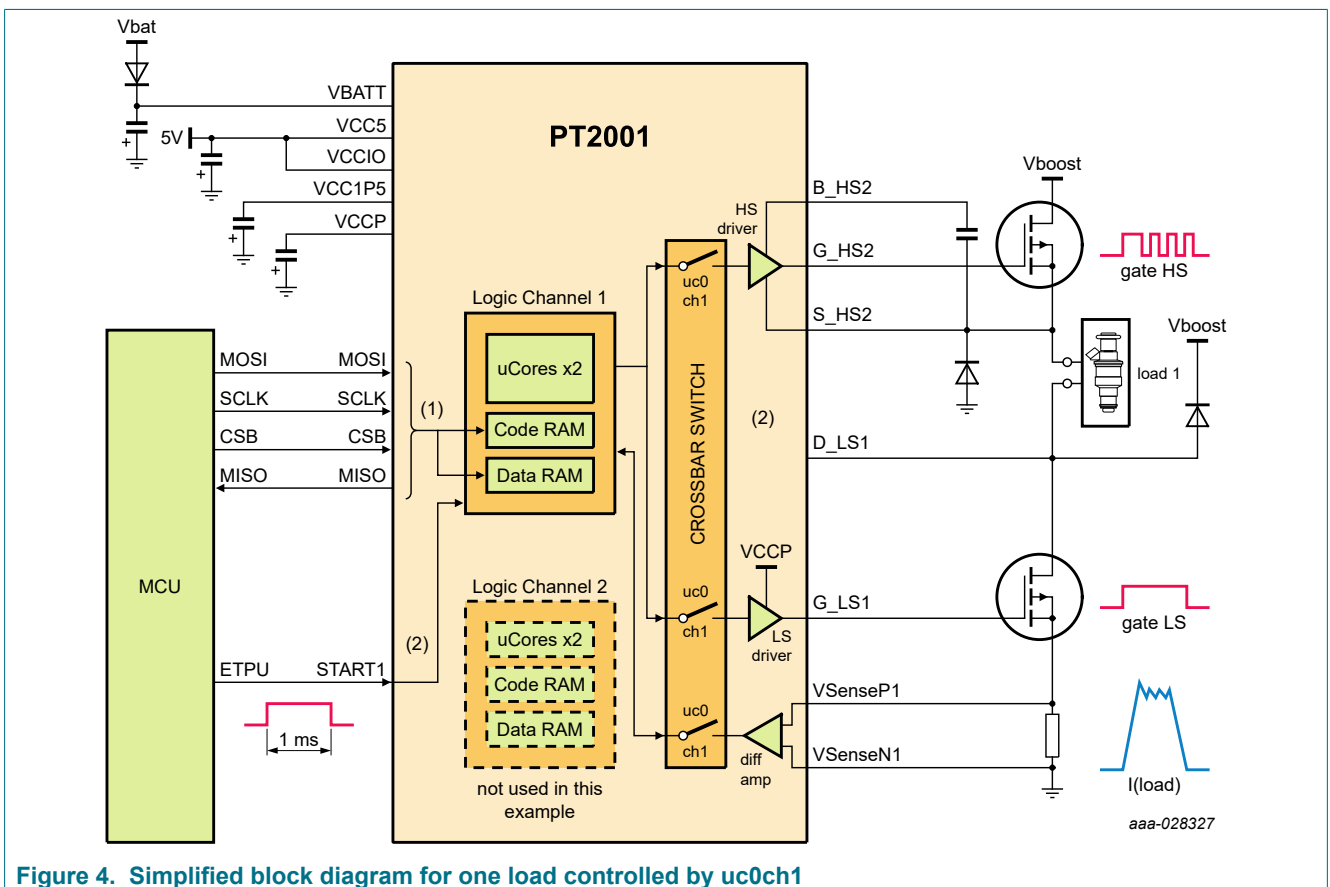


Figure 4. Simplified block diagram for one load controlled by uc0ch1



## 8.2 Features

### High-side and low-side predrivers

- Five high-side predrivers for logic level N-channel MOSFETs using four programmable slew rates
- Six low-side predrivers for logic level N-channel MOSFETs using four programmable slew rates
- Integrated bootstrap circuitry for each high-side predriver
- Integrated charge pump circuitry for each high-side predriver with 100 % duty cycle capability
- Configurable automatic freewheeling capability between high-side and low-side

### DC-to-DC converter

- One low-side predriver, for a logic level N-channel MOSFET, can be optionally dedicated to providing a boost DC-DC converter with four programmable slew rates
- Two different control modes to reduce power dissipation (manual, hysteretic)

### Current measurement

- Three independent current measurement blocks
- One current measurement (channel 4) is optionally configurable to support DC-to-DC converter

### Diagnostics and monitoring

- $V_{DS}$  and  $V_{SRC}$  monitoring (programmable values) for fault protection and diagnostics
- $V_{BOOST}$  monitoring
- $V_{BAT}$  monitoring
- Temperature monitoring

### Integrated end of injection detection

- Accurate detection of end of injection for each high-side source and low-side drain without any external component needed

### Power supplies

- Integrated 7.0 V linear regulator (VCCP) for the HS/LS gate power supply
- Integrated 1.5 V linear regulator (VCC1P5) for the digital core supply based on the VCC5 input supply
- External 5.0 V supply (VCC5)
- Selectable VCCIO external supply (5.0 V or 3.3 V) for digital I/O

### Digital block

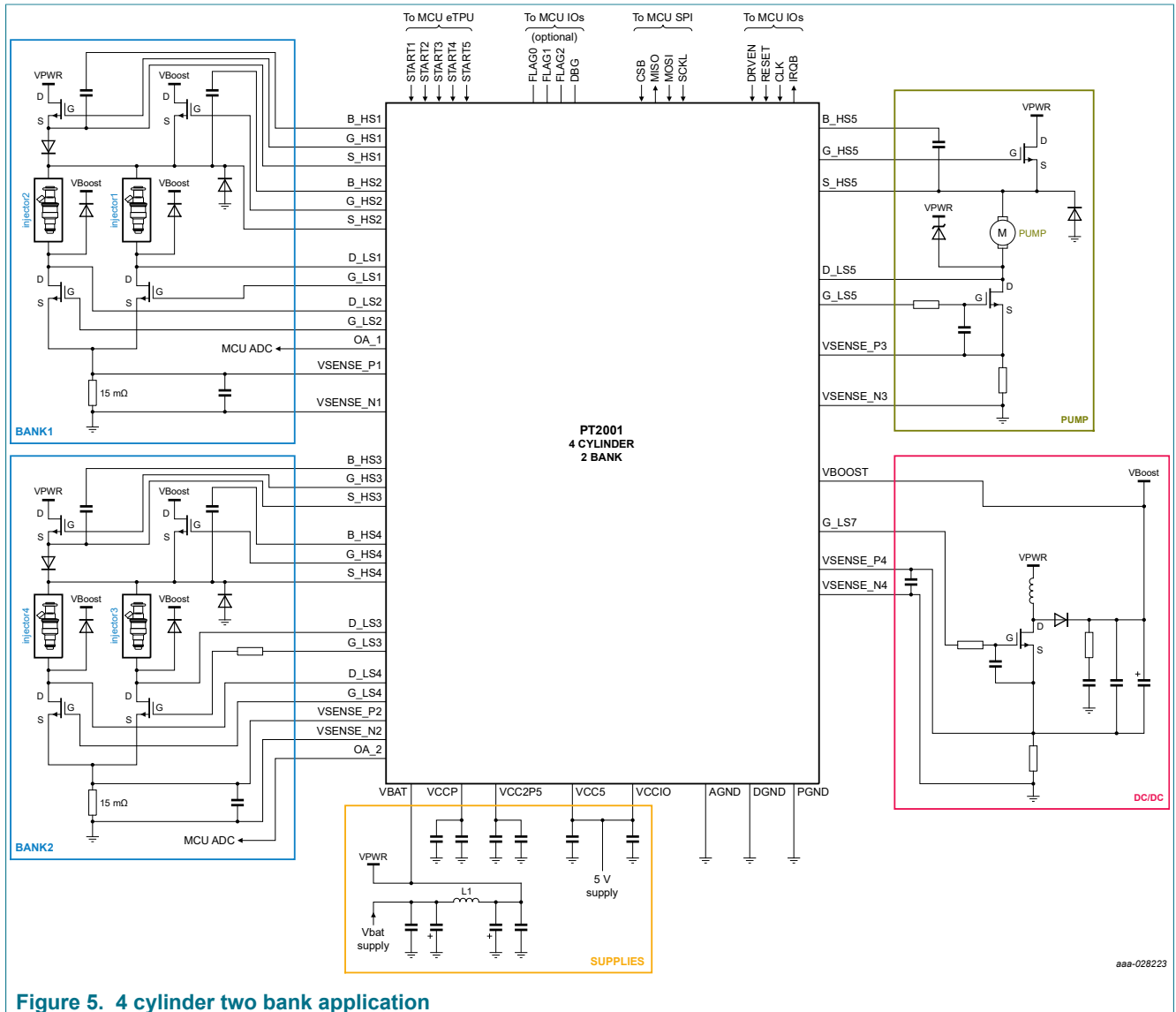
- Four digital microcores, each with their own ALU, and full access to the system crossbar switch
- Two memory banks: 1024 x 16-bit of code RAM with built-in error detection and 64 x 16-bit of data RAM
- Memory BIST activated by the SPI, with pass/fail status
- Control interface

### Control interface

- 16-bit slave SPI up to 10 MHz - two protocols - programmable slew rate
- 13 general-purpose digital IOs able to sustain up to 36 V

- Independent direct predriver inhibition input for safety purposes

## 9 Typical application



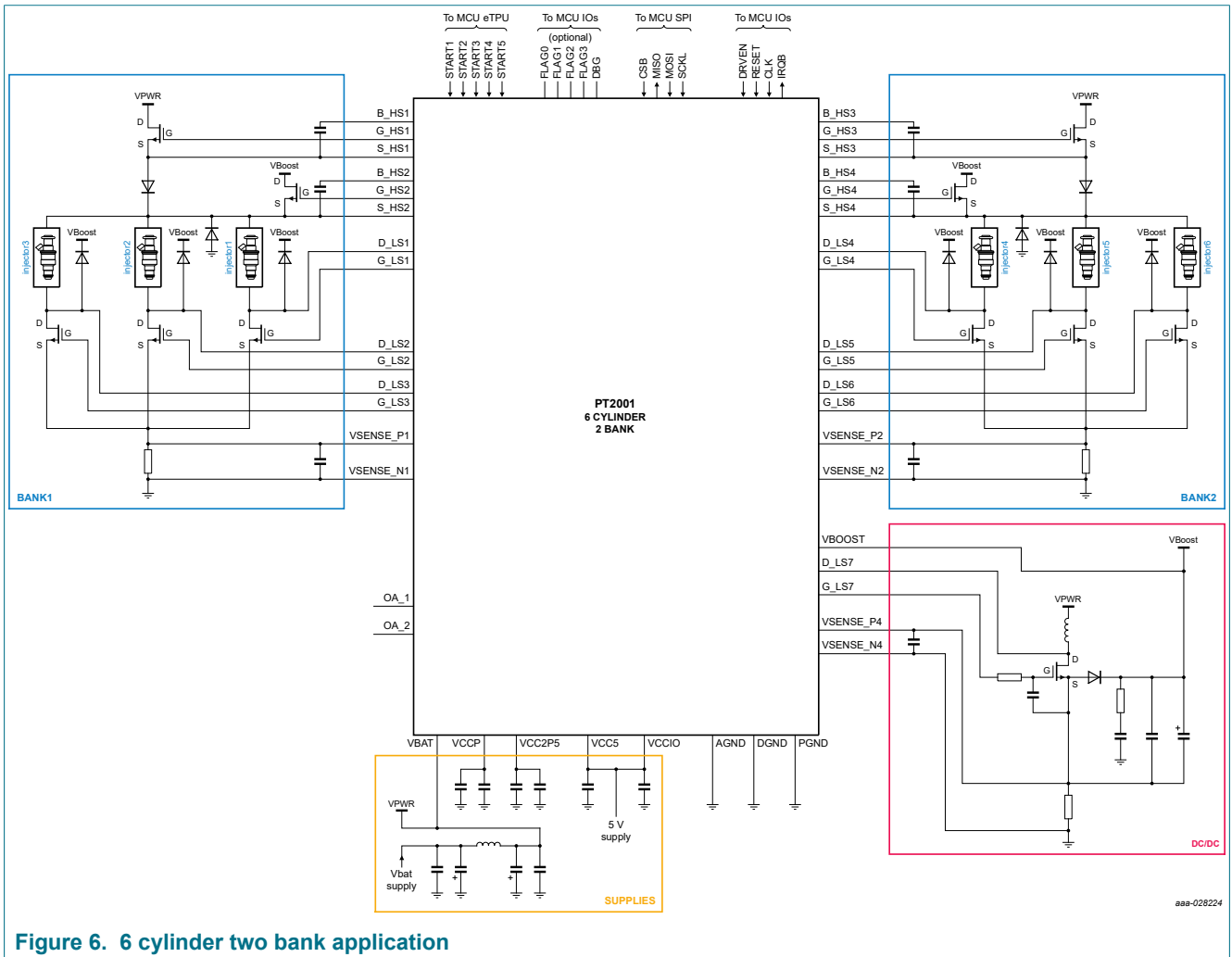


Figure 6. 6 cylinder two bank application

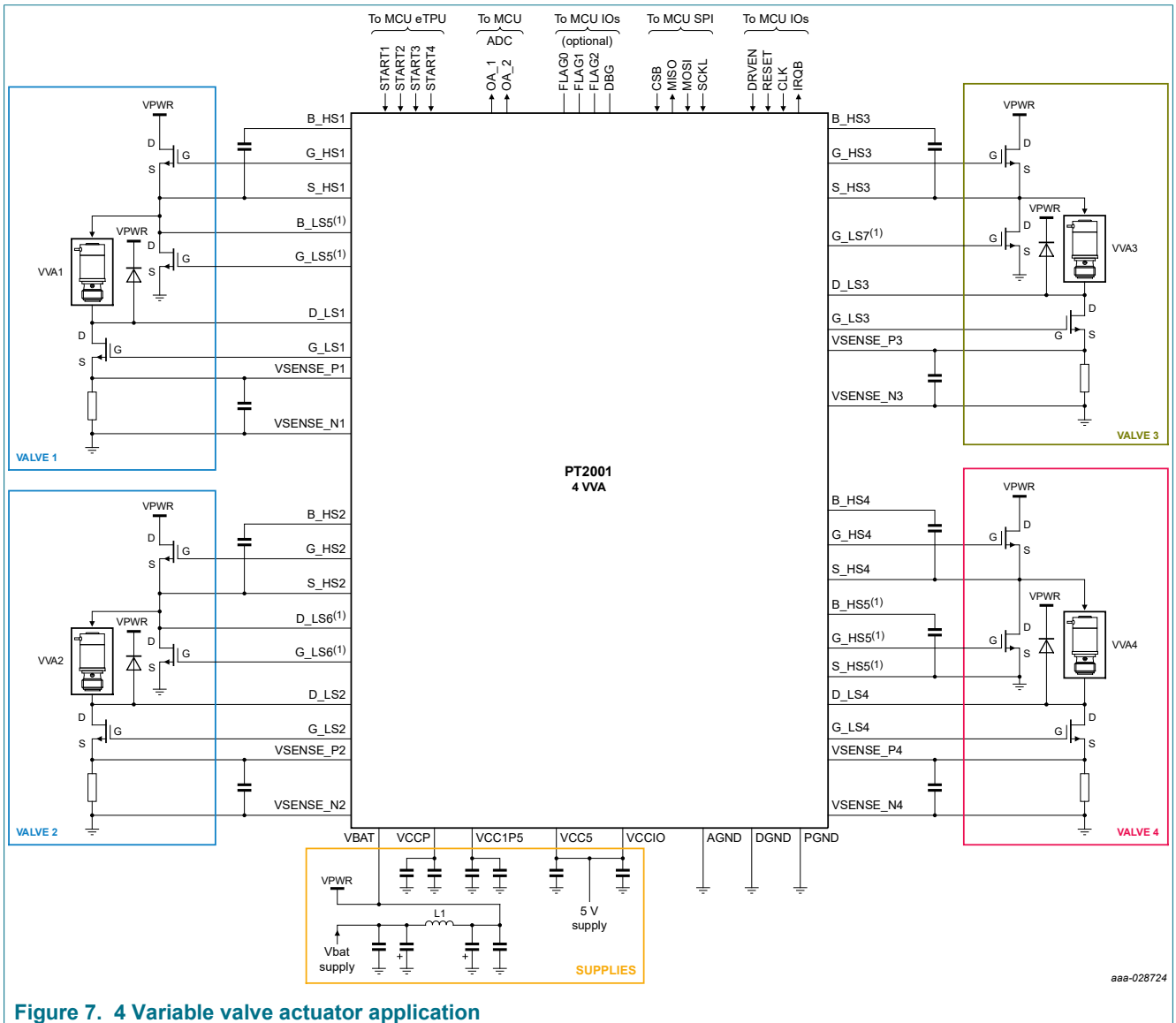


Figure 7. 4 Variable valve actuator application

## 10 Maximum ratings

Table 3. Maximum ratings

All voltages are with respect to ground, unless otherwise noted. Exceeding these ratings may cause a malfunction or permanent damage to the device.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Electrical ratings</b>						
V <sub>BOOST</sub>	DC voltage at VBOOST	—	0	—	72	V
V <sub>BATT</sub>	DC voltage at VBATT	—	-0.3	—	72	V
V <sub>CC5</sub>	DC voltage at VCC5	—	-0.3	—	36	V
V <sub>CCIO</sub>	DC voltage at VCCIO	—	-0.3	—	36	V
V <sub>CC1P5</sub>	DC voltage at VCC1P5	—	-0.3	—	2.0	V
V <sub>DIG</sub>	DC voltage at CLK, MISO, MOSI, SCLK, CSB, IRQB, RESETB	—	-0.3	—	36	V
V <sub>DRV_EN</sub>	DC voltage at DRVEN	—	-0.3	—	36	V
V <sub>STARTX</sub>	DC voltage at STARTx	—	-0.3	—	36	V

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V <sub>FLAGX</sub>	DC voltage at FLAGx	—	-0.3	—	36	V
V <sub>DBG</sub>	DC voltage at DBG	—	-0.3	—	36	V
V <sub>OA_OUTX</sub>	DC voltage at OA_1, OA_2	—	-0.3	—	36	V
V <sub>DGND</sub>	DC voltage at DGND	—	-0.3	—	0.3	V
V <sub>AGND</sub>	DC voltage at AGND	—	-0.3	—	0.3	V
V <sub>CCP</sub>	DC voltage at VCCP	—	-0.3	—	9.0	V
V <sub>S_HSx</sub>	S_HSx	• DC voltage	-3.0	—	V <sub>BOOSTMAX</sub>	V
		• Transients t < 800 ns	-6.0	—	V <sub>BOOSTMAX</sub>	
		• Transients t < 400 ns	-8.0	—	V <sub>BOOSTMAX</sub>	
V <sub>B_HSx</sub>	B_HSx	• DC voltage	-0.3	—	V <sub>S_HSx</sub> + V <sub>BS_HSx_CL</sub>	V
		• Transients t < 800 ns	-2.0	—		
		• Transients t < 400 ns	-4.0	—		
V <sub>G_HSx</sub>	DC voltage at G_HSx	—	V <sub>S_HSx</sub> -0.3	—	V <sub>B_HSx</sub> +0.3	V
V <sub>G_LSx</sub>	G_LSx	• DC voltage	-0.3	—	V <sub>CCP</sub> +0.3	V
		• Transients t < 5.0 μs; V = 8.0 V; energy of pulses < 0 V or > V is limited to 2.0 μJ due to capacitive coupling	-1.5	—	V <sub>CCP</sub> + 1.5	
V <sub>D_LSx</sub>	D_LSx	• DC voltage	-3.0	—	75	V
		• Transients t < 400 ns	-8.0	—	75	
V <sub>VSENSE1/2/3</sub>	DC voltage at VSENSE1/2/3	• Static at VCC5 < 10 V	-1.0	—	1.0	V
		• Dynamic for max 5.0 μs, 1.0 kHz repetition rate at VCC5 < 5.25 V	-5.0	—	5.0	
		• Dynamic for max 1.0 μs at VCC5 < 5.25 V	-15	—	15	
V <sub>VSENSEP1/2/3</sub>	DC voltage at VSENSEP1/2/3	• DC voltage at VCC5 < 10 V	-2.5	—	2.5	V
		• Dynamic for max 5.0 μs, 1.0 kHz repetition rate at VCC5 < 5.25 V	-5.0	—	5.0	
		• Dynamic for max 1.0 μs at VCC5 < 5.25 V	-15	—	15	
V <sub>VSENSE4</sub>	DC voltage at VSENSE4	• DC voltage at VCC5 < 10 V	-3.0	—	1.0	V
		• Dynamic for max 5.0 μs, 1.0 kHz repetition rate at VCC5 < 5.25 V Dynamic for max 1.0 μs at VCC5 < 5.25 V	-5.0	—	5.0	
		• Dynamic for max 1.0 μs at VCC5 < 5.25 V	-15	—	15	
V <sub>VSENSEP4</sub>	DC voltage at VSENSEP4	• DC voltage at VCC5 < 10 V	-4.2	—	2.5	V
		• Dynamic for max 5.0 μs, 1.0 kHz repetition rate at VCC5 < 5.25 V	-5.0	—	5.0	
		• Dynamic for max 1.0 μs at VCC5 < 5.25 V	-15	—	15	
<b>ESD voltage</b>						
	Human body model (HBM)					V
V <sub>ESD-HBM1</sub>	• VBOOST, VBATT, S_HSx	—	-4000	—	4000	
V <sub>ESD-HBM2</sub>	• D_LSx	—	-8000	—	8000	
V <sub>ESD-HBM3</sub>	• All other pins	—	-2000	—	2000	
	Machine model					
V <sub>ESD-CDM1</sub>	• Corner pins	—	-750	—	750	
V <sub>ESD-CDM2</sub>	• All other pins	—	-500	—	500	
<b>Thermal ratings</b>						
	Operating temperature					°C
T <sub>A</sub>	• Ambient	—	-40	—	125	
T <sub>J</sub>	• Junction	—	-40	—	150	
T <sub>THRESHOLD</sub>	Temperature monitoring threshold	—	167	—	187	°C

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
T <sub>STG</sub>	Storage ambient temperature	—	-55	—	150	°C
<b>Thermal resistance</b>						
R <sub>θJA</sub>	Thermal resistance junction to ambient	—	—	—	25.3	°C/W
R <sub>θJCTOP</sub>	Thermal resistance junction to case top	—	—	—	13.2	°C/W
R <sub>θJCBOTTOM</sub>	Thermal resistance junction to case bottom	—	—	—	0.8	°C/W

## 11 Package outline

For the most current package revision, visit <http://www.nxp.com> and perform a keyword search using the 98ASA00237D listed.

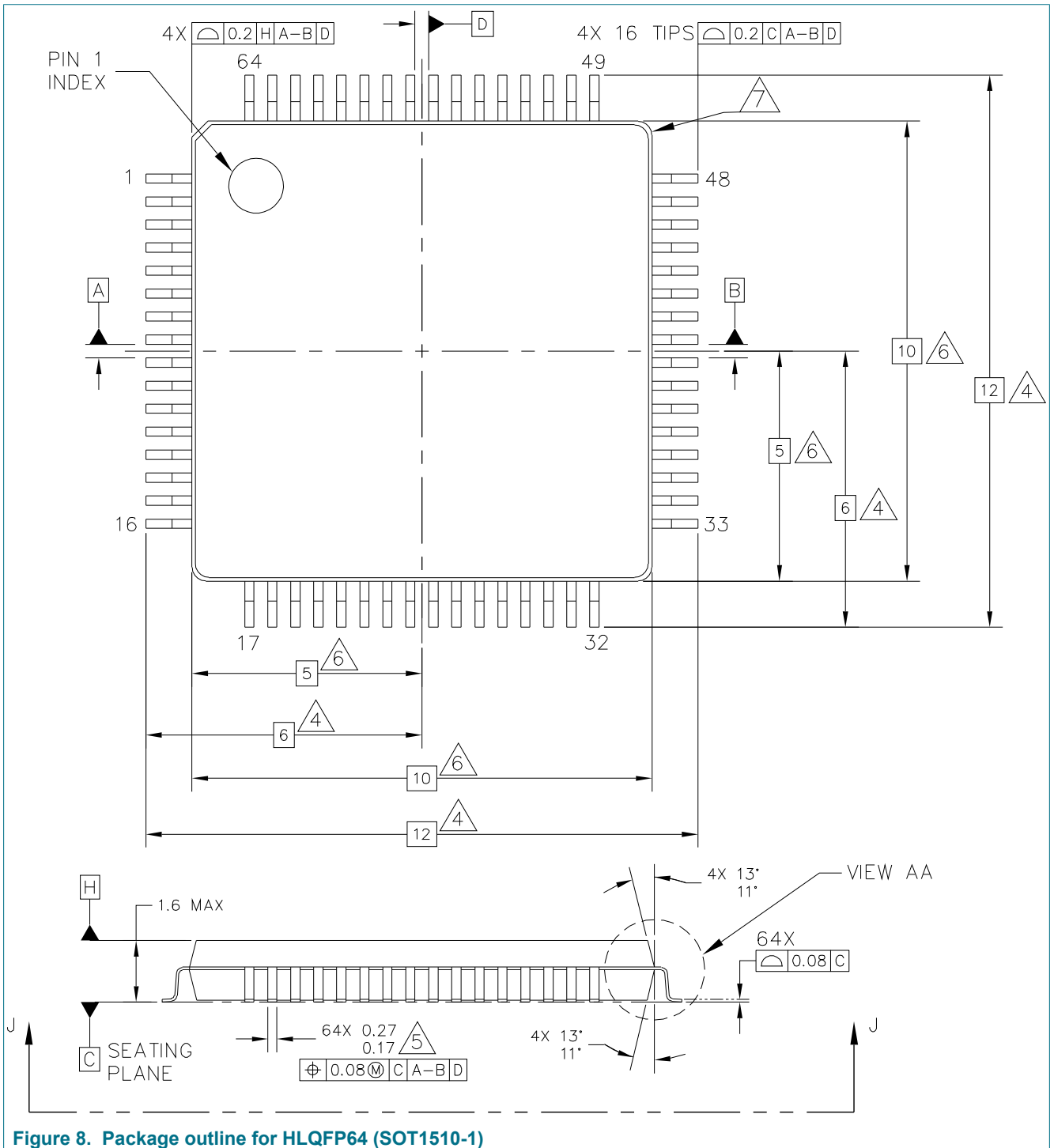
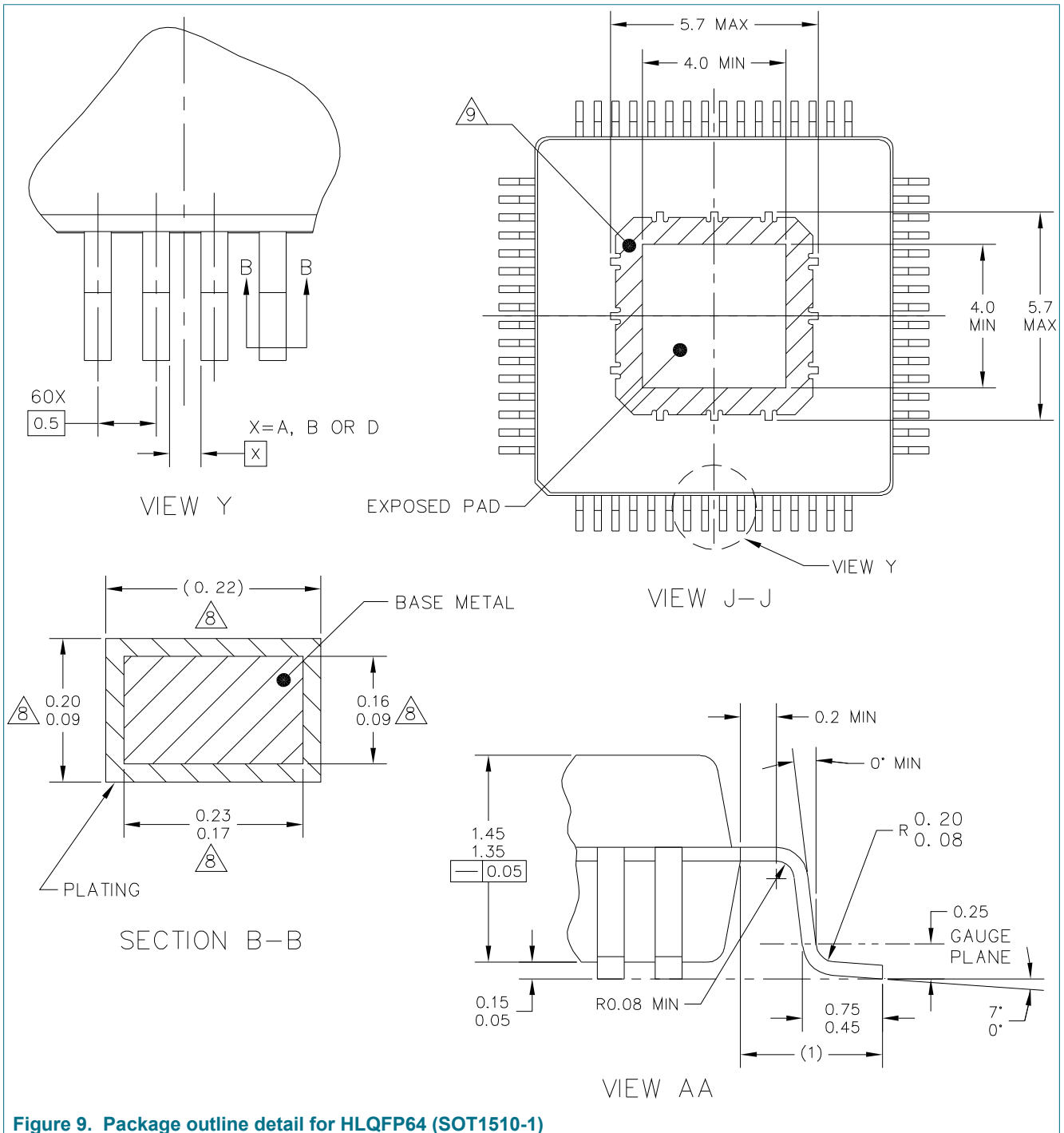


Figure 8. Package outline for HLQFP64 (SOT1510-1)





## NOTES:

1. DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.
3. DATUMS A, B AND D TO BE DETERMINED AT DATUM PLANE H.

4. DIMENSION TO BE DETERMINED AT SEATING PLANE C.

5. THIS DIMENSION DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED THE UPPER LIMIT BY MORE THAN 0.08 MM AT MAXIMUM MATERIAL CONDITION. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE FOOT. MINIMUM SPACE BETWEEN PROTRUSION AND ADJACENT LEAD SHALL NOT BE LESS THAN 0.07 MM.

6. THIS DIMENSION DOES NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS 0.25 MM PER SIDE. THIS DIMENSION IS MAXIMUM PLASTIC BODY SIZE DIMENSION INCLUDING MOLD MISMATCH.

7. EXACT SHAPE OF EACH CORNER IS OPTIONAL.

8. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.1 MM AND 0.25 MM FROM THE LEAD TIP.

9. HATCHED AREA TO BE KEEP OUT ZONE FOR PCB ROUTING.

**Figure 10. Package outline notes for HLQFP64 (SOT1510-1)**

## 12 Revision history

Table 4. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
MC33PT2001_SDS v.7.0	20191105	Product data sheet	—	MC33PT2001_SDS v.6.0
Modifications	<ul style="list-style-type: none"> <li>• <a href="#">Section 8.2</a>: replaced "16 general-purpose digital IOs by "13 general-purpose digital IOs"</li> <li>• <a href="#">Section 9</a>: updated <a href="#">Figure 5</a></li> </ul>			
MC33PT2001_SDS v.6.0	20190619	Product data sheet	—	MC33PT2001_SDS v.5.0
Modifications	<ul style="list-style-type: none"> <li>• <a href="#">Section 9</a>: updated <a href="#">Figure 7</a></li> </ul>			
MC33PT2001_SDS v.5.0	20190515	Product data sheet	—	MC33PT2001_SDS v.4.0
Modifications	<ul style="list-style-type: none"> <li>• Global: changed document status from Preliminary to Product</li> <li>• <a href="#">Table 1</a>: changed PC part to MC and added MC33PT2001MAE part</li> </ul>			
MC33PT2001_SDS v.4.0	20190321	Preliminary data sheet	—	MC33PT2001_SDS v.3.0
Modifications	<ul style="list-style-type: none"> <li>• Global: changed document status from Objective to Preliminary</li> </ul>			
MC33PT2001_SDS v.3.0	20181130	Objective data sheet	—	MC33PT2001_SDS v.2.2
Modifications	<ul style="list-style-type: none"> <li>• Changed revision number to match data sheet</li> </ul>			
MC33PT2001_SDS v.2.2	20180807	Objective data sheet	—	MC33PT2001_SDS v.2.1
MC33PT2001_SDS v.2.1	20180622	Objective data sheet	—	—

## 13 Legal information

### 13.1 Data sheet status

Document status <sup>[1][2]</sup>	Product status <sup>[3]</sup>	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL <http://www.nxp.com>.

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