HIGH-PERFORMANCE USB PD SINK CONTROLLER

Description

The DIODES™ AP33772 is a highly integrated USB Type-C® PD3.0/PPS sink controller targeted for DC power request and control for USB Type-C connector-equipped devices (TCD). To leverage the increasing popularity of standard USB Type-C PD3.0 power adaptors, the AP33772 negotiates with an existing PD3.0 adaptor to acquire the required power profile to power the TCD.

For more flexible PD3.0 and PPS power applications where direct voltage and current request with fine-tuning capabilities (20mV/Step, 50mA/Step) are required, the AP33772 supports I2C communication – I2C Interface pins (SCL, SDA), I2C registers and command setting, for host CPU of TCD to communicate with.
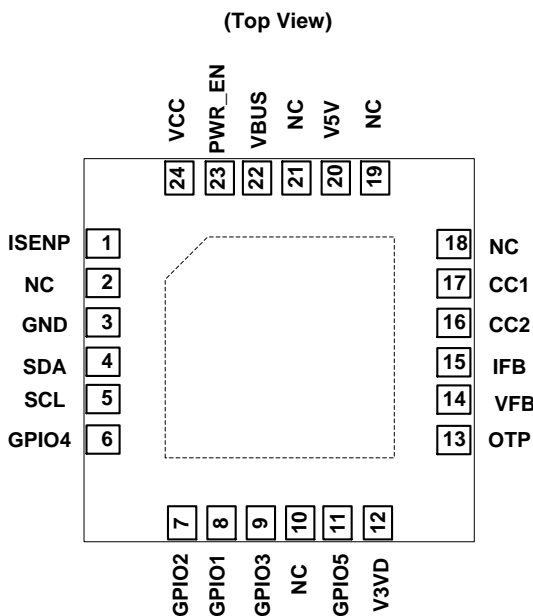
Rich power functions embedded on the chip reduce total bill of materials (BOM) while maintaining maximum flexibility. A one-time-programmable (OTP) ROM is provided for the main firmware and a multi-time-programmable (MTP) ROM will be provided for user-configuration purpose.

Features

- Compliant with USB PD Rev. 3.0 v1.2 with PPS
- PD sink controller with I2C bus communication
- Supports PPS with 20mV/step voltage and 50mA/step current
- Supports OTP (overtemperature protection), derating function
- Supports interrupt and its mask to a host MCU
- Supports status register for system monitor and control
- Supports flash FAULT LED indication for negotiation mismatch
- Supports OTP (One-Time-Programmable) for main firmware
- Supports OVP with auto restart
- Supports OCP with auto restart
- Supports power-saving mode
- Supports Driver for N-MOS VBUS power switch
- Supports dead-battery mode
- Operating voltage range: 3.3V to 24V
- MTP (Multi-Time-Programmable) is reserved for future configuration
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/104/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative. https://www.diodes.com/quality/product-definitions/**

Pin Assignments

(Top View)

W-QFN4040-24 (Type A1)

Applications

- USB Type-C connector-equipped battery-powered devices
- USB Type-C connector-equipped DC-power input devices
- USB PD3.0 PPS testers
- USB Type C-to-traditional barrel-connector power-adaptor cables

Notes: 1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

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AP33772
Document number: DS44396 Rev. 1 - 2

1 of 11
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Typical Applications Circuit

The AP33772 is an USB Type-C power delivery sink controller and used to request power from a standard USB PD source adapter, as shown in the figure 1 below.
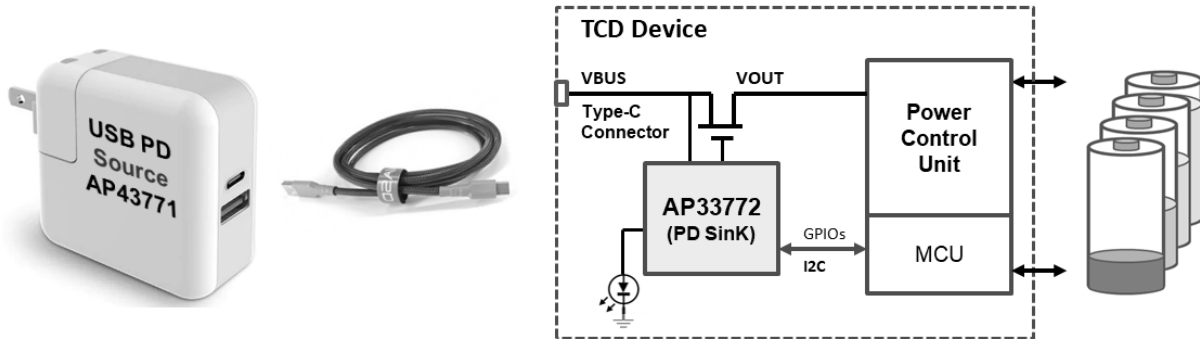

Figure 1. Typical Application structure of AP33772

The AP33772 request a power through I2C communication controlled by the host CPU of the TCD device. A typical AP33772 application circuit which uses I2C bus is shown as below.
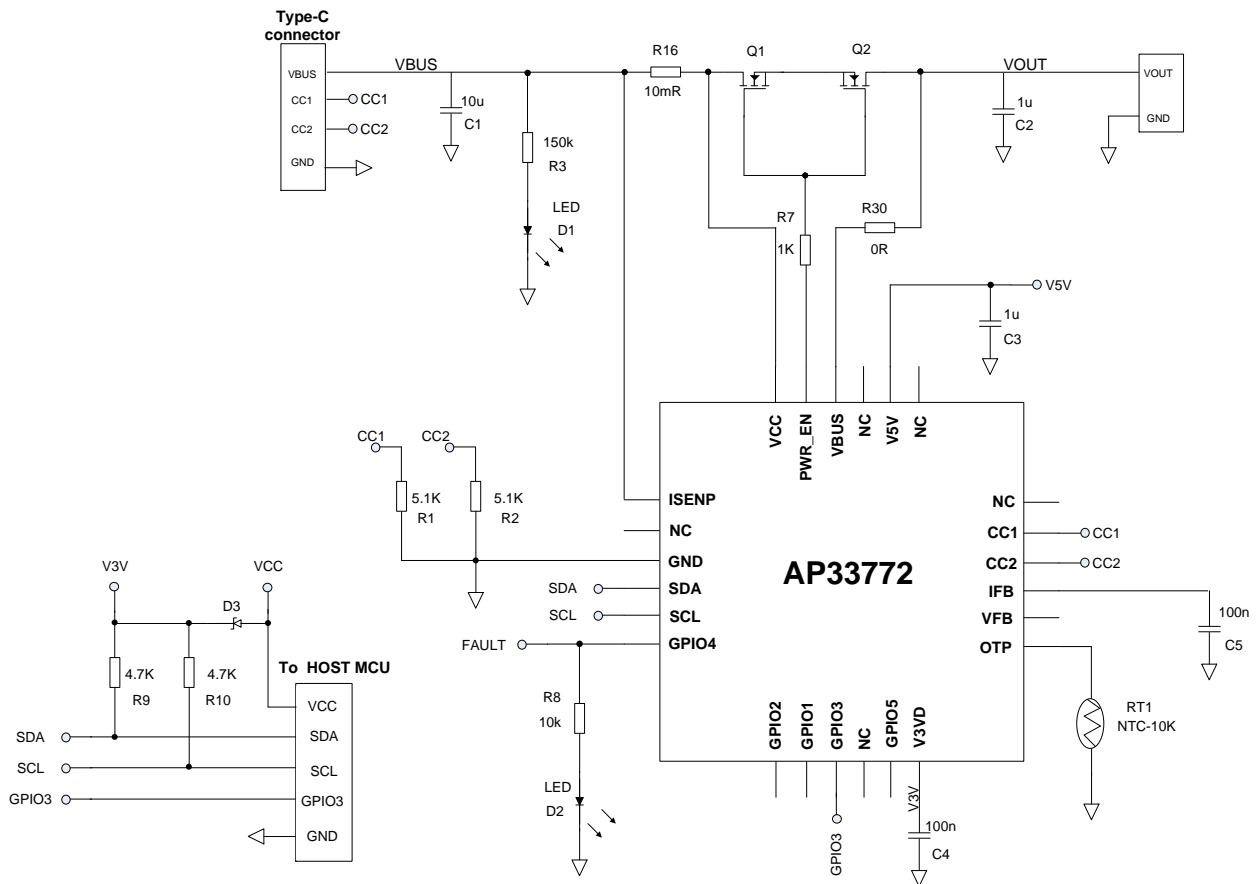

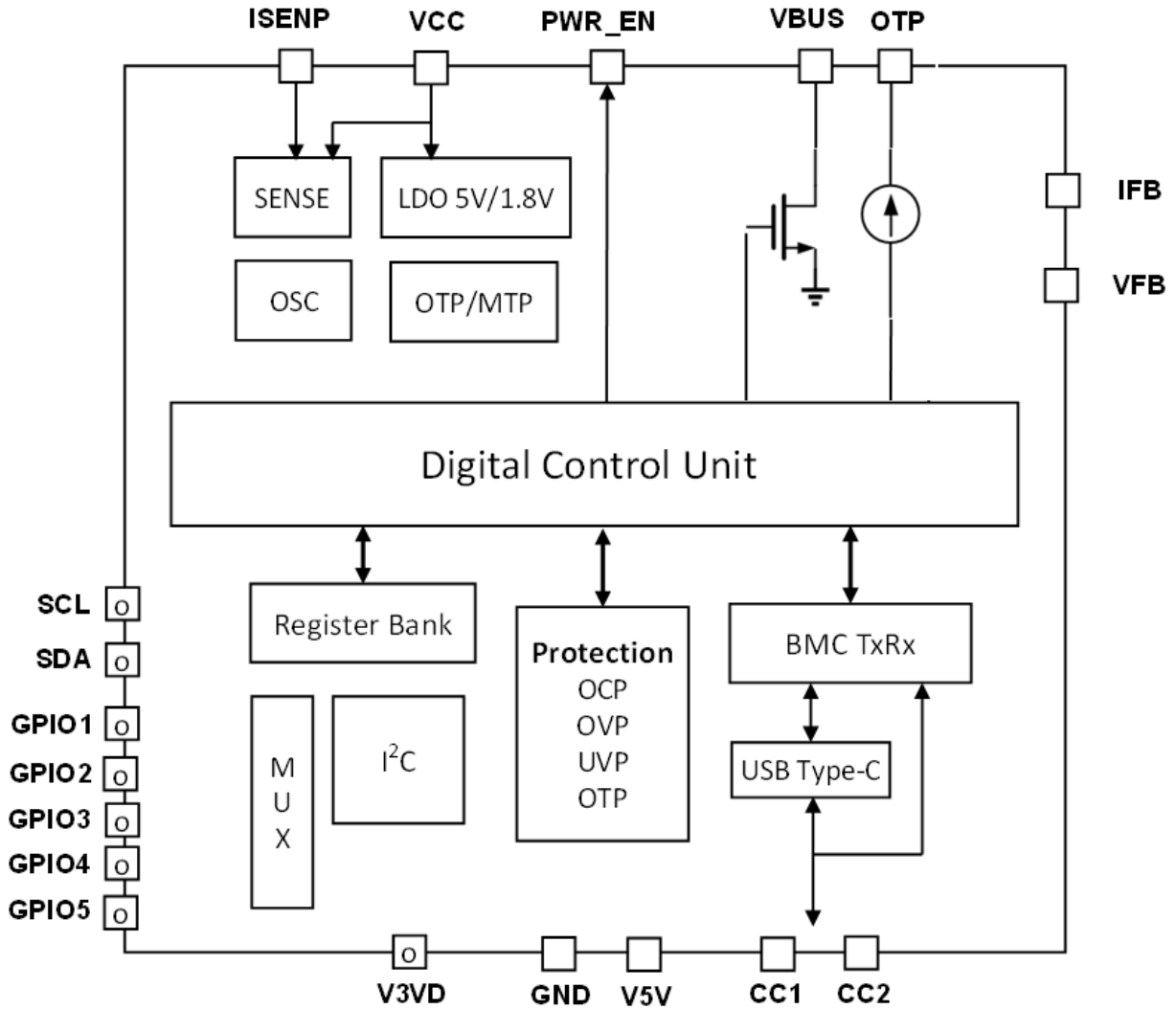**Figure 2. Typical Application Circuit of AP33772**

AP33772
Document number: DS44396 Rev. 1 - 2

2 of 11
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April 2022
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Pin Descriptions

Pin No	Pin Name	Type (Note)	Pin Function
1	ISENP	AIO	Current Sense Positive Node.
2	NC	-	No Connection
3	GND	GND	Ground
4	SDA	DIO	I2C Data
5	SCL	DIO	I2C Clock
6	GPIO4	DIO	General Purpose Input / Output, for LED usage
7	GPIO2	DIO	General Purpose Input / Output
8	GPIO1	DIO	General Purpose Input / Output
9	GPIO3	DIO	For Interrupt usage
10	NC	-	No Connection
11	GPIO5	DIO	General Purpose Input / Output
12	V3VD	DP	3.3V LDO output. Power for Digital circuit and Digital I/O pins, with 100nF to Ground
13	OTP	AIO	Current Source Output. Can be connected to external NTC sensor for Over Temperature Protection.
14	VFB	AI	For Voltage Measurement.
15	IFB	AI	For Current Measurement, with 100nF to Ground
16	CC2	AIO	USB Type-C configuration channel 2
17	CC1	AIO	USB Type-C configuration channel 1
18	NC	-	No Connection
19	NC	-	No Connection
20	V5V	AP	5V LDO output. Power for Analog circuit and Analog I/O pins, with 1uF to Ground
21	NC	-	No Connection
22	VBUS	AHV	Terminal for Discharge Path.
23	PWR_EN	AHV	To control external NMOS switch ON (High) or OFF (Low).
24	VCC	AHV	The power supply of the IC, connected to a ceramic capacitor.
-	EP	GND	Exposed pad is connected to Ground

Note:
AHV– Analog High Voltage pin
AP   – Power for Analog Circuit and Analog I/O pins, 5.0V operation
AI   – Analog Input pin
DP   – Power for Digital Circuit and I/O pins, 3.3V operation
AIO – Analog I/O pin.
DIO – Digital I/O pin.

AP33772
Document number: DS44396 Rev. 1 - 2

3 of 11
www.diodes.com

April 2022
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Functional Block Diagram

AP33772
Document number: DS44396 Rev. 1 - 2

4 of 11
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Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V_{CC}	Input Voltage at VCC Pin	-0.3 to 24	V
V_{FB}, V_{IFB}, V_{OTP}	Input Voltage at VFB, IFB, OTP Pins	-0.3 to 7	V
V_{BUS}, V_{PWR_EN}, V_{ISENP}	Input Voltage at VBUS, PWR_EN, ISENP Pins	-0.3 to 24	V
—	Voltage from PWR_EN to VCC Pin	-16 to 7	V
V_{V5V}	Input Voltage at V5V Pin	-0.3 to 7	V
V_{V3VD}	Input Voltage at V3VD Pin	-0.3 to 5	V
V_{CC1}, V_{CC2}	Input Voltage at CC1, CC2 Pins	-0.3 to 7	V
V_{SCL}, V_{SDA}, V_{GPIO1} ~ V_{GPIO5}	Input Voltage at SCL, SDA, GPIO1 ~ GPIO5 Pins	-0.3 to 5	V
T_J	Operating Junction Temperature	-40 to +150	°C
T_{STG}	Storage Temperature	-65 to +150	°C
T_{LEAD}	Lead Temperature (Soldering, 10s)	+300	°C
θ_{JA}	Thermal Resistance (Junction to Ambient) (Note 5)	28	°C/W
θ_{JC}	Thermal Resistance (Junction to Case) (Note 5)	16	°C/W
ESD	Human Body Model	2	kV
ESD	Charged Device Model	750	V

Notes: 4. Stresses greater than those listed under "*Absolute Maximum Ratings*" can cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "*Recommended Operating Conditions*" is not implied. Exposure to "*Absolute Maximum Ratings*" for extended periods can affect device reliability.
5. Test condition: Device mounted on FR-4 substrate PC board, 2oz copper, with the minimum footprint.

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{CC}	Power Supply Voltage	3.3	24	V
V_{OTP}	Input Voltage at OTP Pin	0	3.7	V
V_{SDA}, V_{SCL}	Input Voltage at SDA, SCL Pins	0	3.7	V
V_{GPIO1} ~ V_{GPIO5}	Input Voltage at GPIO1 ~ GPIO5 Pins	0	3.7	V
T_{OP}	Operating Temperature Range	-40	+85	°C

AP33772
Document number: DS44396 Rev. 1 - 2

5 of 11
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April 2022
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Electrical Characteristics $_{(@\ T_A\ =\ +25°C,\ unless\ otherwise\ specified.)}$

Symbol	Parameter	Condition	Min	Typ	Max	Unit
VCC SECTION						
V_{ST}	Startup Voltage	—	2.5	2.8	3.2	V
V_{UVLO}	Minimum Operating Voltage	—	2.4	2.7	3	V
V_{CC_HYS}	V_{CC} Hysteresis (V_{ST}-V_{UVLO})	—	0.05	—	—	V
I_{CC_OPR}	Operating Supply Current	V_{CC} = 5V	—	3.3	6	mA
CC1/CC2 SECTION						
V_{L_RD3A}	Low Voltage Threshold Used to Distinguish R_D Attached or Detached for 3A Delivery	—	—	1.35	—	V
V_{H_RD3A}	High Voltage Threshold Used to Distinguish R_D Attached or Detached for 3A Delivery	—	—	2.0	—	V
OTP SECTION						
I_{OTP}	OTP Pin Current Source (Note 7)	—	—	100	—	µA
I_{OTP_Range}	OTP Pin Current Source Range (Note 7)	—	-3	—	+3	%
R_{NTC}	NTC Resistance	—	—	10	—	kΩ
GPIO and I2C SECTION						
V_{GPIO_HI}	GPIO1~GPIO5 High Voltage (Note 7)	V_{CC} = 5V	1.4	—	—	V
V_{GPIO_LO}	GPIO1~GPIO5 Low Voltage (Note 7)	V_{CC} = 5V	—	—	0.4	V
I_{GPIO}	GPIO1~GPIO5 Sink/Source Capability (Note 7)	—	2	—	—	mA
V_{I2C_HI}	SDA, SCL High Voltage (Note 7)	V_{CC} = 5V	1.4	—	—	V
V_{I2C_LO}	SDA, SCL Low Voltage (Note 7)	V_{CC} = 5V	—	—	0.4	V
F_{SCL}	SCL clock frequency (Note 7)	—	—	—	400	kHz
PROTECTION FUNCTION SECTION						
V_{OVP5V}	OVP_5V Enable Voltage (Note 6, 7)	—	—	7	—	V
V_{OVP20V}	OVP_20V Enable Voltage (Note 6, 7)	—	—	22	—	V
$t_{DEBOUNCE\_OVP}$	OVP Debounce Time (Note 8)	—	—	90	—	ms
I_{OVD}	Overvoltage Discharge Current	V_{CC} = 5V	150	200	250	mA
t_{OV_DELAY}	Delay from OVP Threshold Trip to NMOS Gate Turn-Off (Note 7)	—	—	—	50	µs
t_{OCP}	OCP Deglitch Time (Note 7)	—	—	30	—	ms

Notes: 6. 110% OVP setting @PDO>18V. PDO+2V OVP setting @PDO<=18V.
7. Guaranteed by design.
8. OVP blanking time during V_O transition from high output voltage to low output voltage, such as 9V to 5V, or 12V to 5V.

AP33772
Document number: DS44396 Rev. 1 - 2

6 of 11
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April 2022
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Performance Characteristics

Function Description

The AP33772 is a USB Type-C power delivery sink controller which meets USB Power Delivery specification Rev. 3.0 v1.2. Because of its high voltage process, the AP33772 provides a cost-effective solution without the need for external discrete high-voltage components like LDOs. During the protocol handshake process, packets are transmitted and received through a Biphase Mark Coding (BMC) transceiver with good eye diagram and high noise immunity. The AP33772 supports I2C communication to implement all of the PD sink functions, such as the requesting of power profiles—Power Device Objects (PDO) and Augmented Power Device Objects (APDO). The on-chip OTP/ MTP memories are used to store main protocol decoding and application programs as well as system configuration parameters. The on-chip multiple-channel ADC converter can be used to sense internal and outside signal variations to support various system status updates and controls accordingly.

CC Interface and BMC Transceiver

For high inter-operability consideration, CC interface detection and BMC transceivers are specially considered to maintain tolerance and noise immunity.

USB Power Delivery Sink Controller

To be compliant with critical USB Power Delivery specification Rev. 3.0 v1.2, the AP33772 is optimally implemented based on a flexible MCU+OTP design style and blended with dedicated hardware circuitry. Leveraging the MCU+OTP design, the AP33772 supports built-in PD3.0 PPS sink-controller-compliant firmware and useful application firmware, which can be requested through the I2C interface by the host MCU for any TCD design.

Sink PDO and APDO Capability

The AP33772 provides search algorithm for fixed PDO and PPS APDO, where 20mV/step voltage resolution and 50mA/step current resolution for power management are supported.

OCP and Rsense

The AP33772 supports OCP to control the output load condition. When the OCP function is enabled, the AP33772 monitors the output current through detection of IR drop on the 10mΩ Rsense resistor. Once the TCD device draws more current than the OCP threshold level, the AP33772 enables OCP by turning off the NMOS VBUS switch. OCP threshold level can also be configured through I2C communication during the AP33772 initialization.

NMOS VBUS Switch Control

With the embedded on-chip gate driver, the AP33772 works with an external NMOS switch for many different controls and protections. To combine it with VBUS voltage and current-sensing circuitry, the AP33772 is used for systems requiring reliable power from USB PD sources. Any non-PD source connected to an A33772-embedded TCD will trigger a mismatch during the power-request process. The VBUS will get to 5V, MOS VBUS switch will turn off, and the LED will start flickering accordingly.

OVP/OTP Protection

The AP33772 implements OVP feature by sending hard reset to the PD source when VBUS is higher than OVP voltage. As soon as OVP is triggered, the AP33772 provides internal discharge path to reduce the overvoltage condition. Thermal management of a TCD is a crucial safety design consideration. The temperature sensing of the TCD is enabled by connecting a 10kΩ NTC (Negative Temperature Coefficient) thermistor between the OTP pin and ground nearby a potential hot spot. The characteristic data of temperature vs. resistance values at four temperature points (25ºC, 50ºC, 75ºC, 100ºC) of the NTC thermistor needs to be set by the user through I2C (TR25, TR50, TR75, and TR100 Register). Leveraging the built-in multiple-channel ADC and application firmware, the AP33772 calculates the actual temperature and stores in the relevant register (TEMP). The AP33772 also implements useful features such as OTP (OTPTHR Register) and thermal power derating (DRTHU Register).
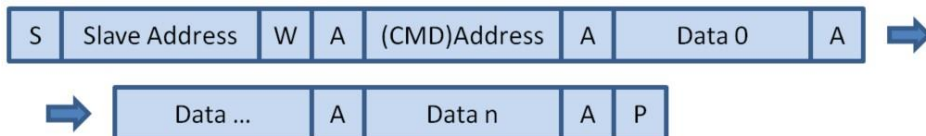
I2C Support

The I2C functions of the AP33772 are enabled by three pins—SDA (Pin 4—I2C data), SCL (Pin 5—I2C Clock), and GPIO3 (Pin 9—Interrupt). The host MCU of the TCD, functioning as the I2C master, writes proper contents to the relevant I2C register of the AP33772, working as an I2C slave device, to specify desired power profiles and various protection features. It also accesses the AP33772 for various statuses to take proper actions and maintain normal functions of the TCD during the charging process.

AP33772
Document number: DS44396 Rev. 1 - 2

7 of 11
www.diodes.com

April 2022
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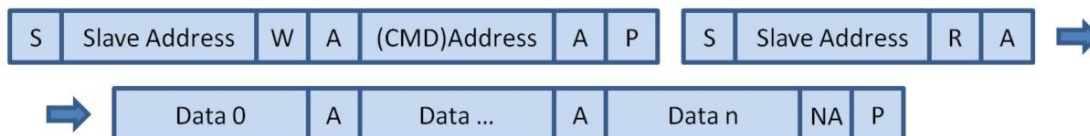## I2C Command/Register Summary

The AP33772, functioning as an I2C slave device, has the assigned slave physical address 0x51. The I2C read and write operations are supported as below. All commands (CMDs) are summarized in the following I2C Register Map table. The AP33772 can be monitored and controlled by the I2C commands.

All transactions begin with a START (S) and end with a STOP (P). A START condition is defined as a HIGH to LOW transition of the SDA while SCL is HIGH. A STOP condition is defined as a LOW to HIGH transition of the SDA while SCL is HIGH. START and STOP conditions are always generated by the I2C master, the host MCU of the TCD.

I2C Format for Write Data:

| S | Slave Address | W | A | (CMD)Address | A | Data 0 | A | → |

| → | Data ... | A | Data n | A | P |

I2C Format for Read Data:

| S | Slave Address | W | A | (CMD)Address | A | P | S | Slave Address | R | A | → |

| → | Data 0 | A | Data ... | A | Data n | NA | P |

I2C Register Map

Register Content	I2C Address	Length	Attribute	Pwr-on	Description
SRCPDO	0x00	28	RO	All 00h	PDO used to expose PD Source (SRC) power capabilities. Total length is 28 bytes
PDONUM	0x1C	1	RO	00h	Valid source PDO number
STATUS	0x1D	1	RC	00h	AP33772 status
MASK	0x1E	1	RW	01h	Interrupt enable mask
VOLTAGE	0x20	1	RO	00h	LSB 80mV
CURRENT	0x21	1	RO	00h	LSB 24mA
TEMP	0x22	1	RO	19h	Temperature, Unit: °C
OCPTHR	0x23	1	RW	00h	OCP threshold, LSB 50mA
OTPTHR	0x24	1	RW	78h	OTP threshold, Unit: °C
DRTHR	0x25	1	RW	78h	De-rating threshold, Unit: °C
TR25	0x28	2	RW	2710h	Thermal Resistance @25°C, Unit: Ω
TR50	0x2A	2	RW	1041h	Thermal Resistance @50°C, Unit: Ω
TR75	0x2C	2	RW	0788h	Thermal Resistance @75°C, Unit: Ω
TR100	0x2E	2	RW	03CEh	Thermal Resistance @100°C, Unit: Ω
RDO	0x30	4	WO	00000000h	Request Data Object (RDO) is use to request power capabilities.

Attribute Convention

    RW: Readable / Writable
    RO: Read-Only
    RC: Read-Clear
    WO: Write-Only

AP33772
Document number: DS44396 Rev. 1 - 2

8 of 11
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April 2022
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Ordering Information

AP33772 X - X - F X X

Product Name	Package	Packing	Firmware Code	Application Code	Firmware Version
	DKZ: W-QFN4040-24 (Type A1)	13: 13 inch Tape and Reel	F: Firmware Loaded Blank: Standard Firmware	A to Z: Application Code Blank: Standard Firmware	01 to 99: Version Code Blank: Standard Firmware
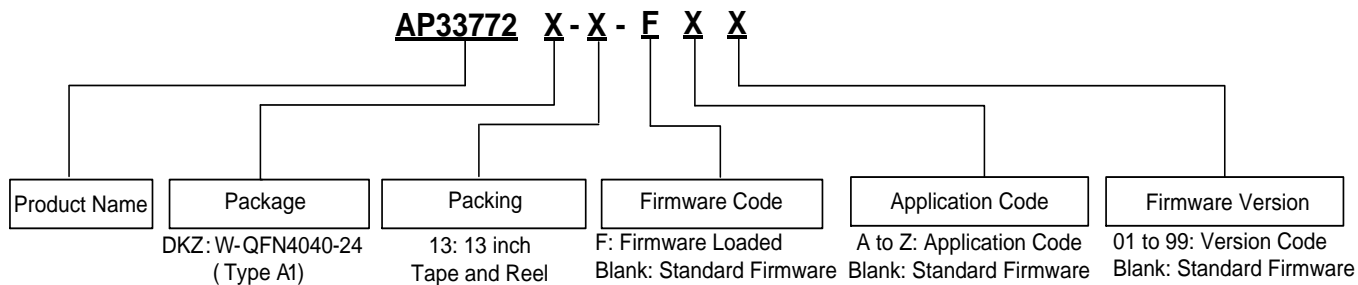
Part Number	Package	Identification Code	13''Tape and Reel	
			Quantity	Part Number Suffix
AP33772DKZ-13-FXX	W-QFN4040-24 (Type A1)	6E	3000/Tape and Reel	-13

Marking Information

W-QFN4040-24

(Top View)

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XX
Y W X
●
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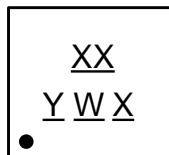
XX : Identification Code
Y : Year : 0~9
W : Week : A~Z : 1~26 week;
  a~z : 27~52 week; z represents
  52 and 53 week
X : Internal Code

AP33772
Document number: DS44396 Rev. 1 - 2

9 of 11
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Package Outline Dimensions

Please see http://www.diodes.com/package-outlines.html for the latest version.
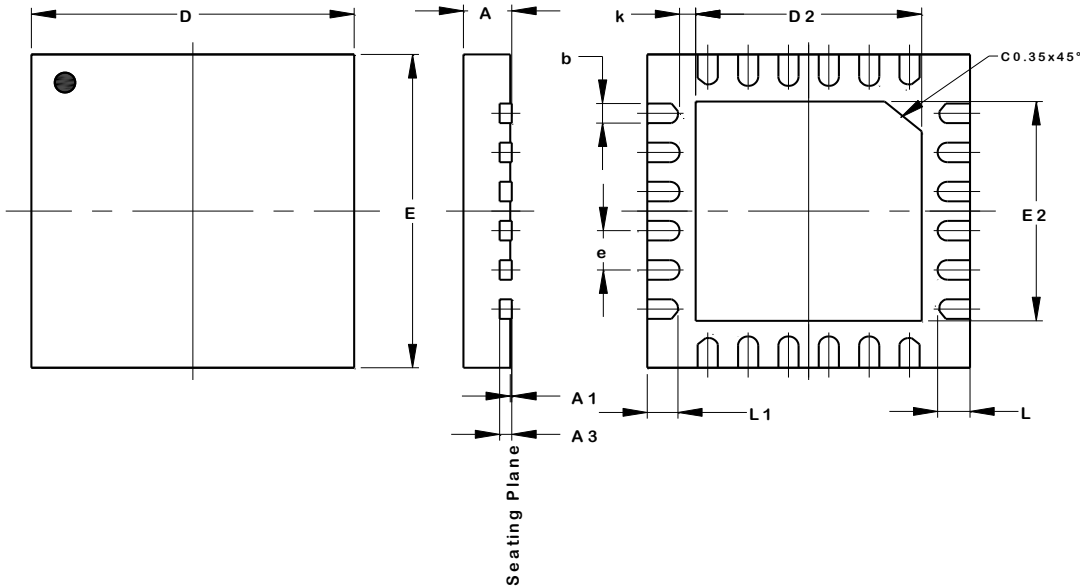
W-QFN4040-24 (Type A1)

W-QFN4040-24 (Type A1)			
Dim	Min	Max	Typ
A	0.70	0.80	0.75
A1	0.00	0.05	0.02
A3	0.203 REF		
b	0.20	0.30	0.25
D	4.00 BSC		
D2	2.75	2.85	2.80
E	4.00 BSC		
E2	2.75	2.85	2.80
e	0.50 BSC		
k	0.20	--	--
L	0.35	0.45	0.40
L1	0.33	0.43	0.38
All Dimensions in mm			

Suggested Pad Layout

Please see http://www.diodes.com/package-outlines.html for the latest version.

W-QFN4040-24 (Type A1)
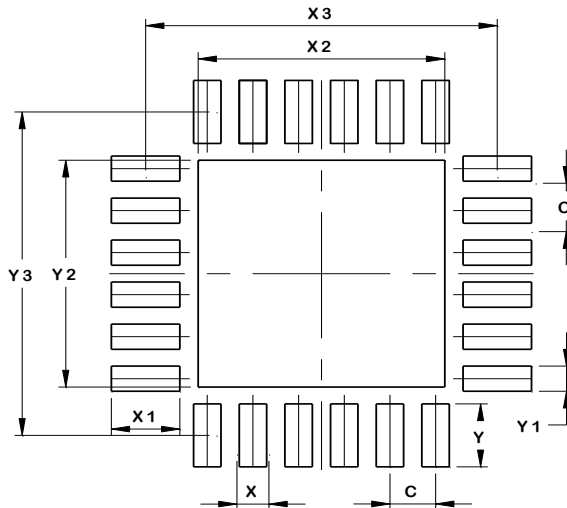
Dimensions	Value (in mm)
C	0.500
X	0.300
X1	0.750
X2	2.700
X3	3.850
Y	0.750
Y1	0.300
Y2	2.700
Y3	3.850

Mechanical Data

- Moisture Sensitivity: Level 1 per J-STD-020
- Terminals: Finish – Matte Tin Plated Leads, Solderable per J-STD-202 e3
- Weight: 0.041 grams (Approximate)

AP33772
Document number: DS44396 Rev. 1 - 2

10 of 11
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IMPORTANT NOTICE

AP33772
Document number: DS44396 Rev. 1 - 2

11 of 11
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