MC33PT2001

Programmable solenoid controller

Rev. 3.0 — 30 November 2018 Objective 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 characteristic 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:
  - 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 free-wheeling control
- Programmable integrated diagnostics:
  - open-load
  - 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

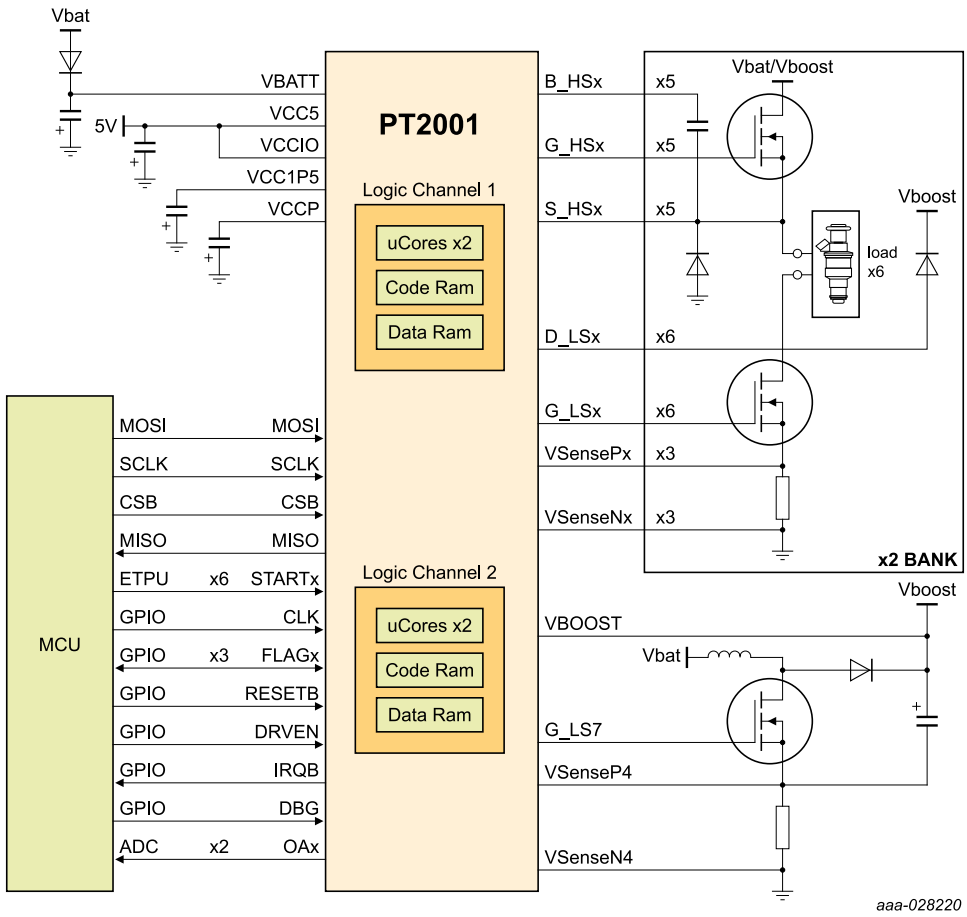


Figure 1. Simplified application diagram

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

This section describes the part numbers available to be purchased along with their differences.

Table 1. Orderable parts

Part number [1]	Temperature (T_A)	Package
PC33PT2001AE	−40 °C to 125 °C	64-pin LQFP with exposed pad

[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

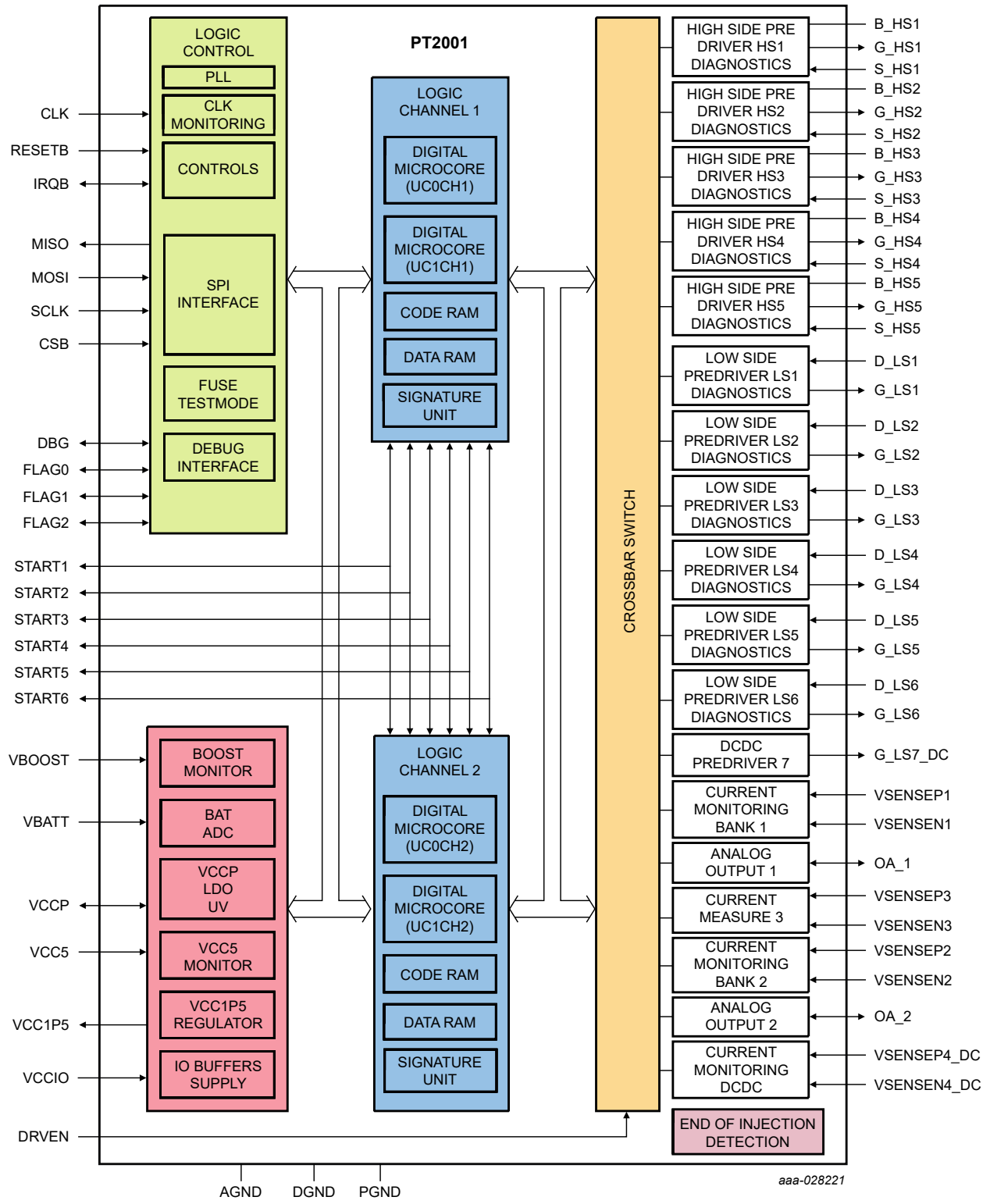


Figure 2. Internal block diagram

7 Pinning information

7.1 Pinning

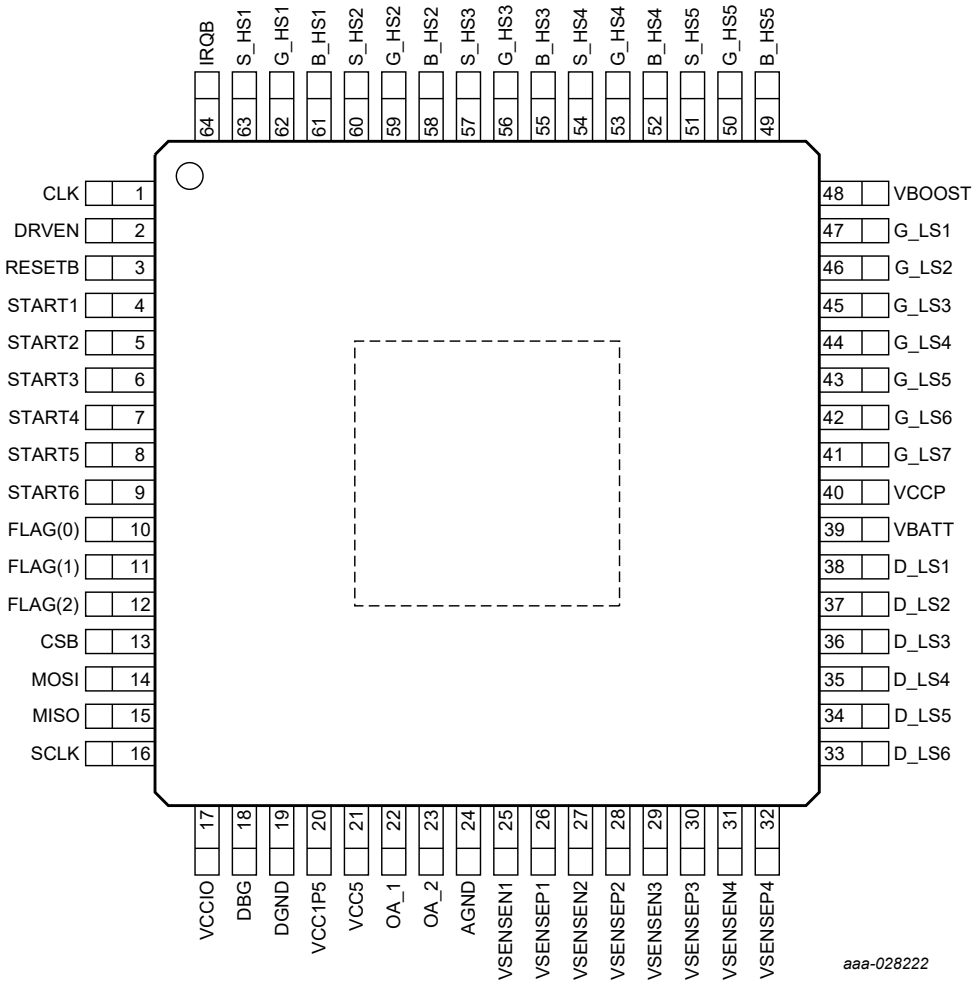


Figure 3. Pin connections

7.2 Pin description

Table 2. Pin definitions

Pin number	Pin name[1][2][3]	Pin function	Definition	Pull-up/pull-down	Reset
1	Clk	In	Clock pin (low frequency reference for internal PLL)	Weak PU [4]	Input
2	DrvEn	In	Driver enable input	Weak PD [5]	Input
3	ResetB	In	Reset pin	Weak PU	Input
4	Start1	In/Out	Trigger pin actuator 1 / Flag_bus(3)	PU/PD[6][7]	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[1][2][3]	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: HiZ
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_ls6	In	Drain pin low-side MOSFET actuator 6	—	—
34	D_ls5	In	Drain pin low-side MOSFET actuator 5	—	—
35	D_ls4	In	Drain pin low-side MOSFET actuator 4	—	—
36	D_ls3	In	Drain pin low-side MOSFET actuator 3	—	—
37	D_ls2	In	Drain pin low-side MOSFET actuator 2	—	—
38	D_ls1	In	Drain pin low-side MOSFET actuator 1	—	—
39	Vbatt	In	Battery voltage and drain pin for high-side predrivers	—	—

Pin number	Pin name[1][2][3]	Pin function	Definition	Pull-up/pull-down	Reset
40	VccP	—	7.0 V Voltage regulator decoupling	—	Regulator off
41	G_ls7	Out	Gate pin low-side MOSFET for DC/DC converter	—	Output: low
42	G_ls6	Out	Gate pin low-side MOSFET actuator 6	—	Output: low
43	G_ls5	Out	Gate pin low-side MOSFET actuator 5	—	Output: low
44	G_ls4	Out	Gate pin low-side MOSFET actuator 4	—	Output: low
45	G_ls3	Out	Gate pin low-side MOSFET actuator 3	—	Output: low
46	G_ls2	Out	Gate pin low-side MOSFET actuator 2	—	Output: low
47	G_ls1	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/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 allow to move the computation from MCU to PT2001 and use 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 will define 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.

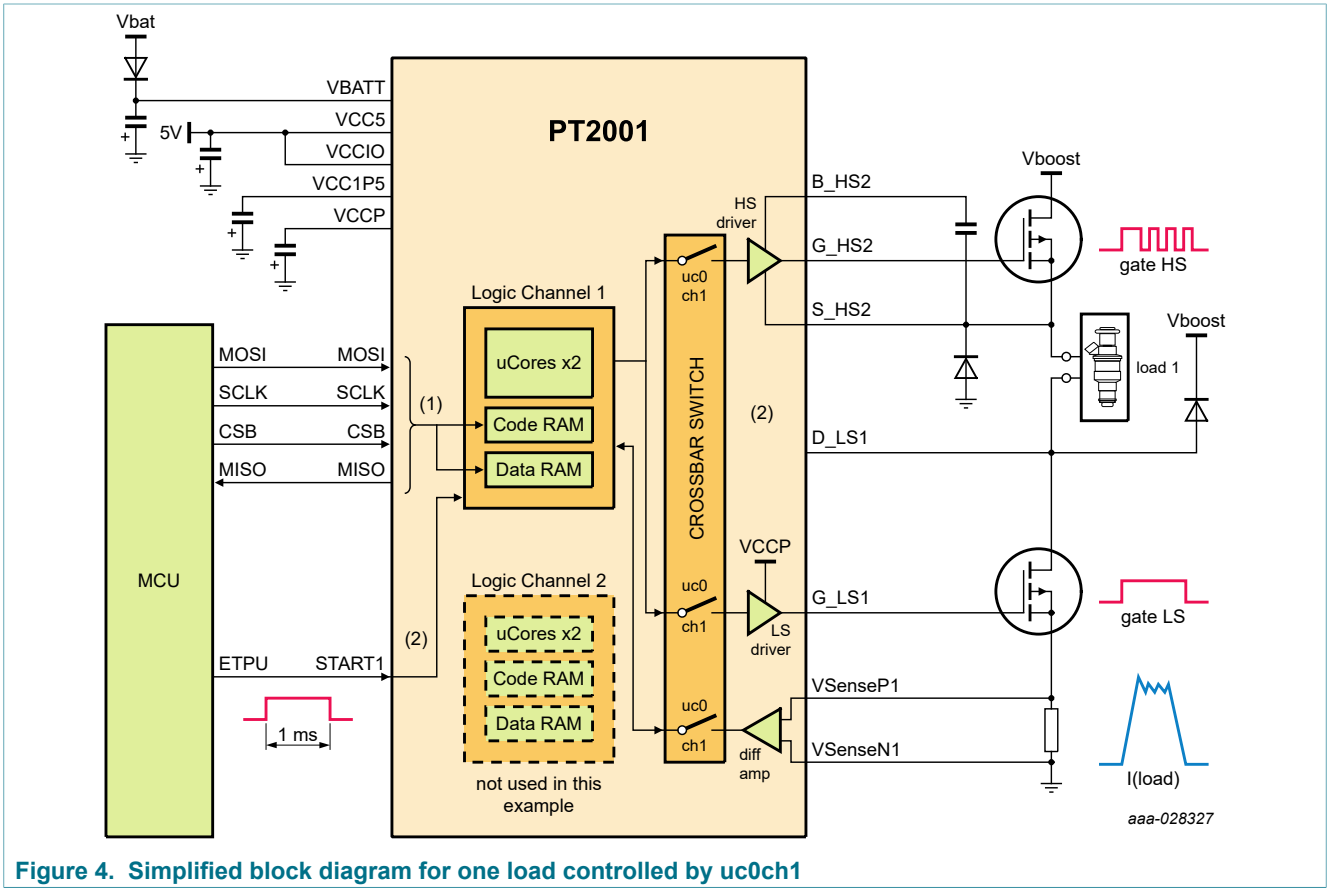


Figure 4. Simplified block diagram for one load controlled by uc0ch1

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/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/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
- 16 general purpose digital IOs able to sustain up to 36 V
- Independent direct predriver inhibition input for safety purposes

9 Typical application

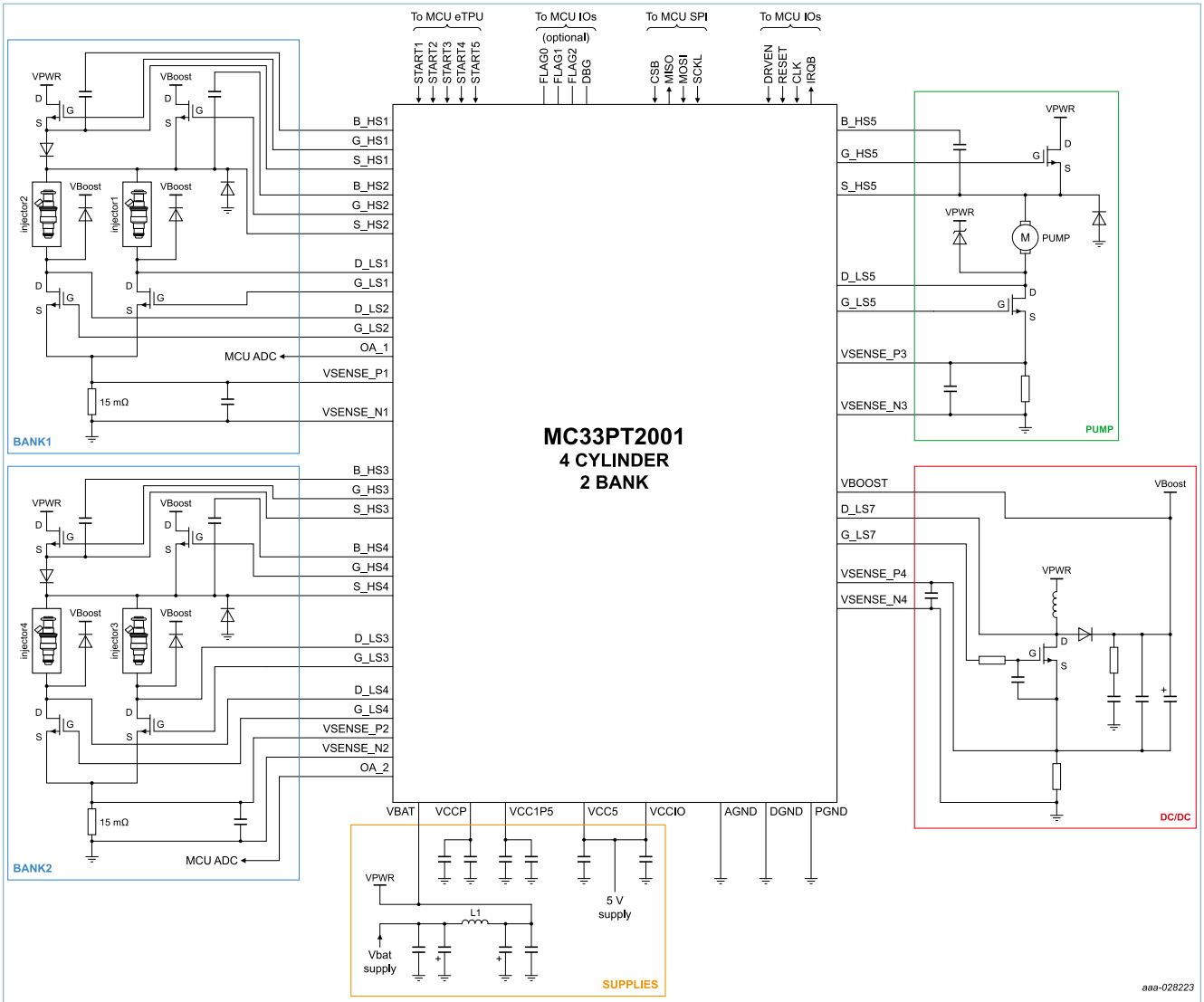


Figure 5. 4 cylinder two bank application

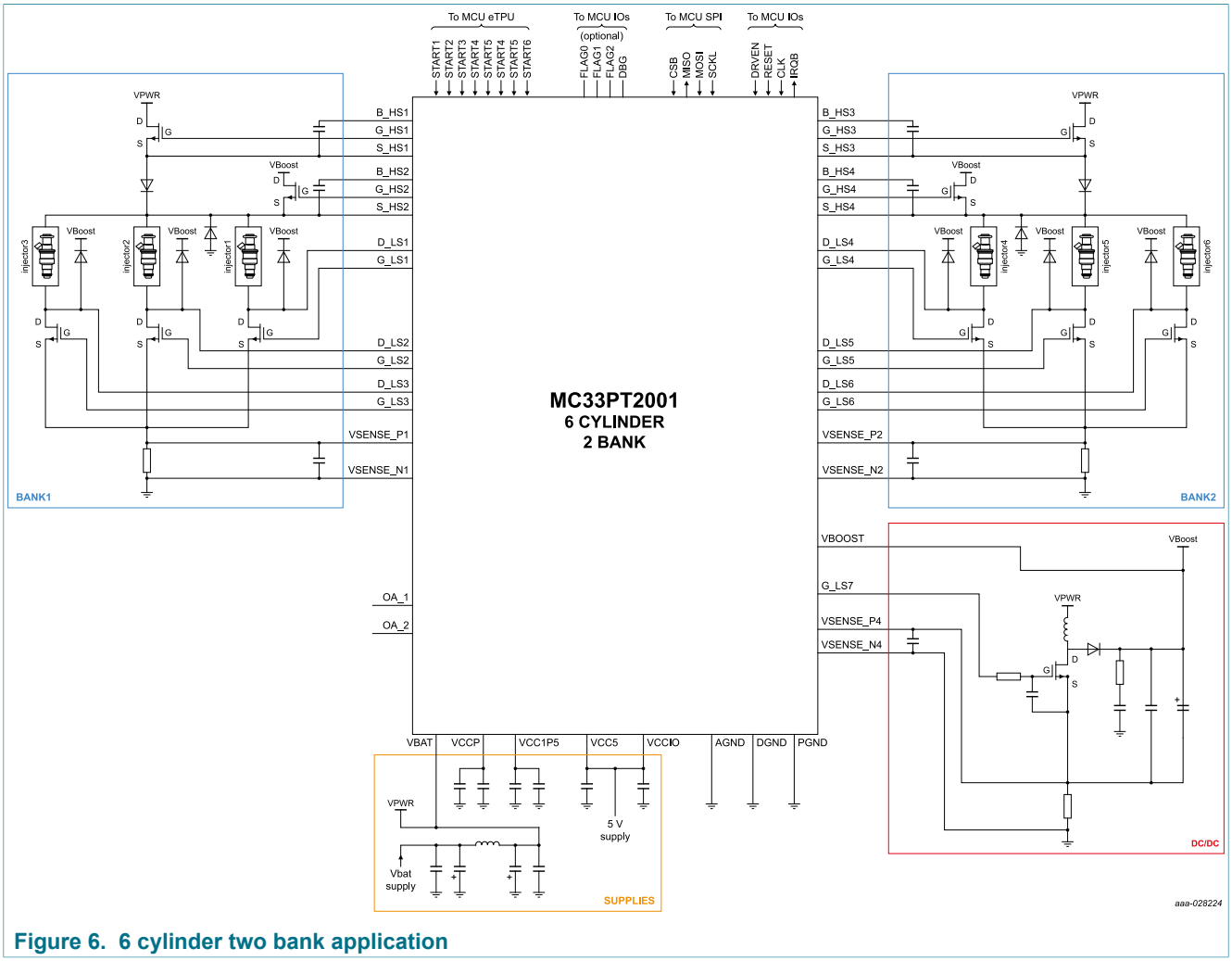


Figure 6. 6 cylinder two bank application

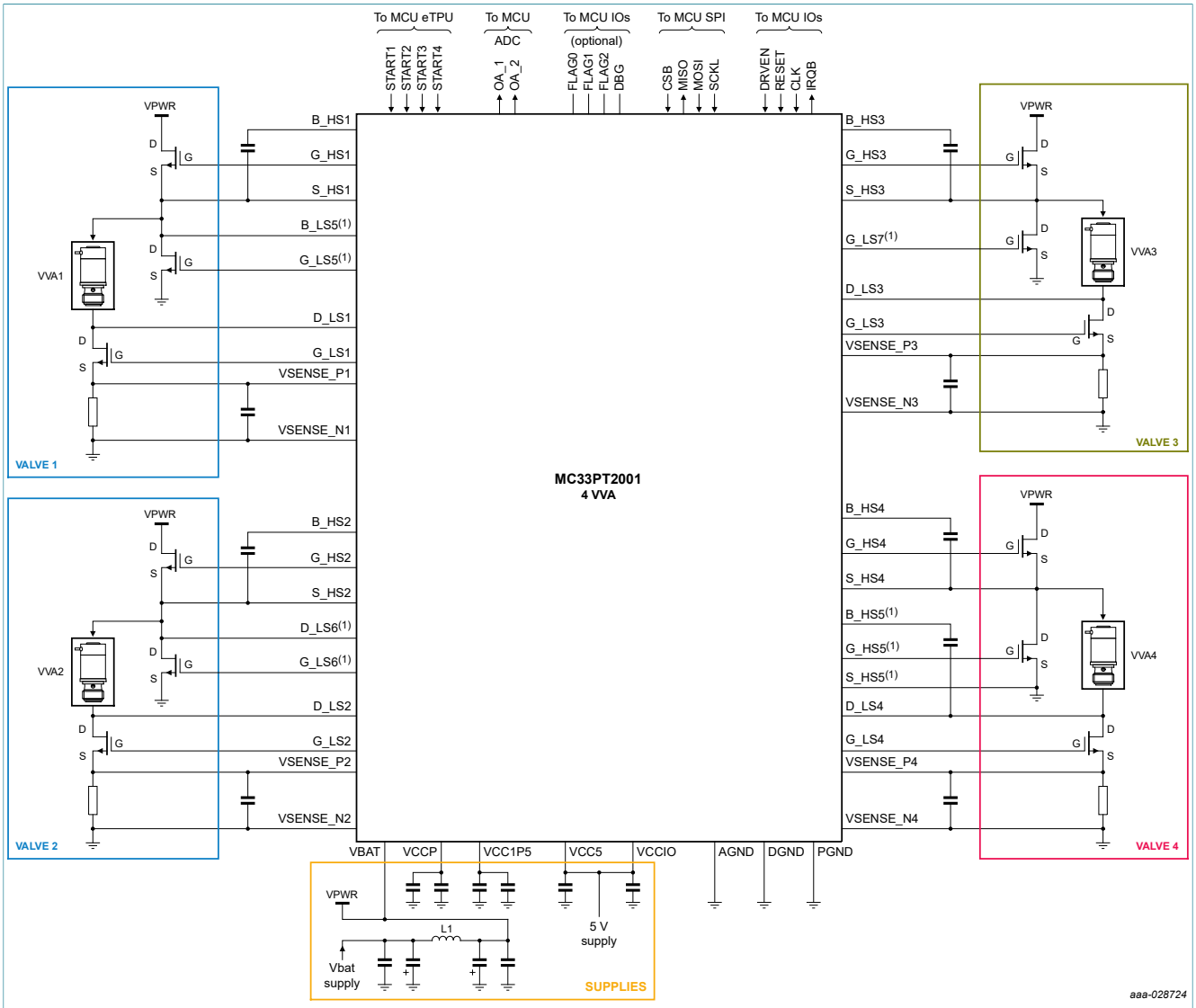


Figure 7. 4 Variable valve actuator application

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.

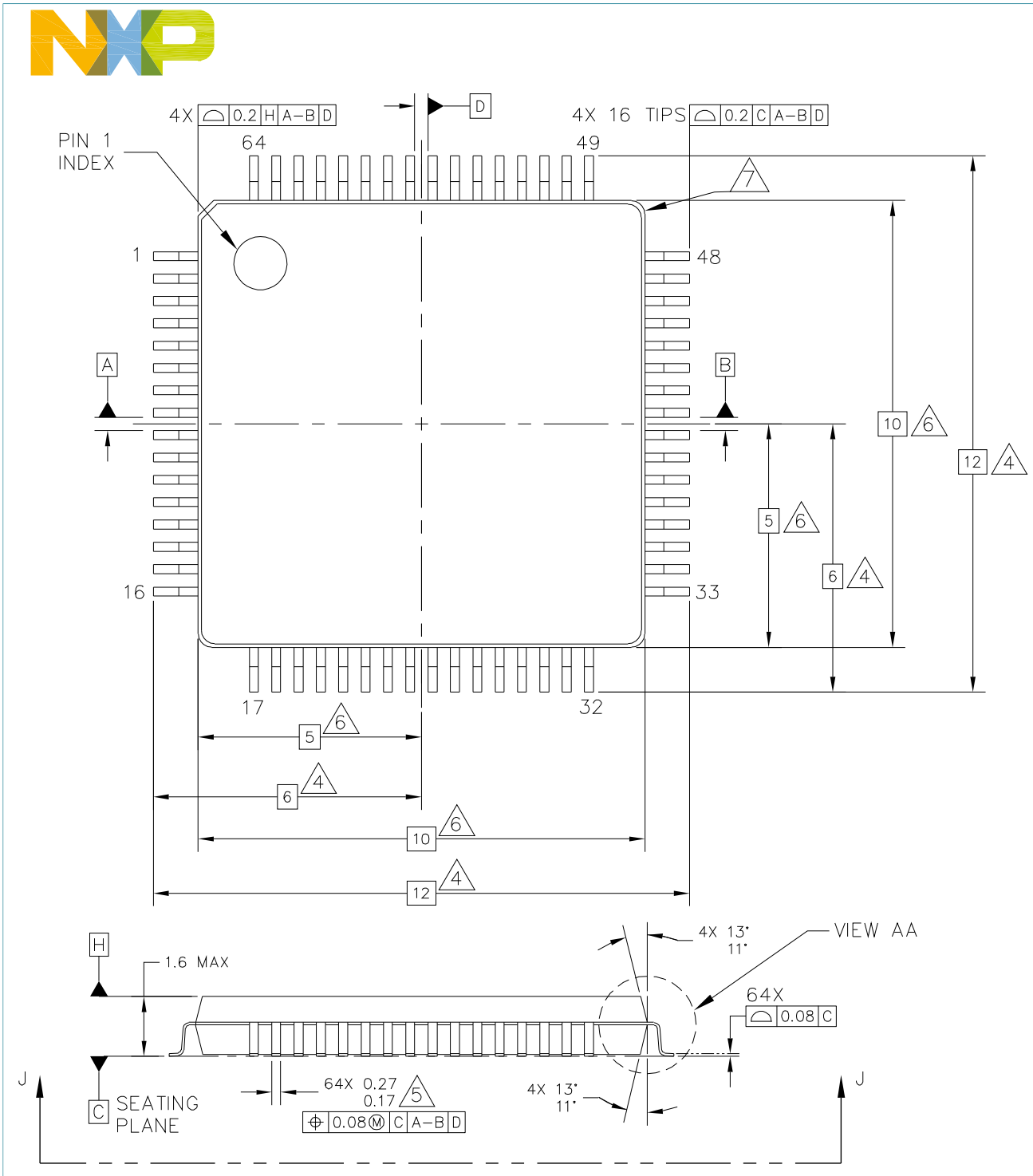
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Electrical ratings						
V_{BOOST}	DC voltage at VBOOST	—	0	—	72	V
V_{BATT}	DC voltage at VBATT	—	–0.3	—	72	V
V_{CC5}	DC voltage at VCC5	—	–0.3	—	36	V
V_{CCIO}	DC voltage at VCCIO	—	–0.3	—	36	V
V_{CC1P5}	DC voltage at VCC1P5	—	–0.3	—	2.0	V

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{DIG}	DC voltage at CLK, MISO, MOSI, SCLK, CSB, IRQB, RESETB	—	–0.3	—	36	V
V_{DRV_EN}	DC voltage at DRVEN	—	–0.3	—	36	V
V_{STARTX}	DC voltage at STARTx	—	–0.3	—	36	V
V_{FLAGX}	DC voltage at FLAGx	—	–0.3	—	36	V
V_{DBG}	DC voltage at DBG	—	–0.3	—	36	V
V_{OA_OUTX}	DC voltage at OA_1, OA_2	—	–0.3	—	36	V
V_{DGND}	DC voltage at DGND	—	–0.3	—	0.3	V
V_{AGND}	DC voltage at AGND	—	–0.3	—	0.3	V
V_{CCP}	DC voltage at VCCP	—	–0.3	—	9.0	V
V_{S_HSX}	S_HSx	• DC voltage	–3.0	—	$V_{BOOSTMAX}$	V
		• Transients t < 800 ns	–6.0	—	$V_{BOOSTMAX}$	
		• Transients t < 400 ns	–8.0	—	$V_{BOOSTMAX}$	
V_{B_HSX}	B_HSx	• DC voltage	–0.3	—	V_{S_HSX} + $V_{BS\_HSX\_CL}$	V
		• Transients t < 800 ns	–2.0	—		
		• Transients t < 400 ns	–4.0	—		
V_{G_HSX}	DC voltage at G_HSx	—	VS_HSx–0.3	—	V_{B_HSx}+0.3	V
V_{G_LSX}	G_LSx	• DC voltage	–0.3	—	V_{CCP}+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_{CCP} + 1.5	
V_{D_LSX}	D_LSx	• DC voltage	–3.0	—	75	V
		• Transients t < 400 ns	–8.0	—	75	
$V_{VSENSEN1/2/3}$	DC voltage at VSENSEN1/2/3	• 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 µsat VCC5 < 5.25 V	–15	—	15	
$V_{VSENSEP1/2/3}$	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 µsat VCC5 < 5.25 V	–15	—	15	
$V_{VSENSEN4}$	DC voltage at VSENSEN4	• 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 µsat VCC5 < 5.25 V	–5.0	—	5.0	
		• Dynamic for max 1.0 µsat VCC5 < 5.25 V	–15	—	15	

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{VSENSEP4}$	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 µsat VCC5 < 5.25 V	–15	—	15	
ESD voltage						
	Human body model (HBM)					V
$V_{ESD-HBM1}$	• VBOOST, VBATT, S_HSx	—	–4000	—	4000	
$V_{ESD-HBM2}$	• D_LSx	—	–8000	—	8000	
$V_{ESD-HBM3}$	• All other pins	—	–2000	—	2000	
	Machine model					
$V_{ESD-CDM1}$	• Corner pins	—	–750	—	750	
$V_{ESD-CDM2}$	• All other pins	—	–500	—	500	
Thermal ratings						
	Operating temperature					°C
T_A	• Ambient	—	–40	—	125	
T_J	• Junction	—	–40	—	150	
$T_{THRESHOLD}$	Temperature monitoring threshold	—	167	—	187	°C
T_{STG}	Storage ambient temperature	—	–55	—	150	°C
Thermal resistance						
$R_{\theta JA}$	Thermal resistance junction to ambient	—	—	—	25.3	°C/W
$R_{\theta JCTOP}$	Thermal resistance junction to case top	—	—	—	13.2	°C/W
$R_{\theta JCBOTTOM}$	Thermal resistance junction to case bottom	—	—	—	0.8	°C/W

11 Package dimensions

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



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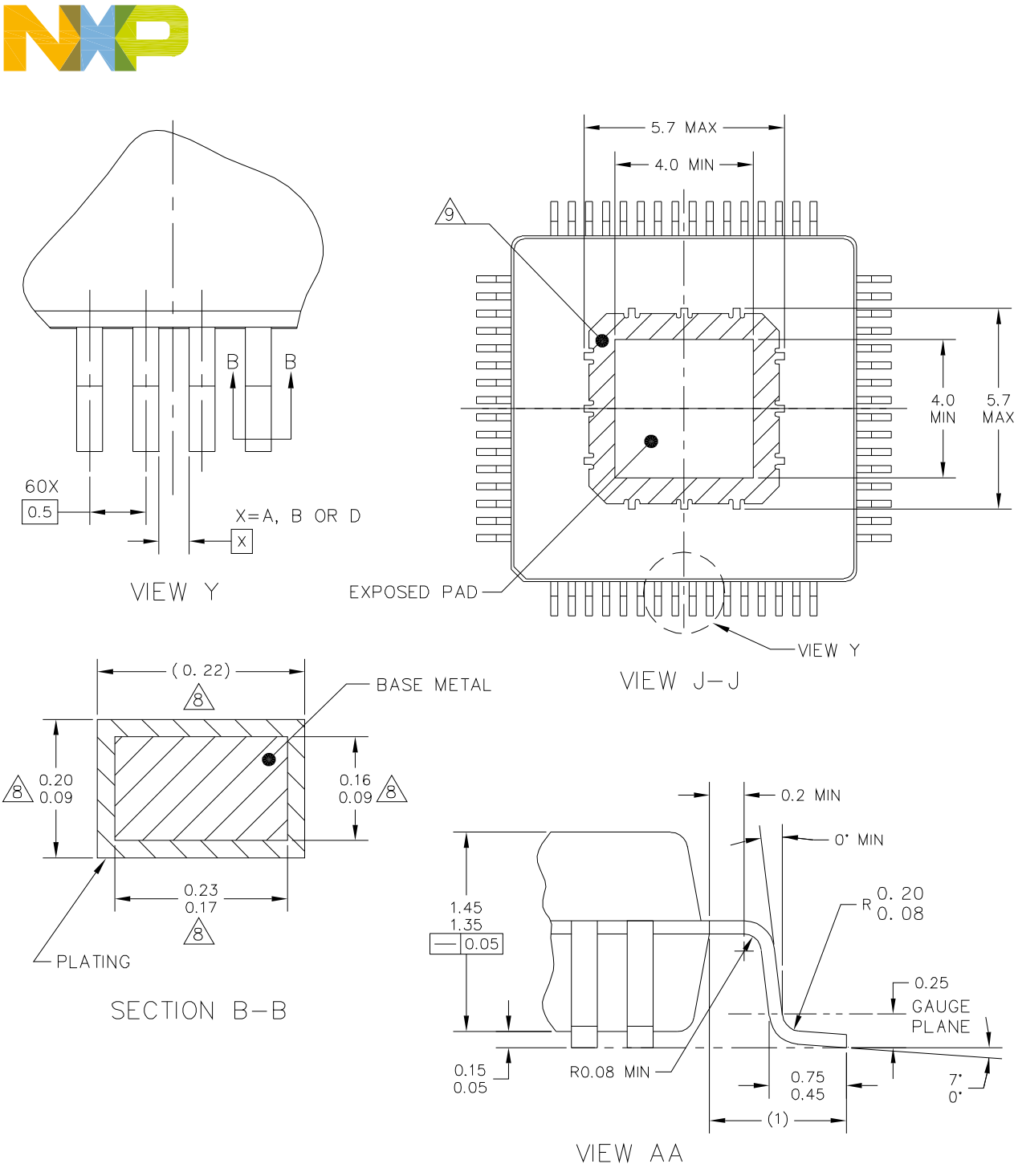

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	SOT1510-1	06 JAN 2016

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.

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	STANDARD: JEDEC MS-026 BCD	
	SOT1510-1	06 JAN 2016

Figure 8. Package outline

12 Revision history

Table 4. Revision history

Document ID	Release date	Data sheet status	Change notice	Supercedes
MC33PT2001_SDS v.3.0	20181130	Objective	—	MC33PT2001_SDS v.2.2
Modifications	• Changed revision number to match data sheet			
MC33PT2001_SDS v.2.2	20180807	Objective	—	MC33PT2001_SDS v.2.1
MC33PT2001_SDS v.2.1	20180622	Objective	—	—

13 Legal information

13.1 Data sheet status

Document status[1][2]	Product status[3]	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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