AP4410AEC

Ultra Low Power Dual Voltage Detector

1. General Description

The AP4410AEC is a voltage detector IC for monitoring battery, power supply and system voltage. The circuit includes dual voltage detection with built-in gate logic and MOSFETs. The AP4410AEC offers ultra-low power consumption that is 0.026μA per channel.
The built- in CMOS logic circuit can be controlled independently from the voltage detector. The polarity of the voltage detection results is controlled by pins. This function enables the AP4410AEC as a load switch by using the results of the voltage detection. The AP4410AEC achieves better performance and PCB area than conventional CMOS voltage detector ICs, with discrete logics and external MOSFETs.
The AP4410AEC is ideal for voltage conversion or load switch of thin and small wearable devices, over charge/discharge protection of Lithium-ion batteries, power management part of energy harvesting applications.

2. Features

- Power management function
  - Dual voltage detection circuits
  - Control logic with independent power supply
  - Built in P-channel MOSFETs and N-Channel MOSFETs for each channel
- Wide range for detection voltage
  - Detection voltage “High” 1.8 to 2.7V (Options)
  - Detection voltage “Low” 1.7 to 2.65V (Options)
- Voltage detection accuracy ±35mV
- Ultra-low power consumption 0.026μA typical/ch. 0.050μA maximum/ ch
- Response Speed 500μs maximum
- On resistance On-chip P-channel MOSFETs 1Ω typical
  On-chip N-channel MOSFETs 2Ω typical
- Operation temperature -40 - +85 °C
- Package 20-pin WLCSP (1.955×1.555mm, 0.4mm pitch)

3. Table of Contents

4. Block Diagram

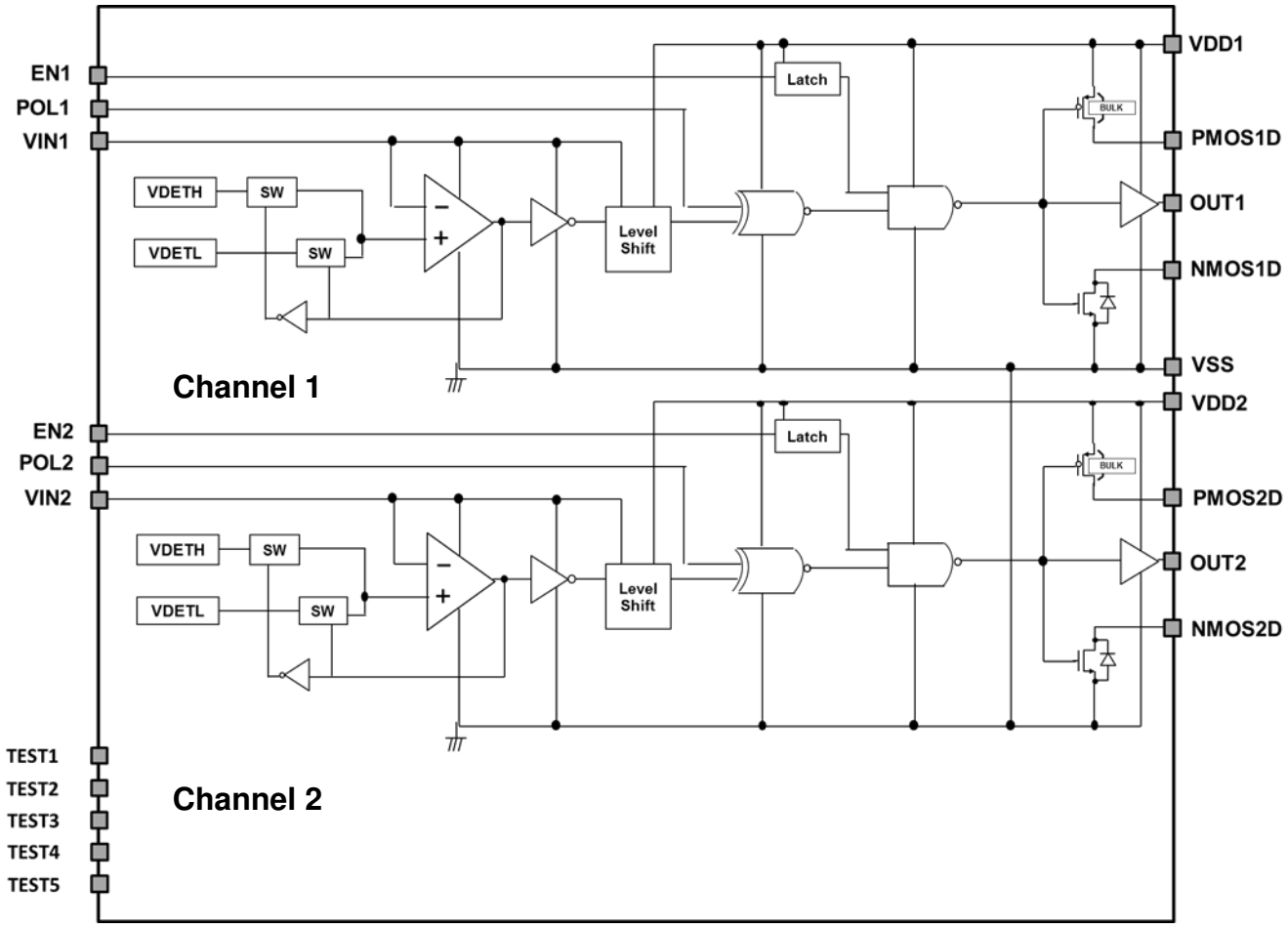


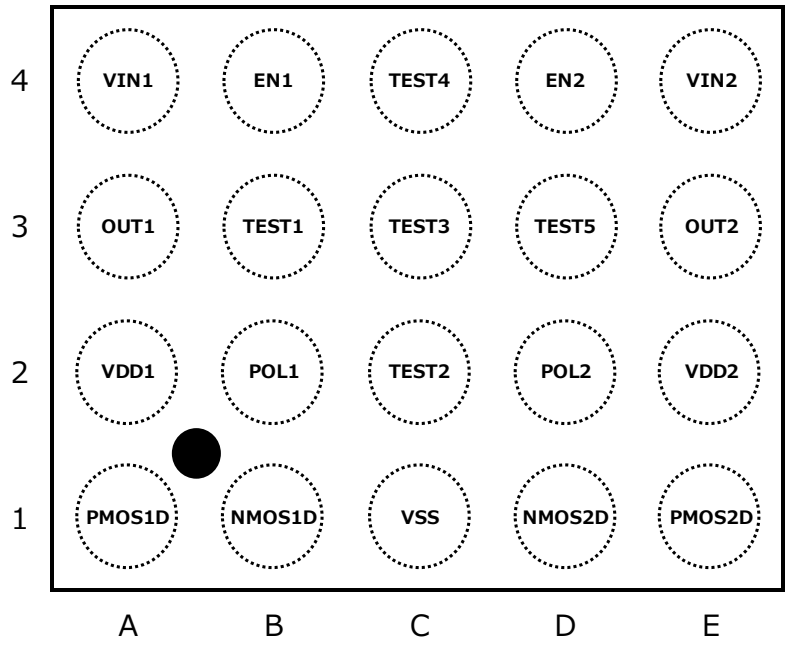
Figure 1. Block Diagram

5. Pin Configuration and Function

■ Pin Configuration

・20-pin WLCSP

TOP View



■ Function

WLCSP Pin	Pin Name	I/O	Function
A1	PMOS1D	Input/Output	PMOS drain pin (Channel 1)
A2	VDD1	Power	Power supply(Channel 1)
A3	OUT1	Output	Logic output (Channel 1)
A4	VIN1	Power	Detection input pin (Channel 1)
B1	NMOS1D	Output	NMOS1 drain pin(Channel 1)
B2	POL1	Input	Polarity cotrol pin (Channel 1)
B3	TEST1	-	For test purposes. This pin should be connected to VSS.
B4	EN1	Input	Enable pin (Channel 1)
C1	VSS	Ground	Ground
C2	TEST2	-	For test purposes. This pin should be connected to VSS.
C3	TEST3	-	For test purposes. This pin should be connected to VSS.
C4	TEST4	-	For test purposes. This pin should be connected to VSS.
D1	NMOS2D	Output	NMOS drain pin(Channel 2)
D2	POL2	Input	Polarity cotrol pin (Channel 2)
D3	TEST5	-	For test purposes. This pin should be connected to VSS.
D4	EN2	Input	Enable pin (Channel 2)
E1	PMOS2D	Input / Output	PMOS drain pin (Channel 2)
E2	VDD2	Power	Power supply(Channel 2)
E3	OUT2	Output	Logic output (Channel 2)
E4	VIN2	Power	Detection input pin (Channel 2)

6. Absolute Maximum Ratings

Parameter	Symbol	min	max	Unit
Pin Voltage (Note 1)	VIN1,VIN2, VDD1,VDD2	-0.3	6.5	V
	OUT1,EN1,POL1	VSS-0.3	VDD1 + 0.3	V
	OUT2,EN2,POL2	VSS-0.3	VDD2 + 0.3	V
	PMOS1D PMOS2D	-0.3	6.5	V
	NMOS1D NMOS2D	-0.3	6.5	V
Power dissipation	Pd	-	0.8	W
Storage Temperature	Tstg	-55	150	°C

Note 1. All voltages are with reference to VSS = 0 V.

WARNING: Stresses exceeding Maximum Ratings may damage the device. Normal operation is not guarantee if the condition exceeds the maximum rating.

7. Recommended Operating Conditions

Parameter	Symbol	min	max	Unit
Operation Temperature	Ta	-40	85	°C
Power Supply Volgtage	VIN1 VIN2 VDD1 VDD2	1.3	5.5	V

8. Electrical Characteristics

(Ta= -40 – +85°C, VIN1, VIN2, VDD1 and VDD2 =1.3V to 5.5V, OUT=open, PMOSD=open, NMOSD=open, unless otherwise specified.)

Parameter	Symbol	min	typ	max	Unit	Condition
Detection Voltage “High”	VDETH	V_{DETH} -0.035	V_{DETH}	V_{DETH} +0.035	V	Ta=25°C VIN= “L”→”H” Please refer 10. Reference data (Detection Voltage vs Ta)
		V_{DETH} -0.045		V_{DETH} +0.045	V	Ta=85°C VIN= “L”→”H” Please refer 10. Reference data (Detection Voltage vs Ta)
Detection Voltage ”Low”	VDETL	V_{DETL} -0.035	V_{DETL}	V_{DETL} +0.035	V	Ta=25°C VIN= “H”→”L” Please refer 10. Reference data (Detection Voltage vs Ta)
		V_{DETL} -0.045		V_{DETL} +0.045	V	Ta=85°C VIN= “H”→”L” Please refer 10. Reference data (Detection Voltage vs Ta)
Power Consumption	IVIN	-	0.026	0.050	μA	Consumption for VIN per channel while the voltage detection circuit is active. Please refer 10. Reference data (Current consumption vs VIN & VDD)
	IVDD (Note 2) (Note 3)	-	0.0001	0.100	μA	Consumption for VDD1 and VDD2. Please refer 10. Reference data (Current consumption vs VIN & VDD)
“High”Level Input Voltage	VIH	VDD ×0.8	-	-	V	
“Low” Level Input Voltage	VIL	-	-	VDD ×0.2	V	
EN pin reverse current (Push, Pull)	$\mid I_{EN} \mid$	0.15		-	μA	
IOH (Note 4)	I_{OH}	0.15	-	-	mA	VIN=V_{DETH}+0.1V, OUT=VDD-0.5V
IOL(Note 4)	I_{OL}	0.2	-	-	mA	VIN=V_{DETL}-0.1V, OUT=0.5V
Response Time (Note 5)	tPLH	-	0.2	0.5	ms	VIN=V_{DETH}-0.1V→V_{DETH}+0.1V VIN= V_{DETL}+0.1V→V_{DETL}-0.1V Please refer 10. Reference data (Response time)
	tPHL	-	0.2	0.5	ms	
P-ch MOSFET On-resistance	RonP	-	1	2.3	Ω	VDD≧1.7V
N-ch MOSFET On-resistance	RonN	-	2	5	Ω	VDD≧1.7V

Note 2. Output drive is not included.
Note 3. Total power consumption VDD1 and VDD2 (VDD1+VDD2).
Note 4. Output current depends on VDD1 and VDD2.
IOL shows N-Channel pull current when AP4410AEC OUT1/OUT2 output low.
IOH shows P-Channel push current when AP4410AEC OUT1/OUT2 output high.
Note 5. Response time for OUT1 pin and OUT2 pin

9. Description

■ Voltage Detection Function

VIN1 pin and VIN2 pin = (Abbreviation ;VIN)
VDD1 pin and VDD2 pin = (Abbreviation ;VDD)
POL1 pin and POL2 pin = (Abbreviation ;POL)
EN1 pin and EN2 pin = (Abbreviation ;EN)

1) When the input volgatge is increasing,
The OUT1 pin and OUT2 pin(Abbreviation ;OUT) will be in undefined status when VIN voltage is from VSS to AP4410AEC minimum operating voltage(1.3V). The AP4410AEC internal signal A(Please refer Figure 2) outputs VSS when VIN volgate exceeds minimum operating voltage. When VIN voltage reaches to the detection voltage (VDETH), the internal signal A outputs VIN voltage.

2) When the input voltage is decreasing,
When VIN voltage is higher than VDETH, internal signal A outputs VIN. When VIN goes under the detection voltage (VDETL), OUT outputs VSS. The internal signal A will be undefined status when VIN voltege becomes lower than AP4410AEC minimum operating voltage(1.3V).

The logic inputs POL and EN become valid when VDD voltage exceeds 1.3V which is the minimum operation voltage. In case of POL = “L”, EN=”H”, OUT behaves as Figure. 3. The AP4410AEC is able to output the inverted results of the voltage detection using POL. EN can control P-channel MOSFET and N-channel MOSFET ON and OFF. EN has latch function so that it keeps its present state if the input becomes Hi-Z. The BULK of the P-channel MOSFET is connected to the higher voltage pin between VDD and PMOSD.

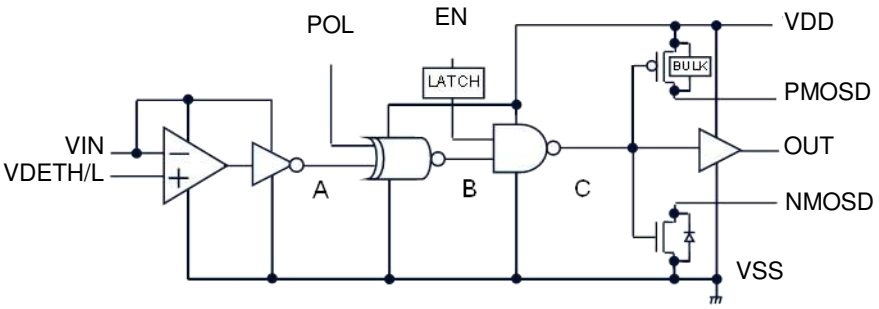


Figure 2. Block Diagram of Control Logic Part (Each channel)

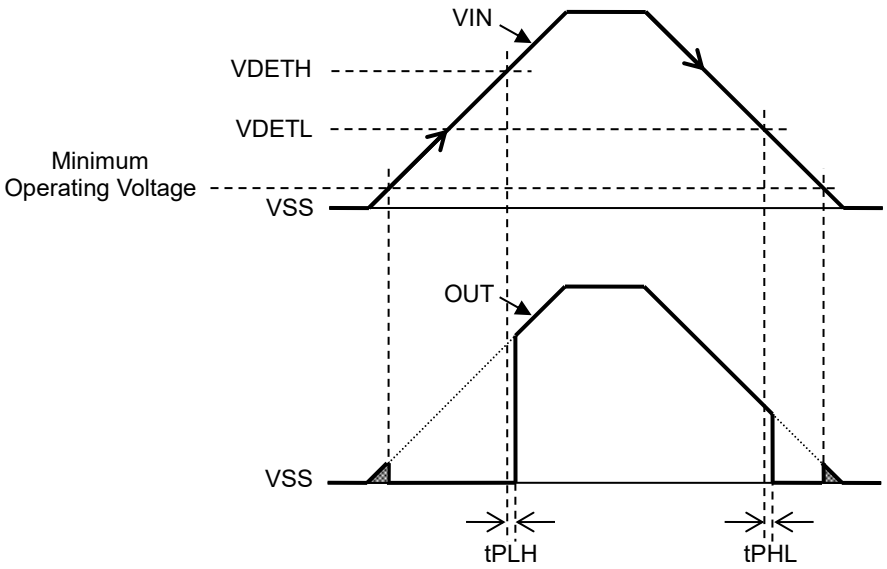


Figure 3.Function of AP4410AEC voltage detection

Table 1. Control logic truth table (Note 6)

POL input	VIN	EN input	Internal signal A	Internal signal B	Internal signal C	PMOSD	NMOSD	OUT	Note
L	VIN<VDETH	L	L	H	H	OPEN	L	H	-
L	VIN<VDETH	H	L	H	L	H	OPEN	L	OUT= positive polarity
L	VIN≧VDETH	H	H	L	H	OPEN	L	H	
L	VIN≧VDETH	L	H	L	H	OPEN	L	H	-
H	VIN<VDETH	L	L	L	H	OPEN	L	H	-
H	VIN<VDETH	H	L	L	H	OPEN	L	H	OUT= negative polarity
H	VIN≧VDETH	H	H	H	L	H	OPEN	L	
H	VIN≧VDETH	L	H	H	H	OPEN	L	H	-

Note 6. When the VIN voltage is increasing from VDETL or lower.

Table 2 Control logic truth table (Note 7)

POL input	VIN	EN input	Internal signal A	Internal signal B	Internal signal C	PMOSD	NMOSD	OUT	Note
L	VIN>VDETL	L	H	L	H	OPEN	L	H	-
L	VIN>VDETL	H	H	L	H	OPEN	L	H	OUT= positive polarity
L	VIN≦VDETL	H	L	H	L	H	OPEN	L	
L	VIN≦VDETL	L	L	H	H	OPEN	L	H	-
H	VIN>VDETL	L	H	H	H	OPEN	L	H	-
H	VIN>VDETL	H	H	H	L	H	OPEN	L	OUT= negative polarity
H	VIN≦VDETL	H	L	L	H	OPEN	L	H	
H	VIN≦VDETL	L	L	L	H	OPEN	L	H	-

Note 7. When the VIN voltage is decreasing from VDETH or higher.

10. Reference Data

■ Detection Voltage “High” (VDETH) and “Low” (VDETL) vs VIN

1) VDETH=2.5V, VDETL=2.1V (POL=”L”)

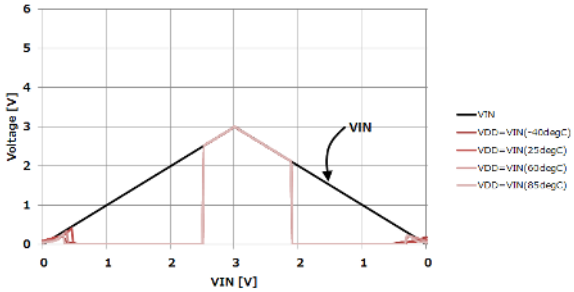


Figure 4. VDD=VIN

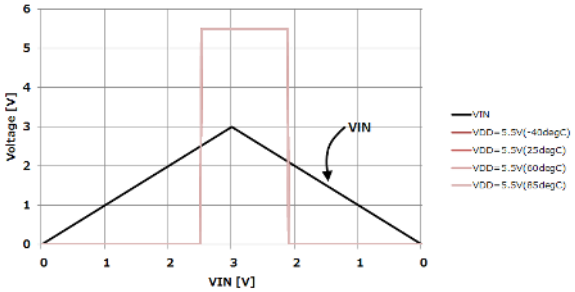


Figure 5. VDD=5.5V

2) VDETH=1.8V, VDETL=1.7V (POL=”L”)

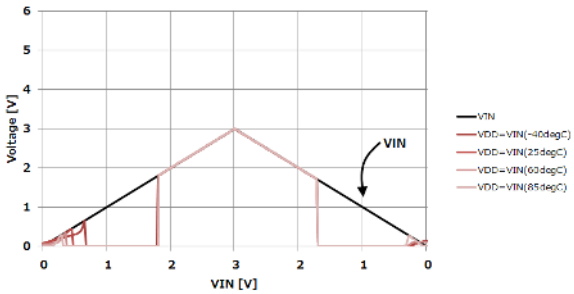


Figure 6. VDD=VIN

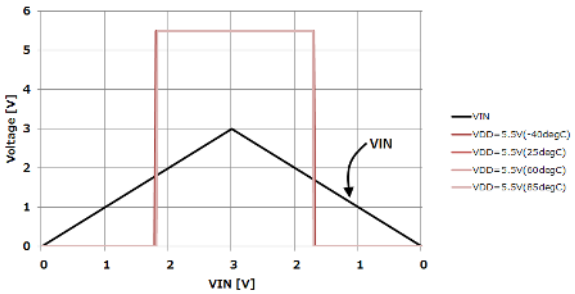


Figure 7. VDD=5.5V

■ Detection Voltage “High” (VDETH) and “Low” (VDETL) vs Ta

ΔVDET(mV) vs Ta

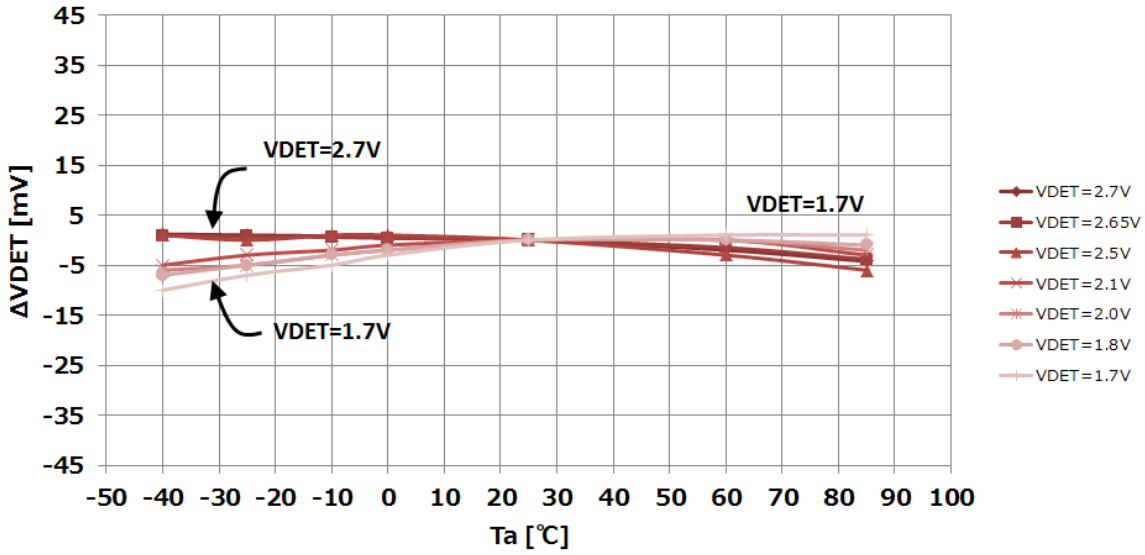


Figure 8. ΔVDET(mV) vs Ta

1) ΔVDET(%) vs Ta

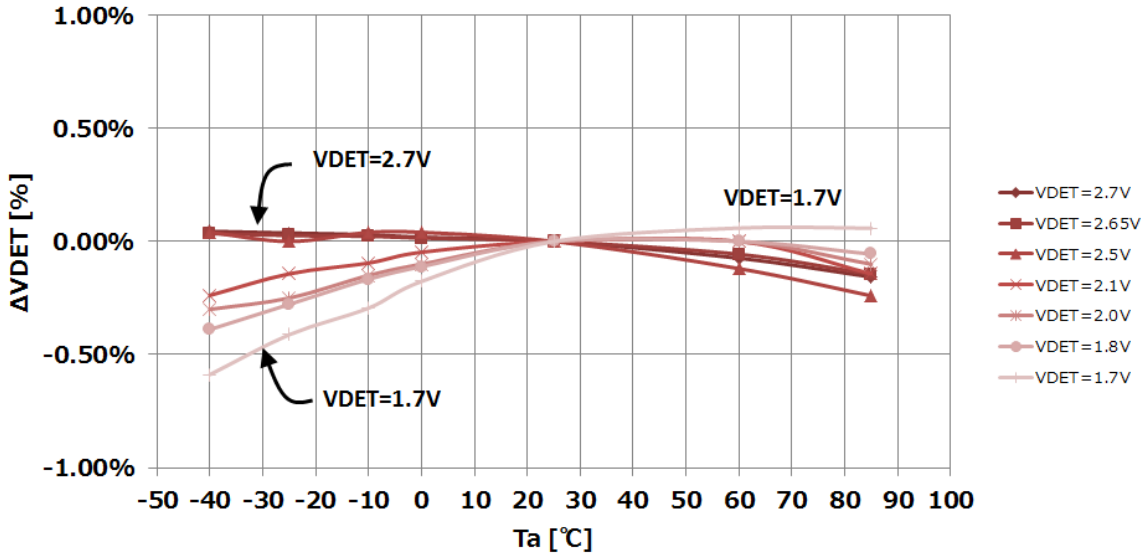


Figure 9. ΔVDET(%) vs Ta

Note 8. ΔVDET(%)=ΔVDET/ VDET (V)

■ Current consumption vs VIN & VDD

1) VDETH=2.5V, VDETL=2.1V (POL="L")

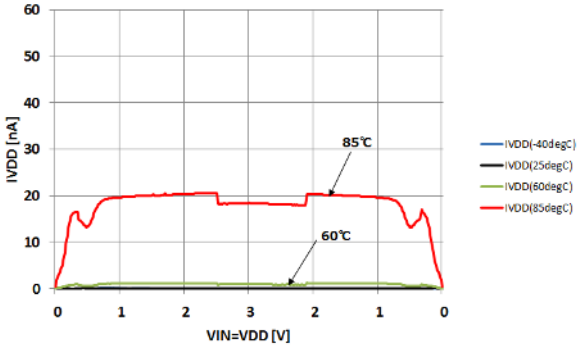


Figure 10. VDD=VIN

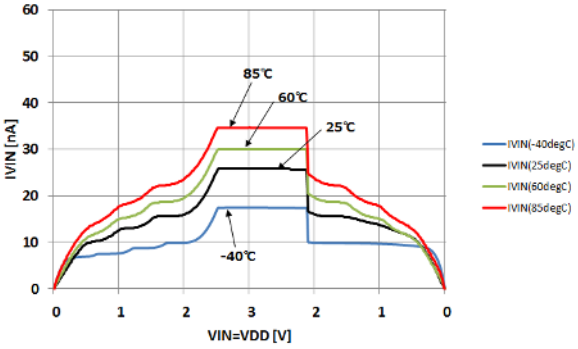


Figure 11. VDD=5.5V

2) VDETH=1.8V, VDETL=1.7V (POL="L")

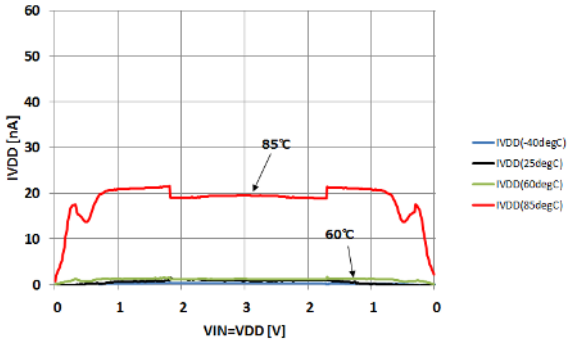


Figure 12. IVDD

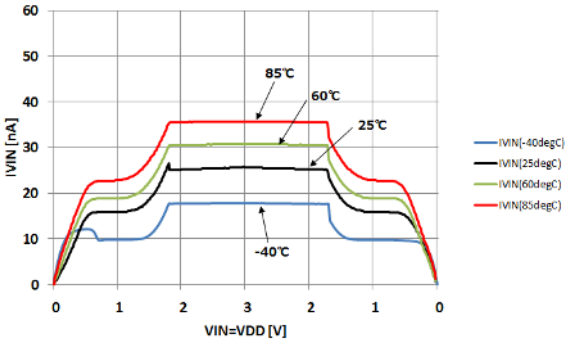


Figure 13. IVIN

■ Power Comsumption vs Ta (VIN=VDD=5.5V)

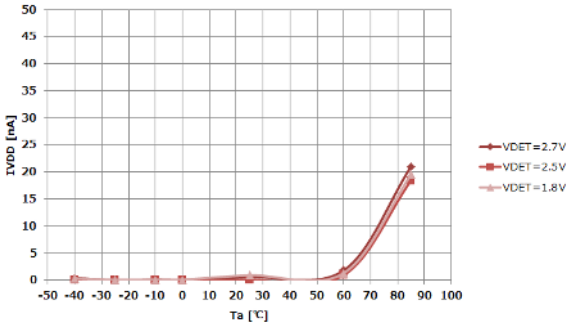


Figure 14. IVDD

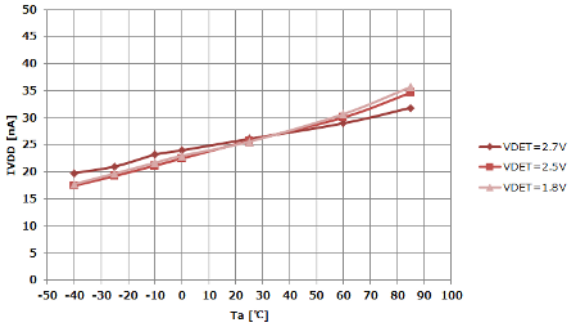


Figure 15. IVIN

■ Response time (tPLH, tPHL)

1) VDETH=2.5V, VDETL=2.1V (POL="L")

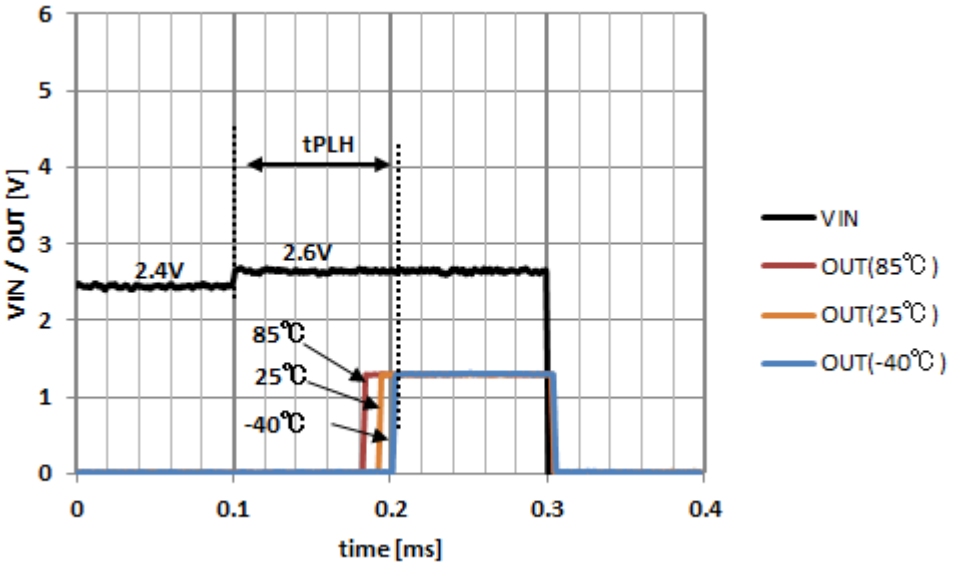


Figure 16. tPLH for VDETH=2.5V, VDETL=2.1V (POL="L"), VDD=1.3V

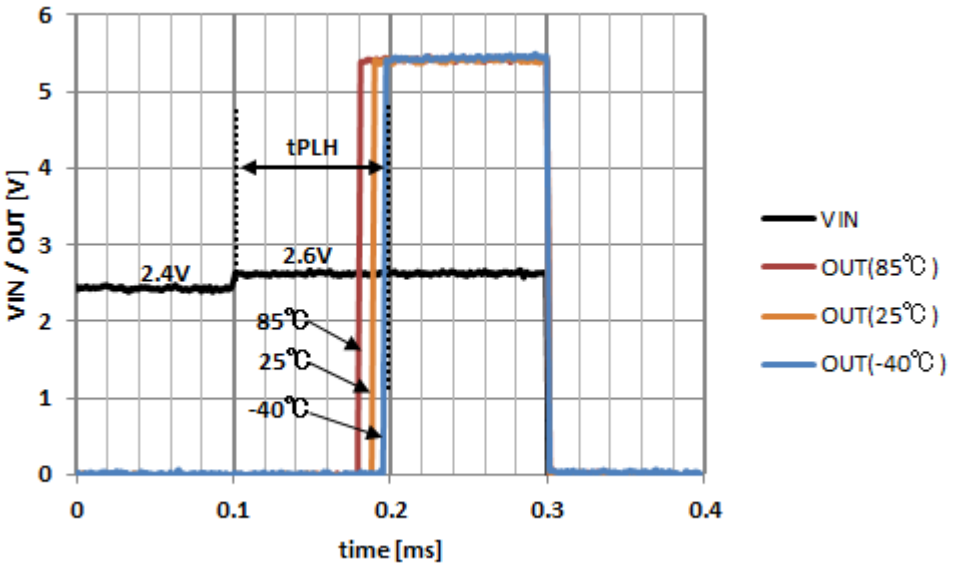


Figure 17. tPLH for VDETH=2.5V, VDETL=2.1V (POL="L"), VDD=5.5V

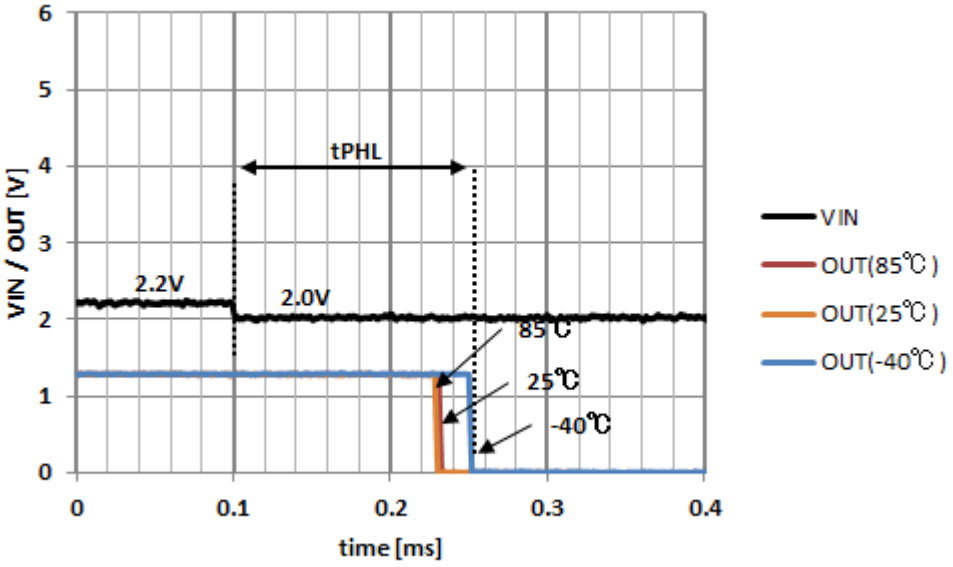


Figure 18. tPHL for VDETH=2.5V, VDETL=2.1V (POL="L"), VDD=1.3V

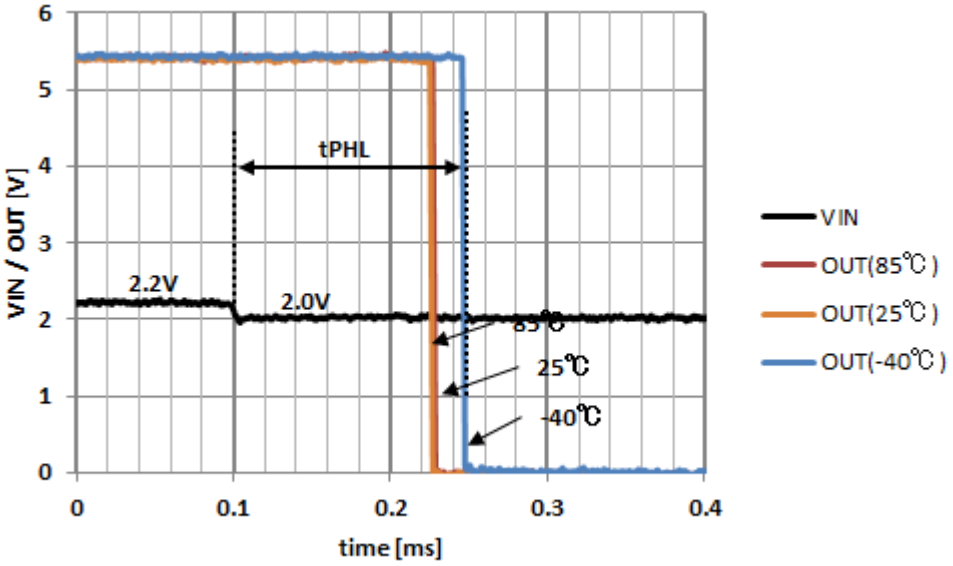


Figure 19. tPHL for VDETH=2.5V, VDETL=2.1V (POL="L"), VDD=5.5V

2) VDETH=1.8V, VDETL=1.7V (POL="L")

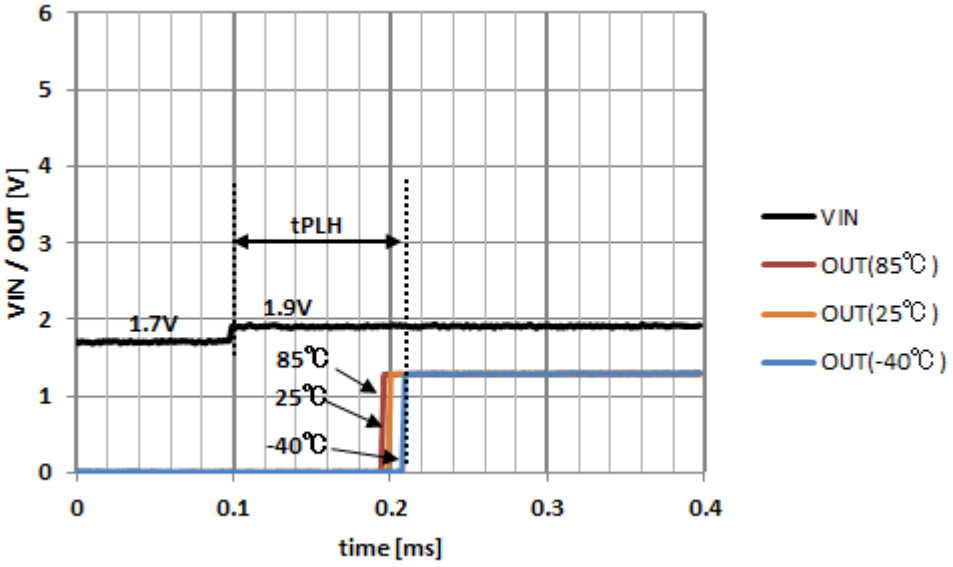


Figure 20. tPLH for VDETH=1.8V, VDETL=1.7V (POL="L"), VDD=1.3V

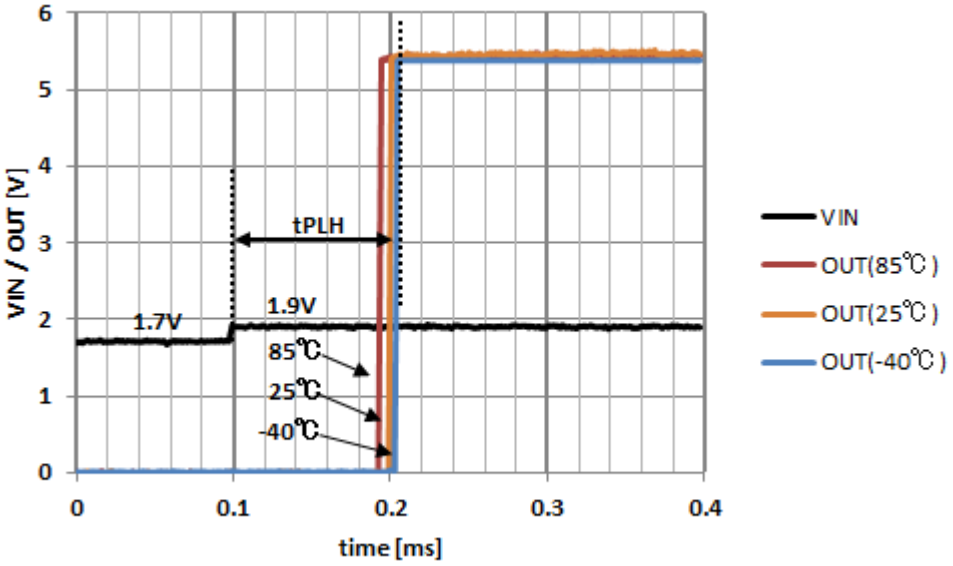


Figure 21. tPLH for VDETH=1.8V, VDETL=1.7V (POL="L"), VDD=5.5V

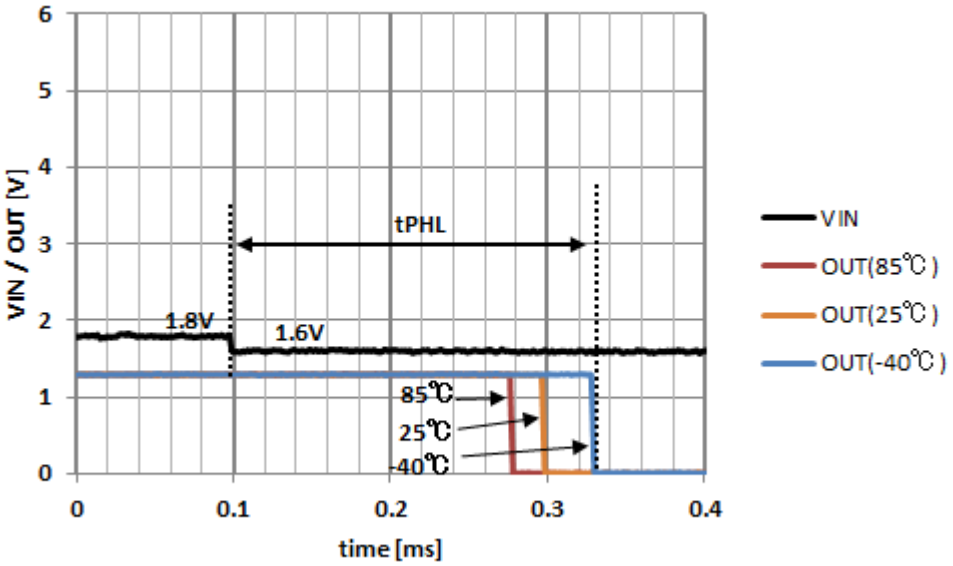


Figure 22. tPHL for VDETH=1.8V, VDETL=1.7V (POL="L"), VDD=1.3V

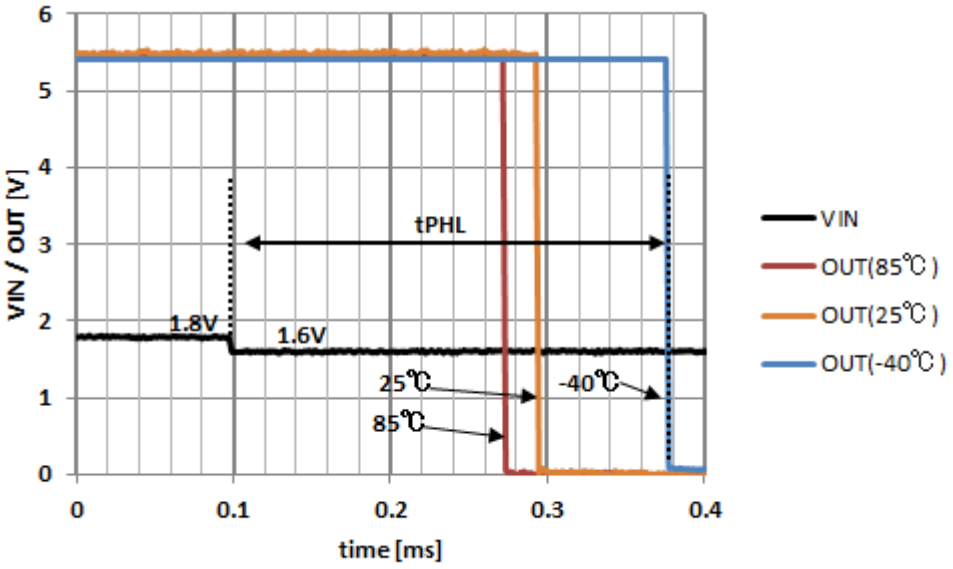


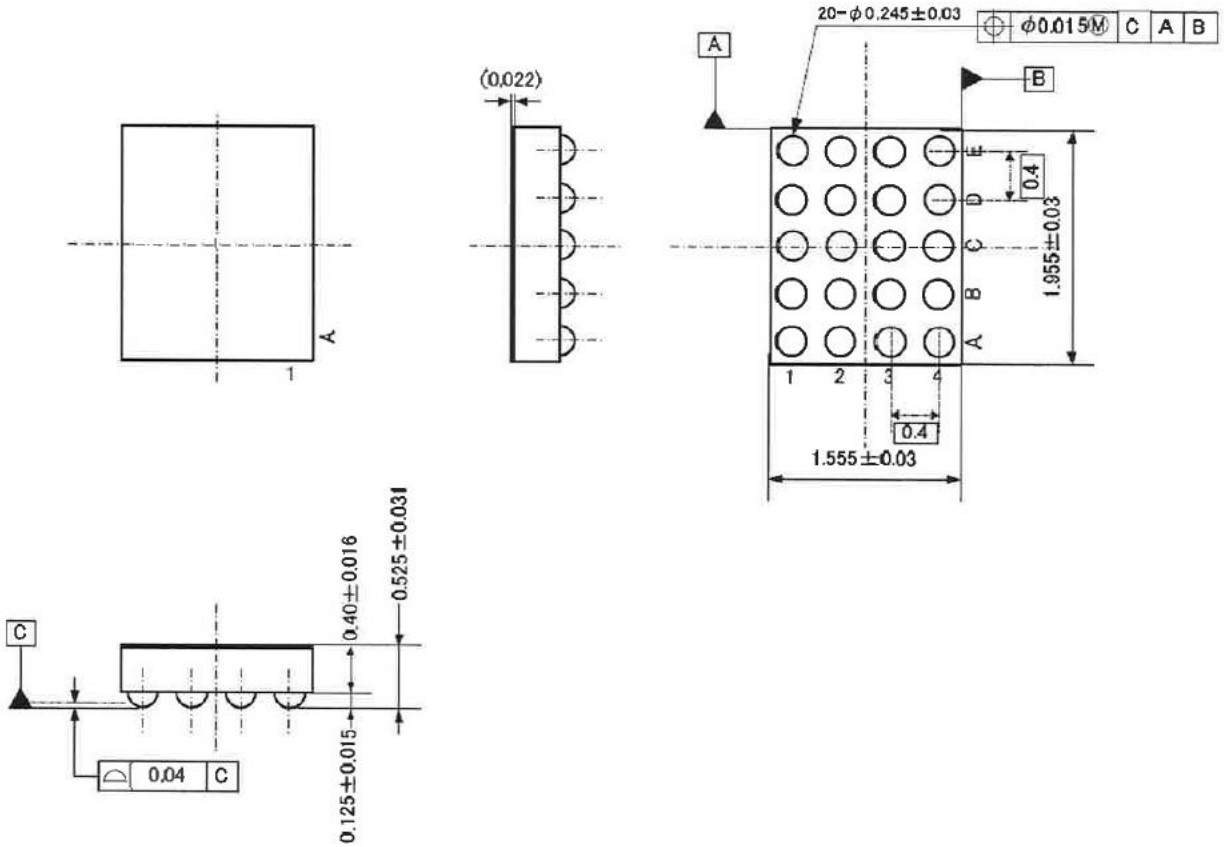
Figure 23. tPHL for VDETH=1.8V, VDETL=1.7V (POL="L"), VDD=5.5V

11. Package

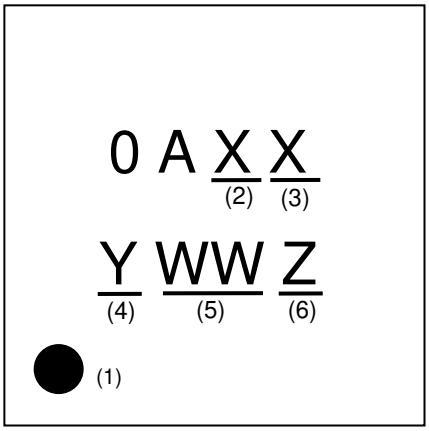
■ Outline Dimensions

20-pin WLCSP (Unit: mm)

When the IC is exposed to light, it might affect the electrical characteristics of the IC due to the light sensitivity of WLCSP package structures.



■ Marking



(1) 1 Pin Indication
(2) Symbol of the detection voltage of system 1
(3) Symbol of the detection voltage of system 2
(4) Year code (last 1 digit)
(5) Week code
(6) Management code

12. Revision History

Date (YY/MM/DD)	Revision	Page	Contents
2017/09/07	00	-	First Edition
2018/06/04	01	1	1. General Description detection → detector
			2. Features -40 - 85 °C → -40 - +85 °C
		6	8. Electrical Characteristics -40 to 85 °C → -40 - +85 °C
			8. Electrical Characteristics 5,5V → 5.5V
		7	9. Description AP4410A→ AP4410AEC
			9. Description incrasing→ increasing
			9. Description Vref →VDET
		8	9. Description incrasing→ increasing
		16	11. Package updated

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