USB Type-C Power Delivery Sink Controller

Hynetek Semiconductor Co., Ltd.

HUSB238

FEATURES

USB-IF certified
- TID: 3666

Standalone USB Power Delivery (PD) sink controller
Legacy charging sink
- Apple divider 3 detection
- BC1.2 SDP, CDP and DCP detection

Dead battery function
SOP' communication function
3V to 25V operation range
30V voltage rating on VIN and GATE pins
25V voltage rating on CC1 and CC2 pins
I^2C access for monitoring and advanced settings
Integrated PMOS driver
VBUS over-voltage protection (OVP) and under-voltage protection (UVP)
Over-temperature protection (OTP) with programmable thresholds
Low power consumption

APPLICATIONS

PD sink devices
USB-C cables
Wireless charger

GENERAL DESCRIPTION

The HUSB238 is a highly integrated USB Power Delivery (PD) controller as sink role for up to 100W power rating.

The HUSB238 is compatible with PD3.0 and Type-C V1.4, and it can also support Apple Divider 3, BC1.2 SDP, CDP and DCP while the source is attached.

The HUSB238 can be used in electronic devices that have legacy barrel connectors or USB micro-B connectors for power such as IoT (Internet of Things) devices, wireless charger, drones, smart speakers, power tools, and other rechargeable devices.

The HUSB238 is available in 3mm x 3mm DFN-10L package options.

TYPICAL APPLICATION CIRCUIT

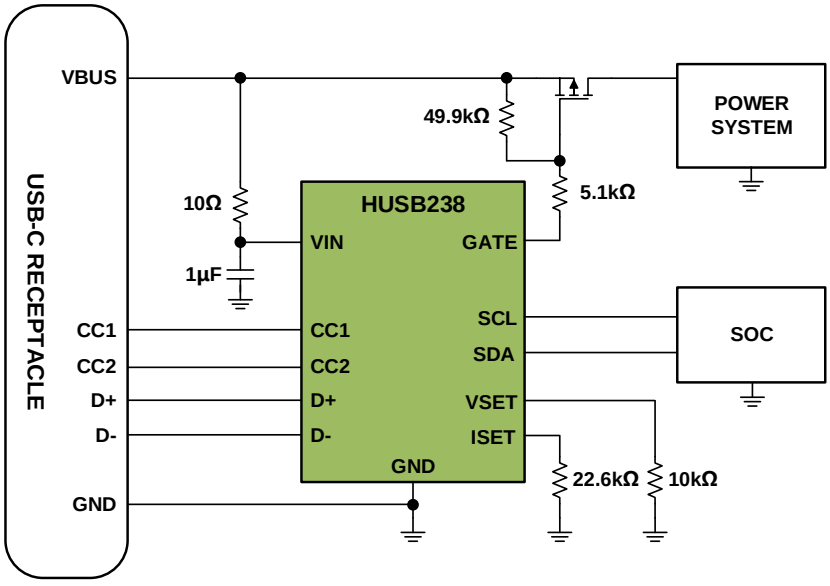

Figure 1. Typical Application Circuit

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REVISION HISTORY

Version	Date	Descriptions
Rev. 1.0	12/2020	Initial version
Rev. 2.0	01/2021	Added SOT33-6L package information
Rev. 2.1	03/2022	Add Recommended Operating Conditions
Rev. 2.2	07/2022	Add new part number: HUSB238_005DD
Rev. 2.3	09/2022	Add Tape and Reel Information Delete SOT33-6L package option
Rev. 2.4	03/2023	Update Ordering Guide Update Package Top Marking
Rev. 2.5	04/2023	Update typo of Package Outline Dimensions

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

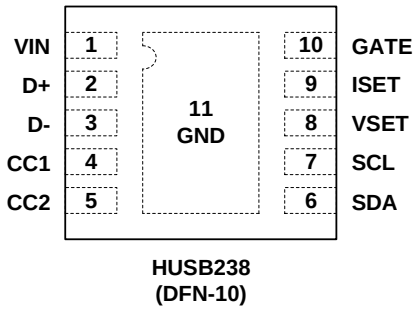


Figure 2. Pin Configuration (Top View)

Table 1. Pin Function Descriptions

Pin No.	Pin Name	Type[1]	Description
1	VIN	P	Power supply input. Connect this pin to VBUS of USB Type-C connector and bias this pin via a 1μF ceramic capacitor.
2	D+	DIO	Positive line of USB 2.0 data line for Apple Divider 3 and BC1.2.
3	D-	DIO	Negative line of USB 2.0 data line for Apple Divider 3 and BC1.2.
4	CC1	AIO	Configuration line 1 used to negotiate a voltage/current with the attached adapter.
5	CC2	AIO	Configuration line 2 used to negotiate a voltage/current with the attached adapter.
6	SDA	DIO	I^2C communication data signal.
7	SCL	DIO	I^2C communication clock signal.
8	VSET	AI	Connect a resistor to indicate the maximum voltage needed by the system from the attached power adapter.
9	ISET	AI	Connect a resistor to indicate the maximum current needed by the system from the attached power adapter.
10	GATE	OD	Open drain gate driver output. Connect this signal to the gate of an external PMOS through a series resistor. Leave this pin open if not used.
11	GND	P	Ground reference. All signals are referred to this pin.

1 Legend:
A = Analog Pin
P = Power Pin
D = Digital Pin
I = Input Pin
O = Output Pin
OD = Open Drain Pin

RECOMMENDED OPERATING CONDITIONS

Table 2.

Parameter	Rating
VIN Input Voltage Range	3.24V to 21V
Operating Temperature Range (Junction)	−40°C to +125°C
Ambient Temperature Range	-40°C to 85°C

SPECIFICATIONS

V_{IN} = 5V, T_A = 25°C, unless otherwise noted.

Table 3.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
POWER SUPPLY						
Supply Voltage	V_{IN}		3		25	V
Supply Voltage UVLO Threshold	$V_{IN\_UVLO\_RISE}$	Rising edge threshold		3.1		V
	$V_{IN\_UVLO\_FALL}$	Falling edge threshold		2.9		V
Supply Current	I_{SC_OPR}	V_{IN} = 5V, CC is attached, normal operation		3.1		mA
CC1 AND CC2 PINS						
Pull-down Voltage in Dead Battery	V_{DBL}	200μA source current	0.45		1.5	V
	V_{DBH}	360μA source current	0.85		2.45	V
Pull-down resistor	R_D		4.6	5.1	5.6	kΩ
Voltage Threshold to Detect a DFP	V_{TH_DEF}	Default current mode	0.15	0.2	0.25	V
	V_{TH_1P5}	1.5A current mode	0.61	0.66	0.70	V
	V_{TH_3P0}	3.0A current mode	1.16	1.23	1.31	V
TX Output Impedance[1]	R_{TX}	PD TX mode	33	48	75	Ω
Voltage Swing				1.125		V
D+/D- PINS						
D- Source Voltage for 0.6V	V_{DM_SRC}		0.5	0.6	0.7	V
D+ Source Voltage for 0.6V	V_{DP_SRC}		0.5	0.6	0.7	V
Data Detect Voltage	V_{DAT_REF}		300	325	350	mV
D- Sink Current	I_{DM_SINK}		50	100	150	μA
D+ Sink Current	I_{DP_SINK}		50	100	150	μA
D+/D- Comparator Threshold for 2.7V Detection	$V_{TH\_2P7\_HI}$	High threshold for Apple divider 3	2.85	2.95	3.05	V
	$V_{TH\_2P7\_LO}$	Low threshold for Apple divider 3	2.25	2.35	2.45	V
VSET AND ISET PINS						
Source Current	I_{VSET}	On VSET pin	95	100	105	μA
	I_{ISET}	On ISET pin	95	100	105	μA
Detect Debounce Time[1]	t_{DB_VSET}	For VSET pin		2		ms
	t_{DB_ISET}	For ISET pin		2		ms
I²C PARAMETERS						
Supply Range			2.5		5.5	V
Low Level Input Voltage		Apply for SDA, SCL pins			0.4	V
High Level Input Voltage		Apply for SDA, SCL pins	1.4			V
Low Level Output Voltage		Apply for SDA pin, 2mA load current			0.4	V
GATE PIN						
Maximum Sink Current[1]					10	mA
Pull Low Impedance				100	300	Ω

[1] Guaranteed by design

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
PROTECTIONS						
Over-Voltage Protection Threshold	V_{VIN_OV}	Refer to V_{IN}	115	120	125	%
OVP Debounce Time[1]	t_{DB_OV}			50		μs
Under-Voltage Protection Threshold	V_{VIN_UV}	Refer to V_{IN}		-2		V
UVP Debounce Time[1]	t_{DB_UV}			1		ms
Over-Temperature Protection Threshold[1]		Rising Threshold		150		ºC
		Falling Threshold		130		ºC
OTP Debounce Time[1]	t_{DB_OT}			100		ms
VIN Discharge Resistor	R_{DIS}			500		Ω

ABSOLUTE MAXIMUM RATINGS

Table 4.

Parameter	Rating
VIN, GATE	−0.3V to +30V
CC1, CC2	−0.3V to +25V
D+, D−	−0.3V to +12V
VSET, ISET, SDA, SCL	−0.3V to +6V
Operating Temperature Range (Junction)	−40°C to +125°C
Soldering Conditions	JEDEC J-STD-020
Electrostatic Discharge (ESD)	
Human Body Mode (HBM)	±6000V

Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

THERMAL RESISTANCE

Thermal performance is directly linked to printed circuit board (PCB) design and operating environment. Close attention to PCB thermal design is required.

θ_{JA} is the natural convection junction to ambient thermal resistance measured in a one cubic foot sealed enclosure.

θ_{JC} is the junction to case thermal resistance.

Table 5. Thermal Resistance

Package Type	θ_{JA}	θ_{JC}	Unit
DFN-10L	75	54	°C/W

ESD CAUTION

Electrostatic Discharge Sensitive Device.

Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

FUNCTIONAL BLOCK DIAGRAM

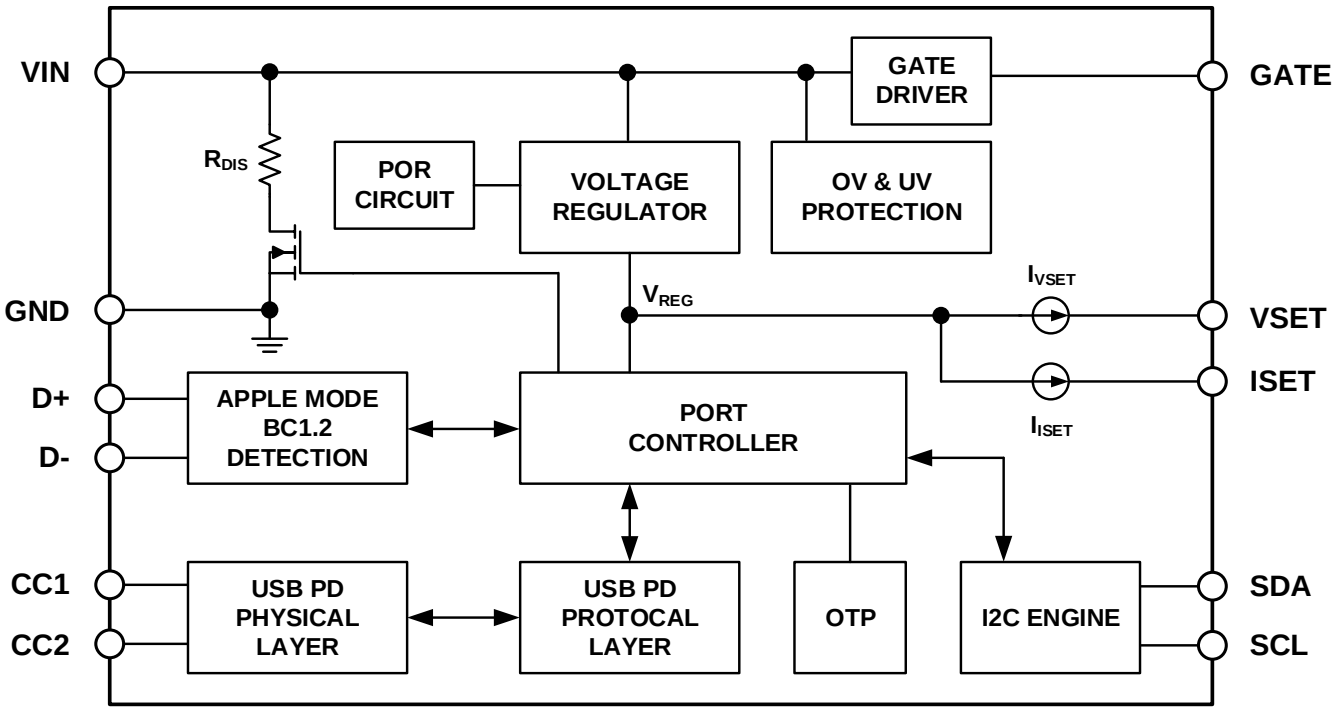


Figure 3. HUSB238 Functional Block Diagram

THEORY OF OPERATION

OVERVIEW

The HUSB238 is a highly integrated USB Power Delivery (PD) controller as sink role. It's compatible with PD3.0 and Type-C V1.4. It can also support Apple Divider 3, BC1.2 SDP, DCP and CDP while source is attached. When HUSB238 is connected to power source, it applies Rd to both CC lines, trying to establish USB Type-C connection. After the USB Type-C connection is established, it monitors the CC lines to get source capabilities pack from USB PD source. If there is valid source capabilities pack before time out, the HUSB238 policy engine requests a power supply with voltage no greater than the programmed request voltage. If there is no valid source capabilities pack after time out, the HUSB238 switches to Apple divider 3 or BC1.2 mode trying to determine corresponding charging protocol.

VIN PIN

VIN pin is the power supply input of the HUSB238, which is derived from the output of the PD source. Connect a 1μF decoupling MLCC between VIN pin and GND pin as closer as possible.

The VIN pin is also connected to an internal MOSFET and 500Ohm discharging resistor, which is used as a bleeder to help discharge the output capacitor to vSafe5V upon the hard reset, over-voltage fault, over-temperature fault or detachment of a connected device.

GATE PIN

The GATE pin is open–drain output which allows to drive an external PMOS load switch directly. The GATE pin can be programmed to turn on after POR or after the explicit contract. The default option is to turn on after POR. Please contact local Hynetek sales for a device with options other than the default option.

CC1 AND CC2 PINS

CC1 and CC2 are the Configuration Channel pins used for connection and attachment detection, plug orientation determination and system configuration management across USB Type-C cable. CC1 and CC2 pins can support as high as 25V voltage, which is used for protection when CC1 or CC2 is shorted to VBUS pin on the connector.

Through the Type-C detection, one of the CC pin is connected to the internal BMC block to achieve PD communication.

VSET PIN

A fixed 100μA current source is applied on VSET pin. Connect a resister between VSET and GND to indicate the VSET_VOLTAGE value as shown in Table 6.

Table 6. VSET_VOLTAGE Setting

R_{VSET} (kΩ)	VSET_VOLTAGE (V)
0	5
6.04	9
10	12
14	15
17.8	18
Open	20

The RDO voltage of the HUSB238 is determined by the lower value between VSET_VOLTAGE and SNK_PDO2_VOLTAGE. SNK_PDO2_VOLTAGE is programmable by internal fuse options and the default value is 20V. The requested voltage value can be changed dynamically with the resistance value change.

ISET PIN

A fixed 100μA current source is applied on ISET pin. Connect a resister between ISET and GND to indicate the ISET_CURRENT value as shown in Table 7.

Table 7. ISET_CURRENT Setting

R_{ISET} (kΩ)	ISET_CURERNT (A)
0	1.25
4.53	1.5
7.5	1.75
10.5	2
13.7	2.25
16.5	2.5
19.6	2.75
22.6	3
Open	3.25

The RDO current of the HUSB238 is determined by the lower value between ISET_CURRENT and SNK_PDO2_CURRENT. SNK_PDO2_CURRENT is programmable by internal fuse options and the default value is 3.25A. The requested current value can be changed dynamically with the resistance value change.

RDO DETERMINATION

There are two ways to determine the RDO that the HUSB238 requests from the PD source. Set by the VSET and ISET pins or set by the internal factory programmed fuse options. The HUSB238 compares the two values and uses the lower value as its RDO.

For example, if the VSET and ISET is configured as 9V / 3A. The internal factory fuse option is 12V / 2A. Then the RDO that HUSB238 requests from the PD source is 9V / 2A.

After the RDO is determined, the HUSB238 loops through the PD source PDOs from highest voltage first to find the first PDO that satisfies the following conditions:

1. SOURCE_PDO_VOLTAGE ≤ RDO_VOLTAGE
2. SOURCE_PDO_CURRENT ≥ RDO_CURRENT

If both the conditions above are satisfied, then HUSB238 sends a request for this source PDO with operating current set to the RDO current value.

If either one of the condition is not satisfied, the HUSB238 continues to compare with the second highest voltage source PDO or requests 5V source PDO directly, depending on the internal fuse options. The default fuse option is to continue to compare with the second highest voltage source PDO. Please contact local Hynetek sales for a device with options other than the default option.

OPERATION WITH I²C INTERFACE

The HUSB238 is I²C communication capable with system MCU or processor through SDA and SCL pins. The HUSB238 works as I²C slave role and the I²C address is 0x08.

After POR (Power On Reset), the HUSB238 receives the source capability information from the PD source adapter and the HUSB238 saves the source capability information in registers. The system MCU can visit the HUSB238 registers through the I²C bus and select a proper PDO to request from external PD source.

The I²C has the highest priority. If using I²C to select a source PDO, it over writes the internal RDO which is created by VSET, ISET pins and internal factory fuse option, and the HUSB238 requests the I²C selected source PDO once the I2C commands are written.

LEGACY CHARGER DETECTION

After the power on reset, if the HUSB238 does not establish PD contract with source adapter, the HUSB238 will waits for 1.5 seconds and then switches to Apple Divider 3 and BC1.2 detections sequentially. For BC1.2 detection, the HUSB238 detects SDP (Standard Data Port), CDP (Charging Data Port) and DCP (Dedicated Charging Port) sequentially.

DEAD BATTERY FUNCTION

The HUSB238 works as PD sink role which requires R_D resistor to be presented on the CC pins even in the un-powered state for successful Type-C detection by source adapter.

The dead battery function in the HUSB238 supports default USB, 1.5A and 3.0A source broadcast R_P current.

SOP' FUNCTION

For the USB-C to legacy PC plug applications where high current and high voltage are required, the system needs current more than 3A in most of the cases. If the SOP' function is enabled, the HUSB238 is capable to reply SOP' command, such as Discover Identity, sent by the PD source adapter.

The SOP' function emulates the E-Marker function in the cable so that the system is capable of obtaining more than 3A charging current from PD source adapter.

OVER-VOLTAGE PROTECTION

The HUSB238 senses the voltage on VIN pin for overvoltage protection. The over-voltage threshold is 1.2 times of max requested voltage. The OV debounce time is 50μs.

When OV happens, the HUSB238 turns off the external PMOS and enters into discharge mode where the internal discharge circuit on VIN pin is turned on. The internal 5.1k Rd resistor is also disconnected during discharge mode. After the discharge timeout, the HUSB238 enters into unattached mode and waits for re-connection with PD source adapter.

UNDER-VOLTAGE PROTECTION

The HUSB238 senses the voltage on VIN pin for optional under-voltage protection. The under-voltage threshold is the requested voltage minus 2V. For example, if the requested PDO voltage is 12V, then the UV threshold is 10V. The UV debounce time is 1ms.

When UV happens, the HUSB238 turns off the external PMOS and enters into discharge mode where the internal discharge circuit on VIN pin is turned on. The internal 5.1k Rd resistor is also disconnected during discharge mode. After the discharge timeout, the HUSB238 enters into unattached mode and waits for re-connection with PD source adapter.

The UVP function of the HUSB238 can be enabled or disabled by internal fuse options. The UVP function is disabled for default option. Please contact local Hynetek sales for a device with options other than the default option.

OVER-TEMPERATURE PROTECTION

The HUSB238 integrates over-temperature protection function. It monitors the internal junction temperature. When the junction temperature reaches the over temperature rising threshold, the HUSB238 requests 5V source PDO directly, regardless of the previous established PDO, to reduce the total system power. When the junction temperature falls below the over temperature falling threshold, the HUSB238 re-negotiates the previous PDO and tries to recover the normal charging operation.

The over temperature thresholds are programmable by internal factory fuses. Please contact local Hynetek sales for a device with options other than the default option.

TYPICAL APPLICATION CIRCUITS

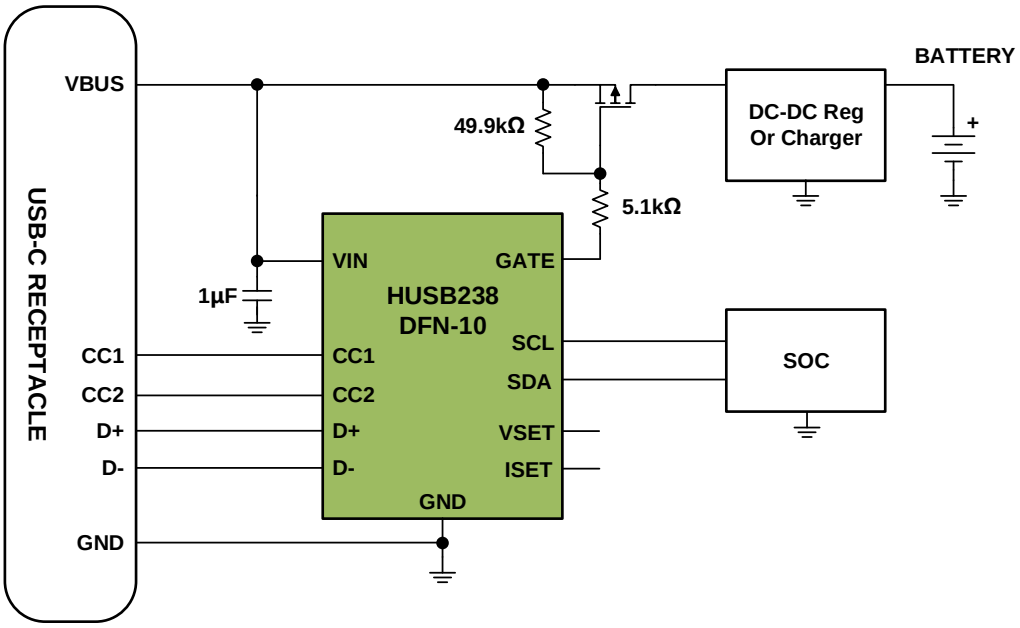
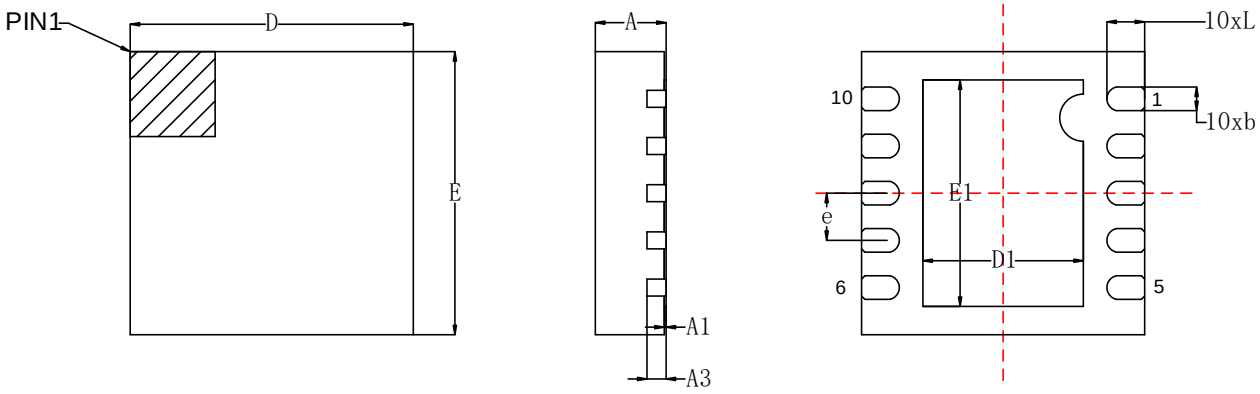


Figure 4. USB-C Device Application

PACKAGE OUTLINE DIMENSIONS



TOP VIEW SIDE VIEW BOTTOM VIEW

SYMBOLS	DIMENSION IN MILLIMETERS		
	MIN	NOM	MAX
A	0.700	0.750	0.800
A1	0.000	0.020	0.050
D	2.924	3.000	3.076
E	2.924	3.000	3.076
D1	1.600	1.700	1.800
E1	2.300	2.400	2.500
b	0.200	0.250	0.300
b1	0.180REF		
e	0.500BSC		
L	0.324	0.400	0.476

Figure 5. DFN-10L Package, 3 mm × 3 mm

PACKAGE TOP MARKING

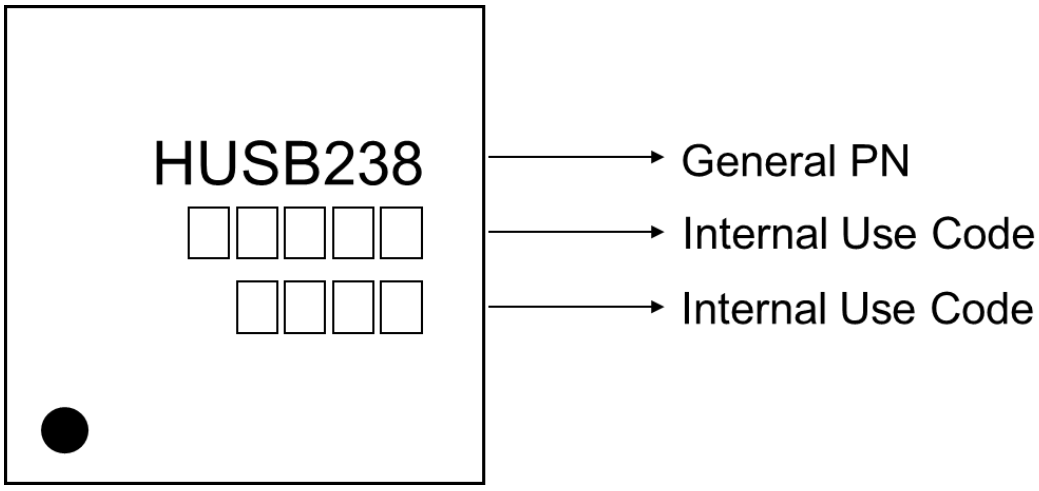


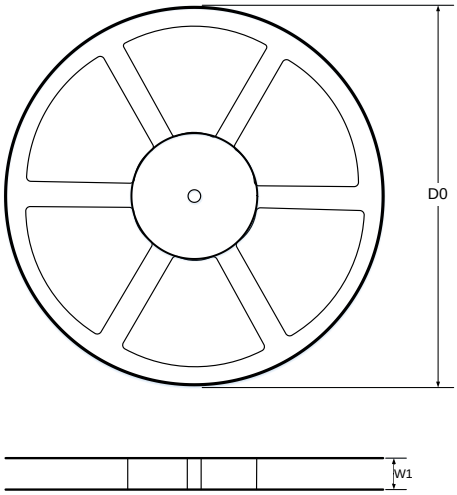
Figure 6. HUSB238 Top Marking

ORDERING GUIDE

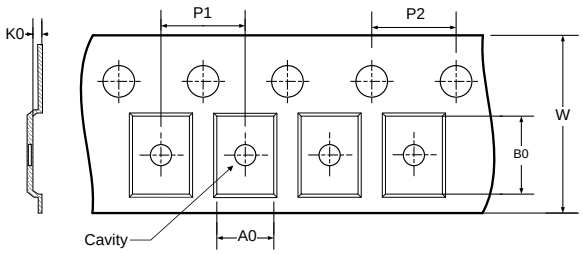
Model	Package	SOP'	OTP Threshold	RDO Mismatch Action	USB Comm	GATE_ON_TIME	Package Option
HUSB238_001DD	DFN-10L	YES	90°C / 75°C	Request 5V	No	During POR	Tape & Reel, 4k
HUSB238_002DD	DFN-10L	NO	150°C / 130°C	Next PDO	No	During POR	Tape & Reel, 4k
HUSB238_003DD	DFN-10L	YES	90°C / 75°C	Next PDO	No	During POR	Tape & Reel, 4k
HUSB238_004DD	DFN-10L	NO	150°C / 130°C	Request 5V	No	During POR	Tape & Reel, 4k
HUSB238_005DD	DFN-10L	NO	150°C / 130°C	Next PDO	Yes	During POR	Tape & Reel, 4k
HUSB238_006DD	DFN-10L	NO	150°C / 130°C	Next PDO	Yes	During Contract	Tape & Reel, 4k

TAPE AND REEL INFORMATION

REEL DIMENSIONS

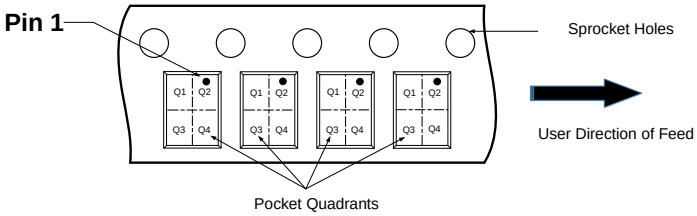


TAPE DIMENSIONS



A0：Dimension designed to accommodate the component width
B0：Dimension designed to accommodate the component length
K0：Dimension designed to accommodate the component thickness
W：Overall width of the carrier tape
P1：Pitch between successive cavity centers
P2：Pitch between sprocket hole
D0：Reel Diameter
W1：Reel Width

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



DIMENSIONS AND PIN1 ORIENTATION

D0 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
330.00	12.40	3.35	3.35	1.13	8.00	4.00	12.00	Q2

All dimensions are nominal

Figure 7. Tape and Reel Information

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