# SY20816C

## 2 to 1 Power MUX for USB PD Application

## General Description

The SY20816C is a 2 to 1 power MUX switch for USB PD applications. The SY20816C integrates two low-on-resistance power paths: one high-voltage power path and a 5V power path. The high-voltage power path is a bi-directional channel. It can be configured as a sink or source port. Both directions have reverse blocking capability.

The SY20816C integrates the CC bypass path. The HOST_CCx is isolated from CONN_CCx in the case of a dead battery or when VCONN is applied. If CONN_CCx input is selected as CC line, CONN_CCx can be bypassed to HOST_CCx using the I²C interface.

The SY20816C supports USB PD fast role swap. Once it's detected that the VBUS is lower than 4.75V, the high voltage channel will shut down, and the 5V power path will be turned on in 100μs and act as a new source.

## Features

- 2 to 1 Power MUX:
  - High Voltage Channel: 4.5V to 23V Range for VCHG
  - V5V Channel: 4V to 5.5V Range for 5V Input
- Smooth Ramp Control during Channel Transitions
- Reverse Blocking Capability
- Bi-directional Control for High Voltage Channel
- Fast Role Swap
- I²C Interface
- CC Bypass and Isolation Control
- Dead Battery Wake-Up Function
- VCONN Path for E-Mark Cable
- Protection:
  - Output Current Limit Setting
  - OCP/OVP/TSD/UVP

## Applications

- USB PD
- Desktop PC
- Laptops
- Smartphones

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## Typical Application

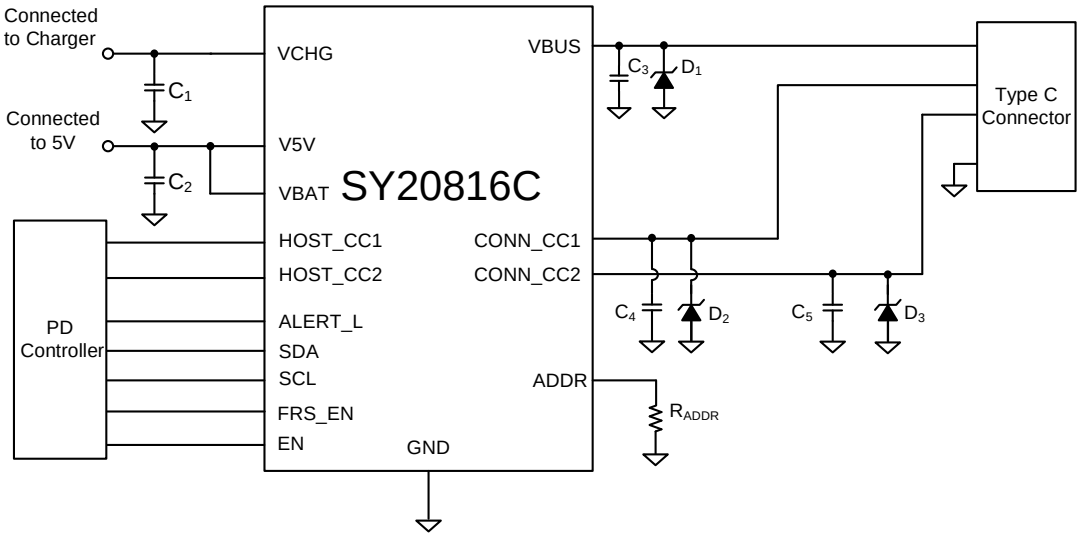


*Figure 1. Schematic Diagram*


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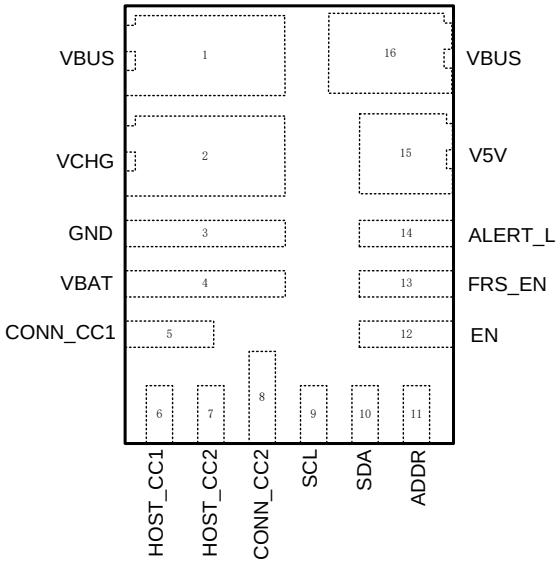
## Ordering Information

| Ordering Part Number | Package Type | Top Mark |
|---|---|---|
| SY20816CQLC | QFN3×4-16<br>RoHS Compliant and Halogen Free | **ECF*xyz*** |

***x=year code, y=week code, z= lot number code***

## Pinout (top view)




| Pin Name | Pin Number | Pin Description |
|---|---|---|
| VBUS | 1,16 | Connector VBUS pin. Input/output and discharge switches, and powers the IC in case of a dead battery. |
| VCHG | 2 | 4.5V to 23V power input pin. Decouple this pin to PGND with a ceramic capacitor. |
| GND | 3 | Ground pin. |
| VBAT | 4 | 2.5V to 5.5V battery input to provide VCONN power. |
| CONN_CC1 | 5 | Connect to Type C connector CC1. |
| HOST_CC1 | 6 | Connect to the host's Type C port controller's CC1 pin. |
| HOST_CC2 | 7 | Connect to the host's Type C port controller's CC2 pin. |
| CONN_CC2 | 8 | Connect to Type C connector CC2. |
| SCL | 9 | $I^2C$ Interface serial clock pin. Logic level input. |
| SDA | 10 | $I^2C$ Interface serial data pin. Logic level input/output. |
| ADDR | 11 | The device address set pin. Connect a resistor to GND to program the $I^2C$ address. |
| EN | 12 | Enable control. Pull high to activate the device. |
| FRS_EN | 13 | Fast role swap function enabling pin. A high level enables the FRS function. Pull low to disable. Do not leave floating. |
| ALERT_L | 14 | Open drain output, routed to the host interrupt input. Requires external pulled up. |
| V5V | 15 | 5V input. Provides power for 5V out. It also powers the IC in normal operation. |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## Block Diagram

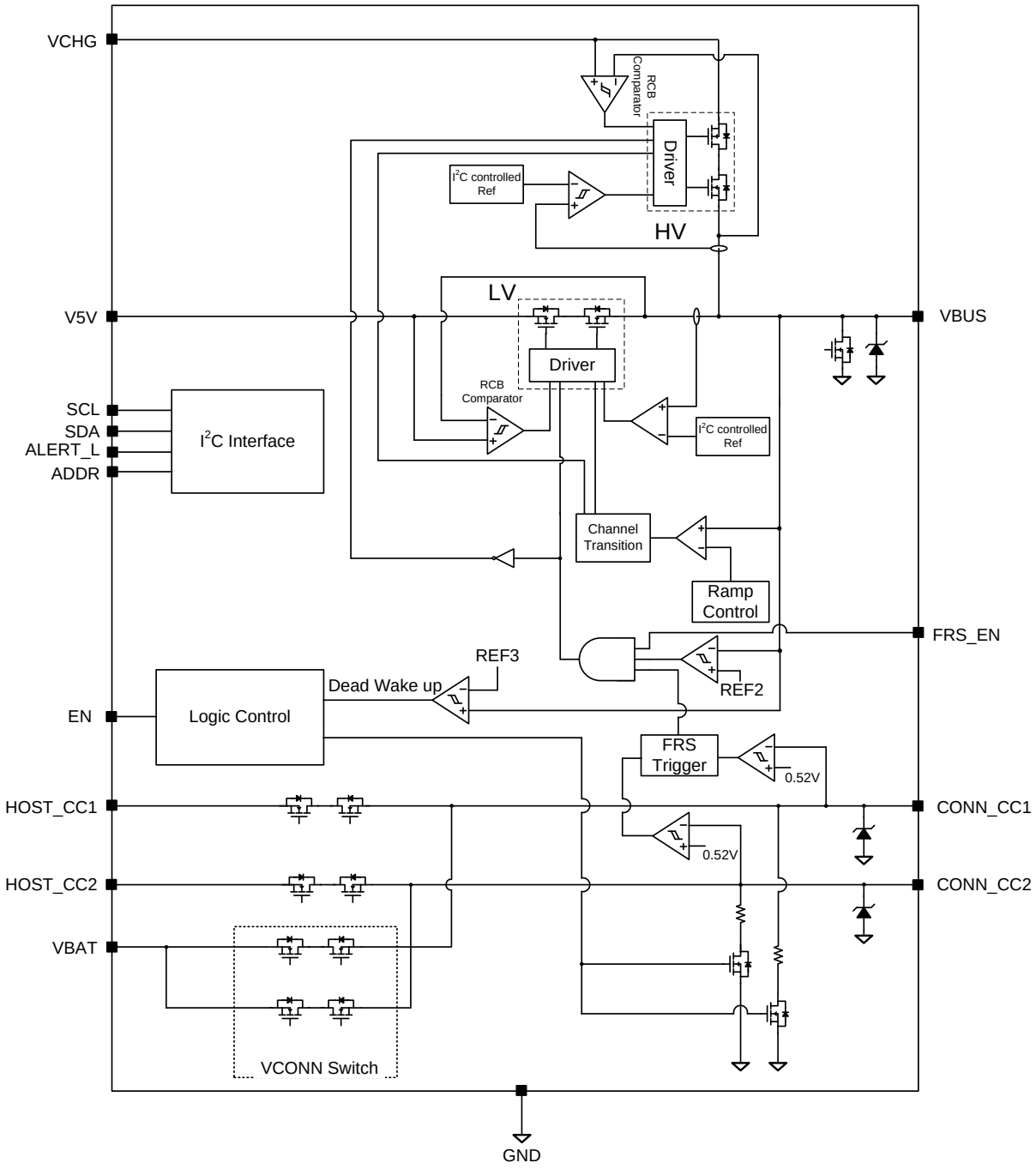


*Figure 2. Block Diagram*


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| Absolute Maximum Ratings (1) | Min | Max | Unit |
|---|---|---|---|
| VCHG | -0.3 | 25 | V |
| V5V, VBAT | -0.3 | 6 | |
| CONN_CCx | -0.3 | 30 | |
| VBUS, EN, FRS | -0.3 | 28 | |
| SCL, SDA, ADDR, ALERT_L, HOST_CCx | -0.3 | 3.6 | |
| Junction Temperature, Operating | -40 | 150 | °C |
| Lead Temperature (Soldering, 10sec.) | | 260 | |
| Storage Temperature | -65 | 150 | |

| Thermal Information (2) | Typ | Unit |
|---|---|---|
| $\theta_{JA}$ Junction-to-ambient Thermal Resistance | 45 | °C/W |
| $\theta_{JC}$ Junction-to-case Thermal Resistance | 28 | |
| $P_D$ Power Dissipation $T_A$=25°C | 2.2 | W |

| ESD Susceptibility | Min | Max | Unit |
|---|---|---|---|
| **HBM (Human Body Mode)** | | | |
| VBUS, CONN_CC1, CONN_CC2 | | 8 | kV |
| VCHG, V5V, VBAT, HOST_CC1, HOST_CC2, ALERT_L, EN, SCL, SDA, ADDR, GND, FRS_EN | | 2 | kV |
| **CDM (Charged Device Mode)** | | | |
| All Pins | | 500 | V |
| | | | |
| **Recommended Operating Conditions (3)** | **Min** | **Max** | **Unit** |
| VCHG | 4.5 | 23 | V |
| V5V, VBAT | 4 | 5.5 | |
| CONN_CCx | 0 | 28 | |
| VBUS, EN, FRS | 0 | 25 | |
| SCL, SDA, ADDR, ALERT_L, HOST_CCx | 0 | 3.3 | |
| Junction Temperature, Operating | -40 | 125 | °C |
| Ambient Temperature | -40 | 85 | |

## Electrical Characteristics (V5V = 5V, VCHG =20V, $T_A$ = 25°C, $I_{OUT}$= 1A. Unless otherwise specified)

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Voltage Range for Charger Pin | $V_{CHG}$ | | 4.5 | | 23 | V |
| Voltage Range for VBUS | $V_{BUS}$ | | 4.0 | | 25 | V |
| Voltage Range for V5V | $V_{V5V}$ | | 4.0 | | 5.5 | V |
| Voltage Range for VBAT | $V_{BAT}$ | | 2.5 | | 5.5 | V |
| Under Voltage Protection for VCHG | $V_{UVP_CHG}$ | | | | 4.4 | V |
| Hysteresis of Under Voltage Protection for VCHG | $V_{UVP_CHG_HYS}$ | | | 0.2 | | V |
| Under Voltage Protection for VBUS | $V_{UVP_VBUS}$ | | | | 3.9 | V |
| Hysteresis of Under Voltage Protection for VBUS | $V_{UVP_VBUS_HYS}$ | | | 0.1 | | V |


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## Electrical Characteristics (V5V = 5V, VCHG =20V, $T_A$ = 25°C, $I_{OUT}$= 1A. Unless otherwise specified)

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Under Voltage protection for V5V | $V_{UVP_V5V}$ | | | | 3.9 | V |
| Hysteresis Under Voltage protection for V5V | $V_{UVP_V5V_HYS}$ | | | 0.2 | | V |
| Under Voltage Protection for VBAT | $V_{UVP_BAT}$ | | | | 2.45 | V |
| Hysteresis Under Voltage Protection for V5V | $V_{UVP_BAT_HYS}$ | | | 0.1 | | V |
| Quiescent Current | $I_{Q_CHG}$ | $V_{CHG}$=20V, $V_{V5V}$=0V, EN=1, $V_{BAT}$=0V, OVP_SET=111, Null load. HV channel is selected, source mode. | | 200 | | μA |
| | | $V_{CHG}$=20V, $V_{V5V}$=5V, EN=1, $V_{BAT}$=0V, OVP_SET=111, Null load. V5V channel is selected | | 200 | | μA |
| | $I_{Q_VBUS}$ | VBUS =20V, $V_{V5V}$=0V, EN=1, OVP_SET=111, VOUT null load. HV channel is selected, sink mode. | | 200 | | μA |
| | $I_{Q_V5V}$ | $V_{CHG}$=0V, $V_{V5V}$=5V, EN=1, $V_{BAT}$=0V, OVP_SET=111, Null load. V5V channel is selected | | 200 | | μA |
| | $I_{Q_BAT}$ | $V_{CHG}$=0V, $V_{V5V}$=0V, EN=1, $V_{BAT}$=5V, OVP_SET=111, Null load. | | 10 | | μA |
| Shutdown Current | $I_{SHDN_CHG}$ | $V_{CHG}$=20V, $V_{V5V}$=0V, EN=0, $V_{BAT}$=0V, OVP_SET=111, Null load. | | 15 | | μA |
| | | $V_{CHG}$=20V, $V_{V5V}$=5V, EN=0, $V_{BAT}$=0V, OVP_SET=111, Null load. | | 20 | | μA |
| | $I_{SHDN_V5V}$ | $V_{CHG}$=0V, $V_{V5V}$=5V, EN=0, $V_{BAT}$=0V, OVP_SET=111, Null load. | | 15 | | μA |
| Shutdown Current | $I_{SHDN_VBAT}$ | $V_{CHG}$=0V, $V_{V5V}$=0V, EN=0, $V_{BAT}$=5V, OVP_SET=111, Null load. | | 8 | | μA |
| On Resistance of HV Power Path | $R_{DS(ON)_HV}$ | HV channel is selected, the load is 1A | | 27 | 33 | mΩ |
| On Resistance of 5V Power Path | $R_{DS(ON)_5V}$ | 5V channel is selected, the load is 2A | | 41 | 48 | mΩ |
| On Resistance of $V_{CONN}$ | $R_{DS(ON)_CC}$ | VCONN is enabled, load=200mA | | 170 | 210 | mΩ |
| On Resistance of CC Bypass | $R_{DS(ON)_BP}$ | CCx_BPS is enabled, load=1mA | | 25 | 40 | Ω |
| Reverse Block Threshold for HV | $V_{TH_RCB_HV}$ | VBUS - VCHG when the HV channel is ON | | 50 | | mV |
| Reverse Block Threshold for LV | $V_{TH_RCB_5V}$ | VBUS - V5V when 5V channel is ON | | 50 | | mV |
| Reverse Block Response Time | $t_{REV}$ | | | 1 | | μs |
| Over Voltage Protection for V5V | $V_{OVP_V5V}$ | | 5.7 | 6 | 6.3 | V |
| Over Voltage Protection for VBAT | $V_{OVP_CC}$ | | 5.7 | 6 | 6.3 | V |
| Over Response Time | $t_{OV}$ | V5V rise from 5V to 7V | | 100 | | ns |
| Over Voltage Protection for HV | $V_{OVP_HV}$ | Default: OVP_SET=000 | 5.7 | 6 | 6.3 | V |
| | | OVP_SET=001 | 8 | 8.4 | 8.8 | V |
| | | OVP_SET=010 | 10.7 | 11.3 | 11.8 | V |
| | | OVP_SET=011 | 11.7 | 12.3 | 12.9 | V |
| | | OVP_SET=100 | 13.5 | 14.2 | 14.9 | V |


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## Electrical Characteristics (V5V = 5V, VCHG =20V, $T_A$ = 25°C, $I_{OUT}$= 1A. Unless otherwise specified)

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Over Response Time of HV Channel | $t_{OV_HV}$ | OVP_SET=101 | 17 | 17.9 | 18.8 | V |
| | | OVP_SET=110 | 20.5 | 21.6 | 22.7 | V |
| | | OVP_SET=111 | 22.5 | 23.7 | 24.9 | V |
| | | OVP_SET=000, VBUS change from 5V to 8V | | 100 | | ns |
| Sourcing/Sinking Current Limit Threshold for HV Power Path | $I_{LIM_HV}$ | Current limit control bit [00] | 1 | 1.25 | 1.5 | A |
| | | Current limit control bit [01] | 1.5 | 1.75 | 2 | A |
| | | Default: Current limit control bit [10] | 3 | 3.3 | 3.6 | A |
| | | Current limit control bit [11] | 5 | 5.5 | 6 | A |
| Sourcing Current Limit Threshold for 5V Power Path | $I_{LIM_5V}$ | Current limit control bit [00] | 1 | 1.25 | 1.5 | A |
| | | Current limit control bit [01] | 1.5 | 1.75 | 2 | A |
| | | Current limit control bit [10] | 2 | 2.25 | 2.5 | A |
| | | Default: Current limit control bit [11] | 3 | 3.3 | 3.6 | A |
| Current Limit Response Time for HV Power Path/ ALERT_L Response Time for Over Current Protection | $t_{OC}$ | Current limit response time control bit [00] | | 1 | | ms |
| | | Default: Current limit response time control bit [01] | | 10 | | ms |
| | | Current limit response time control bit [10] | | 50 | | ms |
| | | Current limit response time control bit [11] | | 100 | | ms |
| $V_{CONN}$ Current Limit Threshold | $I_{VCONN}$ | VBAT=5V, VCONNx=1 | 600 | 660 | 720 | mA |
| Current Limit Response Time of $V_{CONN}$ | $t_{VCONN_OC}$ | | | 4 | | µs |
| Thermal Shutdown Temperature | $T_{SD}$ | | | 150 | | °C |
| Thermal Shutdown Hysteresis | $T_{HYS}$ | | | 15 | | °C |
| **Transition Speciation** | | | | | | |
| Positive Slew Rate of VBUS When Channel Transition | $V_{SLEW_POS}$ | | | 2 | | V/ms |
| Negative Slew Rate of VBUS When Channel Transition | $V_{SLEW_NEG}$ | | | -2 | | V/ms |
| Rise Time of $V_{CONN}$ | $t_{rise_VCONN}$ | | | 250 | | µs |
| Transition Response Time | $t_D$ | Measure from the I2C ACK signal to the point when VOUT begins to rise or fall. | | 1 | | ms |
| Discharge Resistance | $R_{DSG}$ | RDSG bit [00] | | 200 | | Ω |
| | | RDSG bit [01] | | 400 | | Ω |
| | | RDSG bit [10] | | 800 | | Ω |
| | | RDSG bit [11] | | 1600 | | Ω |
| Discharge Time | $t_{DSG}$ | TDSG bit [00] | | 50 | | ms |
| | | TDSG bit [01] | | 100 | | ms |
| | | TDSG bit [10] | | 200 | | ms |
| | | TDSG bit [11] | | 400 | | ms |
| Fast Role Swap Trigger Threshold | $V_{FRS}$ | HV_DR=0, FRS_EN=1, VBUS drop, measure V5V - VBUS | | 40 | | mV |
| Fast Role Swap Trigger Threshold on CC | $V_{FRS_CC}$ | HV_ER=0, FRS_EN=1, CC_FRS=1 | 0.49 | 0.52 | 0.55 | V |


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## Electrical Characteristics (V5V = 5V, VCHG =20V, $T_A$ = 25°C, $I_{OUT}$= 1A. Unless otherwise specified)

| Parameter | | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Fast Role Swap Response | | $t_{FRS}$ | V5V =5V. When VOUT drops below 4.75V and then returns to 4.75V. | | | 100 | μs |
| EN/ Threshold | Logic-low Voltage | $V_{IL}$ | (Note 4) | | | 0.4 | V |
| | Logic-high Voltage | $V_{IH}$ | (Note 4) | 1.5 | | | V |
| **I²C Compatible Interface** | | | | | | | |
| Maximum Operating Frequency | | | (Note 4) | | 1 | | MHz |
| SDA and SCL Input Logic Threshold | | Logic_L | (Note 4) | | | 0.4 | V |
| | | Logic_H | (Note 4) | 1.5 | | | V |
| SDA Output Low Voltage | | | (Note 4) | | | 0.4 | V |

**Note 1**: Stresses beyond the "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

**Note 2**: $\theta_{JA}$ is measured in the natural convection at $T_A$ = 25°C on a highly effective 4-layer thermal conductivity test board of JEDEC 51-7 thermal measurement standard.

**Note 3:** The device is not guaranteed to function outside its operating conditions.

**Note 4:** Guaranteed by design, not production test.


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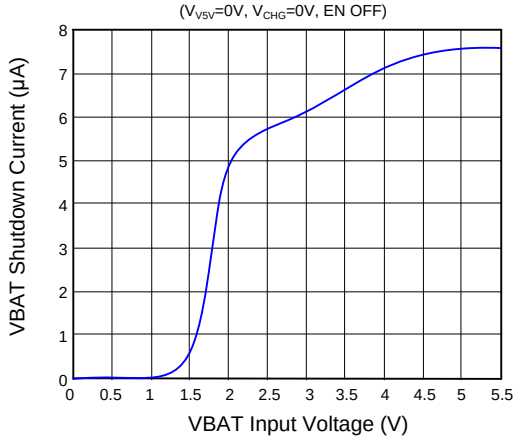
## Typical Performance Characteristics

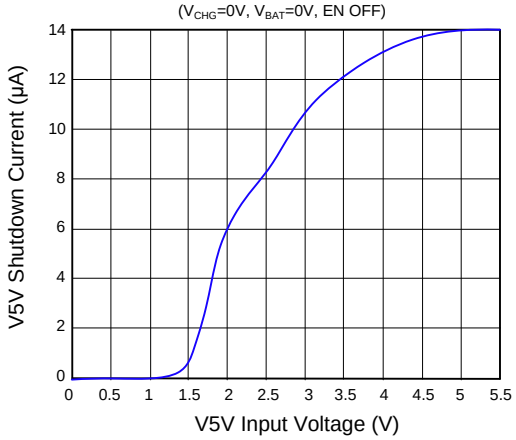
VBAT Shutdown Current vs. VBAT Input Voltage

($V_{V5V}$=0V, $V_{CHG}$=0V, EN OFF)



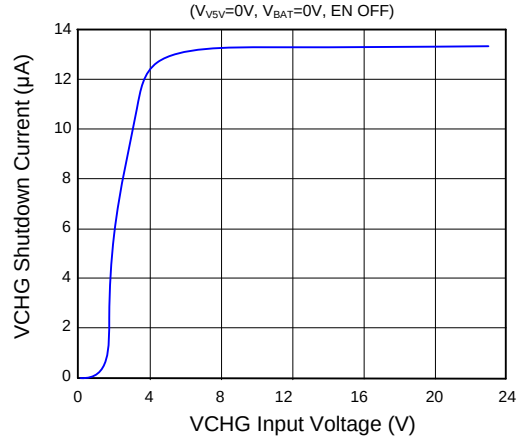

V5V Shutdown Current vs. V5V Input Voltage

($V_{CHG}$=0V, $V_{BAT}$=0V, EN OFF)



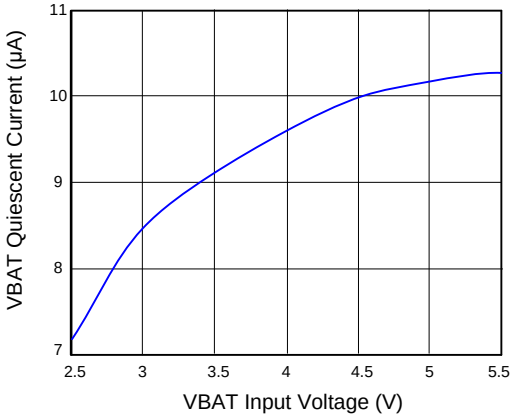

VCHG Shutdown Current vs. VCHG Input Voltage

($V_{V5V}$=0V, $V_{BAT}$=0V, EN OFF)



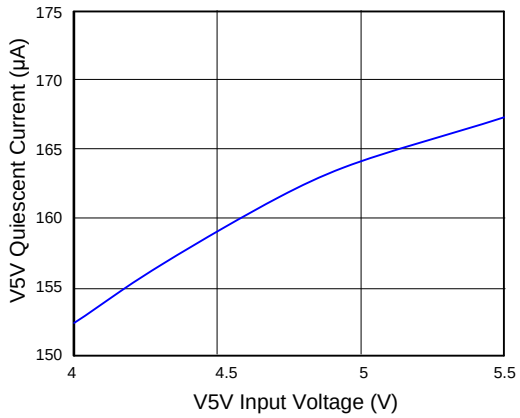

VBAT Quiescent Current vs. VBAT Input Voltage

($V_{CHG}$=0V, $V_{V5V}$=0V, EN ON)



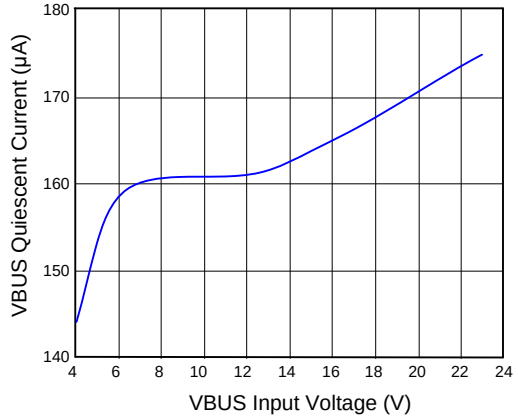

V5V Quiescent Current vs. V5V Input Voltage

($V_{CHG}$=0V, $V_{BAT}$=0V, V5V channel is selected, EN ON)




VBUS Quiescent Current vs. VBUS Input Voltage

($V_{V5V}$=0V, $V_{BAT}$=0V, CHG channel is selected, OVP_SET=111, EN ON)





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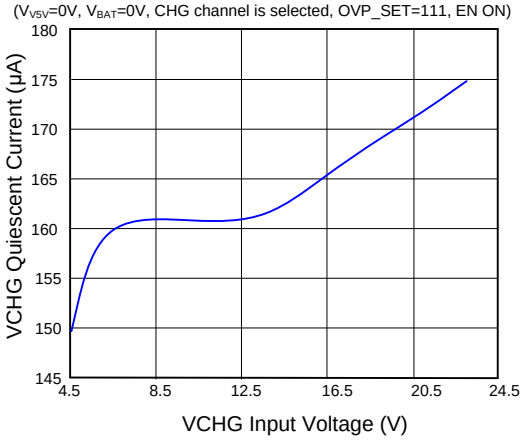
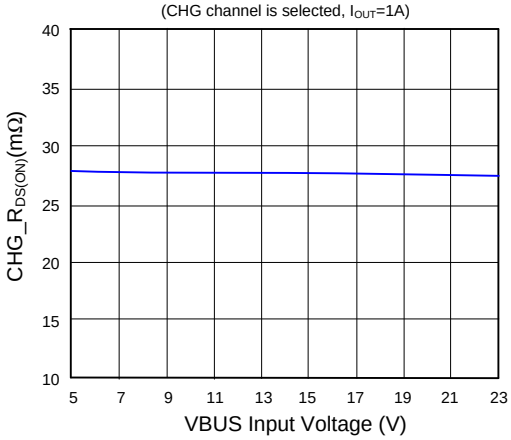
VCHG Quiescent Current vs. VCHG Input Voltage

($V_{V5V}$=0V, $V_{BAT}$=0V, CHG channel is selected, OVP_SET=111, EN ON)



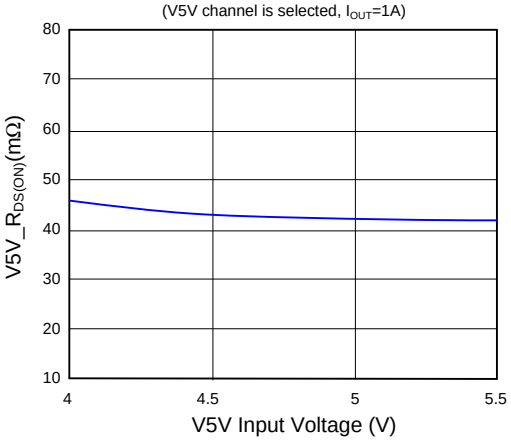

CHG_$R_{DS(ON)}$ vs. VBUS Input Voltage

(CHG channel is selected, $I_{OUT}$=1A)



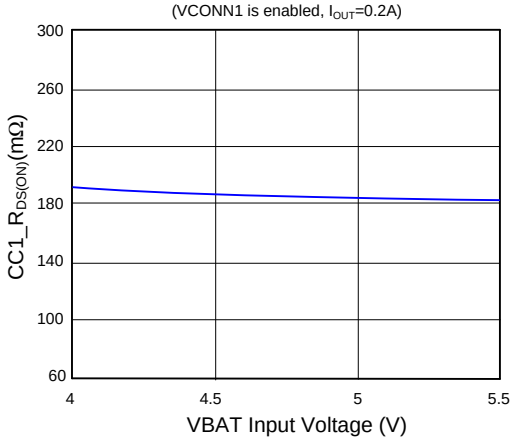

V5V_$R_{DS(ON)}$ vs. V5V Input Voltage

(V5V channel is selected, $I_{OUT}$=1A)



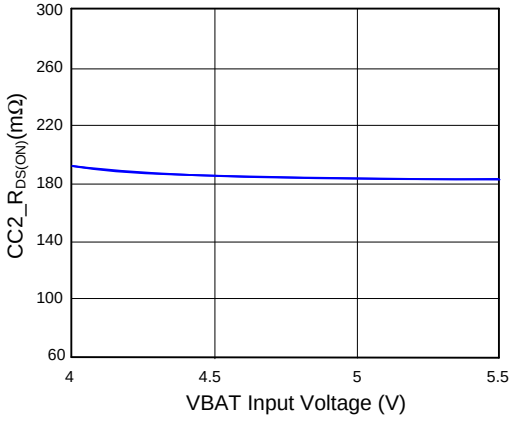

CC1_$R_{DS(ON)}$ vs. VBAT Input Voltage

(VCONN1 is enabled, $I_{OUT}$=0.2A)



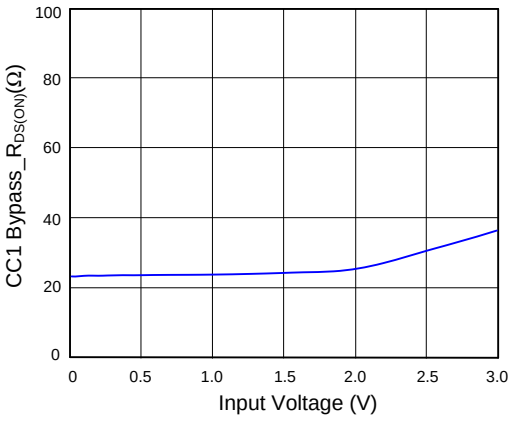

CC2_$R_{DS(ON)}$ vs. VBAT Input Voltage

(VCONN2 is enabled, $I_{OUT}$=0.2A)




CC1 Bypass_$R_{DS(ON)}$ vs. Input Voltage

(CC1_BPS is enable, $I_{OUT}$=1mA)





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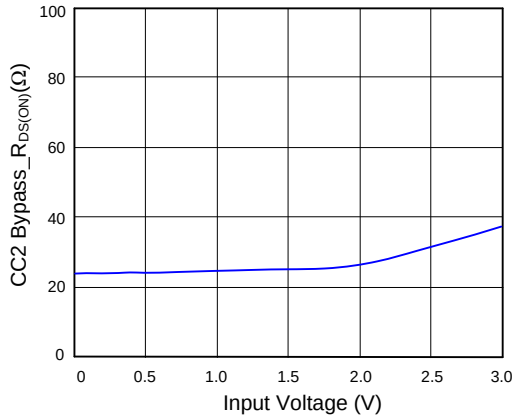
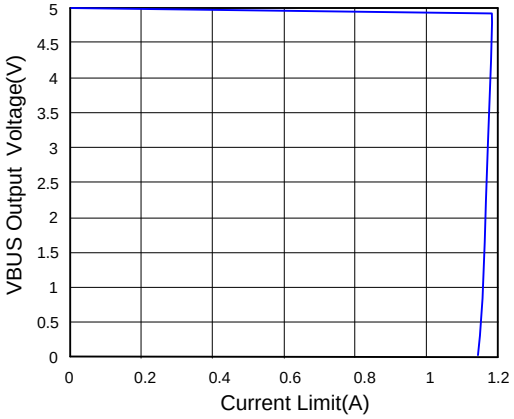
CC2 Bypass_$R_{DS(ON)}$ vs. Input Voltage

(CC2_BPS is enable, $I_{OUT}$=1mA)



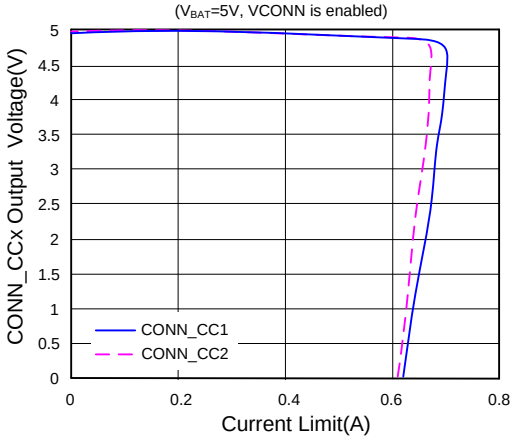

Current Limit vs. VBUS Output Voltage

($V_{V5V}$=5V, V5V channel is selected, 5V_ILIM=00)



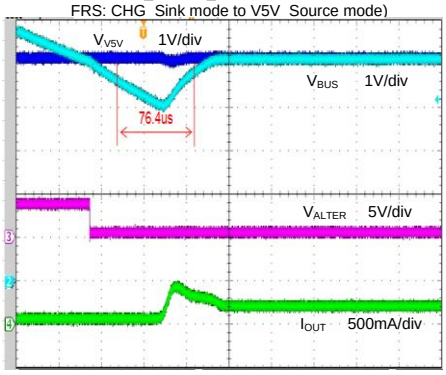

Current Limit vs. CONN_CCx Output Voltage

($V_{BAT}$=5V, VCONN is enabled)




Fast Role Swap

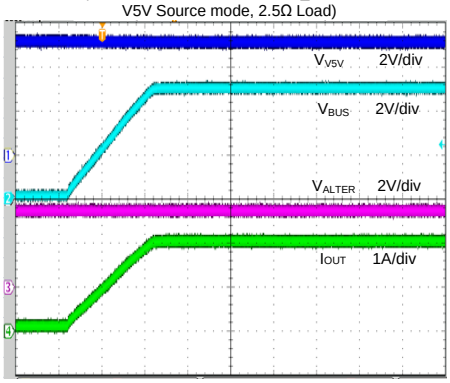
($V_{V5V}$=5V , $V_{BUS}$=10V plug out , $C_{V5V}$=$C_{BUS}$=10uF,
FRS_EN=CC_FRS=1,0.2A Load,
FRS: CHG Sink mode to V5V Source mode)




Time (40μs/div)

V5V_Source ON

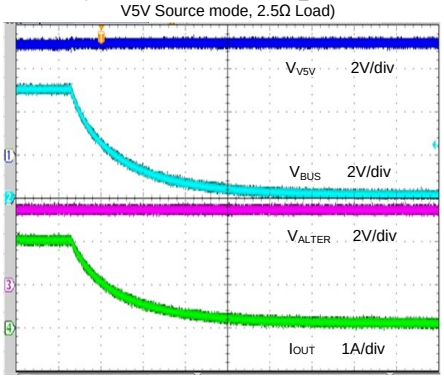
($V_{V5V}$=5V, $C_{V5V}$=$C_{BUS}$=10uF, 5V_ILIM=11,
V5V Source mode, 2.5Ω Load)




Time (800μs/div)

V5V_Source OFF

($V_{V5V}$=5V, $C_{V5V}$=$C_{BUS}$=10uF, 5V_ILIM=11,
V5V Source mode, 2.5Ω Load)




Time (20μs/div)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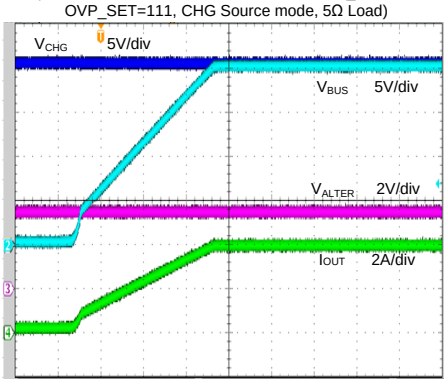
CHG_Source ON

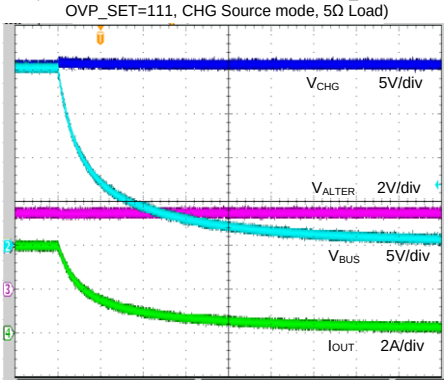
($V_{CHG}$=20V, $V_{V5V}$=5V, $C_{CHG}$=$C_{BUS}$=10uF,CHG_ILIM=11, OVP_SET=111, CHG Source mode, 5Ω Load)




Time (2ms/div)

CHG_Source OFF

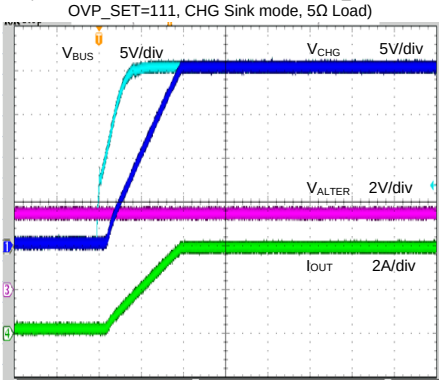
($V_{CHG}$=20V, $V_{V5V}$=5V, $C_{CHG}$=$C_{BUS}$=10uF, CHG_ILIM=11, OVP_SET=111, CHG Source mode, 5Ω Load)




Time (20μs/div)

VBUS ON

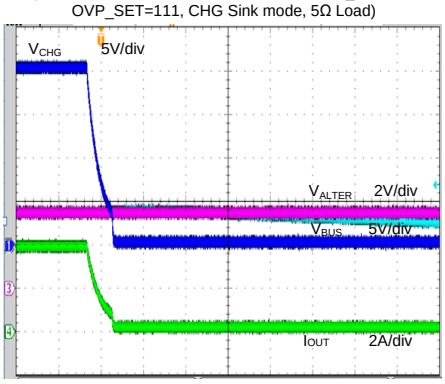
($V_{BUS}$=20V, $V_{V5V}$=5V, $C_{CHG}$=$C_{BUS}$=10uF, CHG_ILIM=11, OVP_SET=111, CHG Sink mode, 5Ω Load)




Time (4ms/div)

VBUS OFF

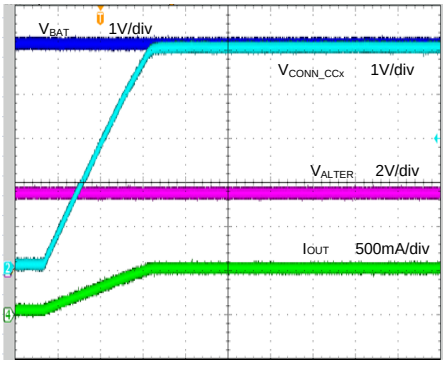
($V_{BUS}$=20V, $V_{V5V}$=5V, $C_{CHG}$=$C_{BUS}$=10uF, CHG_ILIM=11, OVP_SET=111, CHG Sink mode, 5Ω Load)




Time (4ms/div)

VCONN Switch ON

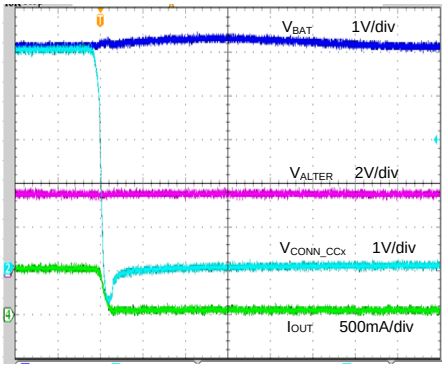
($V_{BAT}$=5V, $C_{BAT}$=1uF, VCONN=1, 10Ω Load)




Time (100μs/div)

VCONN Switch OFF

($V_{BAT}$=5V, $C_{BAT}$=1uF, VCONN=0, 10Ω Load)




Time (1μs/div)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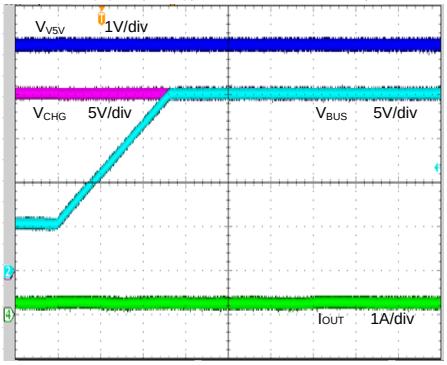
Positive Voltage Transitions

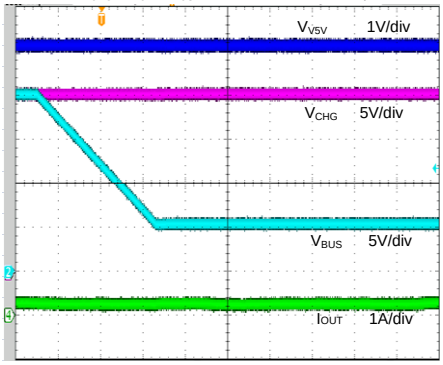
($V_{V5V}$=5V, $V_{CHG}$=20V, $V_{BUS}$=5V→20V,OVP_SET=111, $C_{CHG}$=$C_{V5V}$=$C_{BUS}$=10uF, 150mA CC Load)




Time (2ms/div)

Negative Voltage Transitions

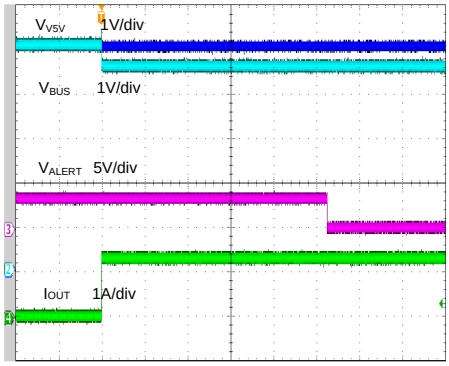
($V_{V5V}$=5V, $V_{CHG}$=20V, $V_{BUS}$=20V→5V,OVP_SET=111, $C_{CHG}$=$C_{V5V}$=$C_{BUS}$=10uF, 150mA CC Load)




Time (2ms/div)

V5V Channel Over Current Response

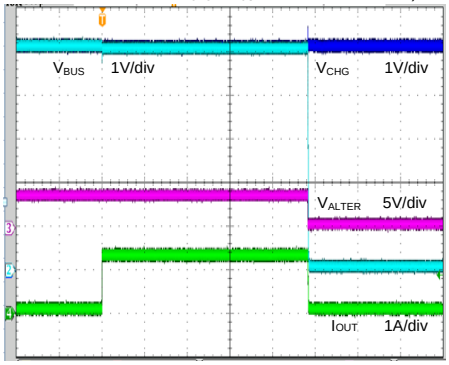
($V_{V5V}$=5V, V5V Source mode, 5V_ILIM=00, OC_DELAY=10, 3.5Ω switch on)




Time (10ms/div)

CHG Channel Over Current Response

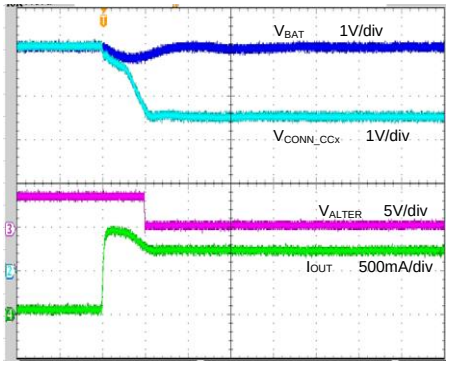
($V_{CHG}$=5V, CHG_ILIM=00, DSG_Time=00, OC_DELAY=10, CHG Source mode, $C_{CHG}$=$C_{BUS}$=10uF, 3.5Ω switch on)




Time (10ms/div)

VCONN Channel Over Current Response

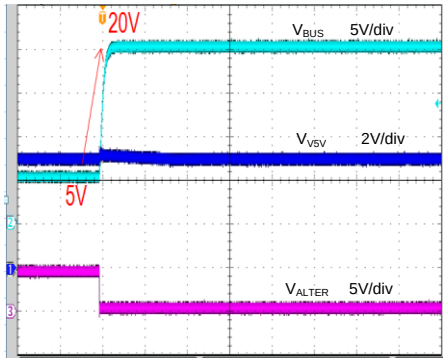
($V_{BAT}$=5V, $C_{BAT}$=1uF, Load=5Ω ON)




Time (4μs/div)

V5V Over Voltage Protection Response

($V_{V5V}$=5V, $V_{BUS}$=5.0V→20.0V, V5V Source mode, $C_{V5V}$=$C_{VBUS}$=10uF)




Time (10ms/div)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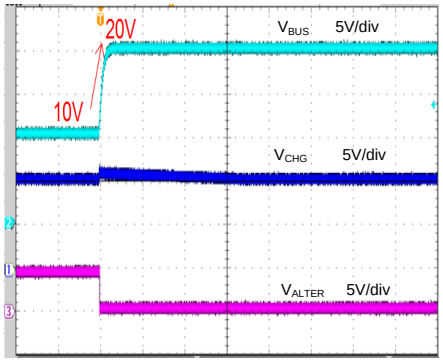
CHG Over Voltage Protection Response

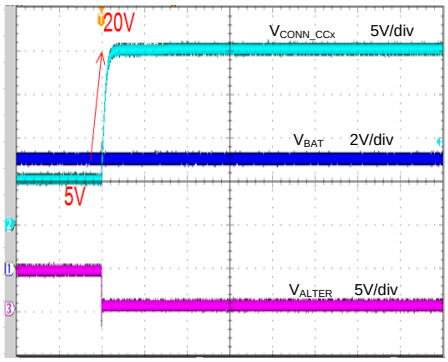
($V_{V5V}$=5V, $V_{CHG}$=10V, OVP_SET=010,$V_{BUS}$=10.0V→20.0V, CHG Source mode, $C_{CHG}$=$C_{VBUS}$=10uF)




Time (10ms/div)

VBAT Over Voltage Protection Response

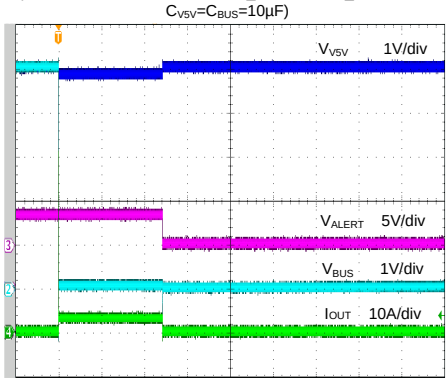
($V_{V5V}$=$V_{BAT}$=5V, VCONN is enabled $V_{CONN_CC1/2}$=5.0V→20.0V, $C_{BAT}$=1uF)




Time (10ms/div)

V5V Channel Short Response

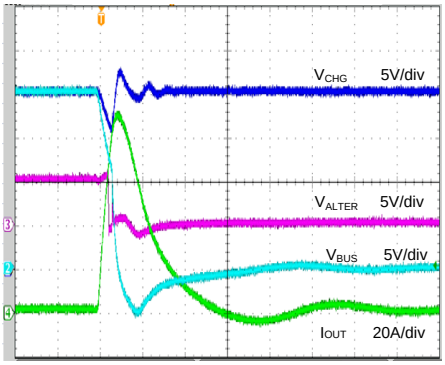
($V_{V5V}$=5V, V5V Source Mode, 5V_ILIM=11, OC_DELAY=10, $C_{V5V}$=$C_{BUS}$=10μF)




Time (20ms/div)

CHG Channel Short Response

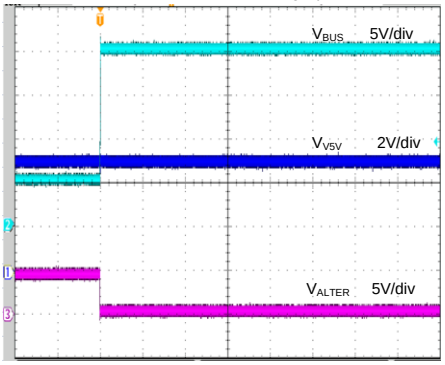
($V_{CHG}$=20V, CHG Source mode, EN=ON, $C_{CHG}$=$C_{BUS}$=10uF)




Time (2μs/div)

V5V Channel Hot Plug Response

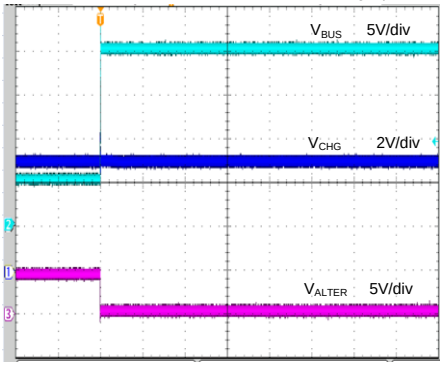
($V_{V5V}$=5V, V5V Souece mode, EN ON,$C_{V5V}$=$C_{BUS}$=10uF, Null load, $V_{BUS}$=20V Plug In)




Time (10ms/div)

CHG Channel Hot Plug Response

($V_{CHG}$=5V, CHG Source mode, EN ON, OVP_SET=000, $C_{CHG}$=$C_{BUS}$=10uF, Null load, $V_{BUS}$=20V Plug In)




Time (10ms/div)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## Detailed Description

The SY20816C is a 2 to 1 power multiplexer switch providing programmable over-current and over-voltage protections for USB PD applications. The SY20816C has a bi-directional high-voltage power path capable of sinking or sourcing modes through an internal switch path designed to support USB-PD power up to 23V and 5A current.

The SY20816C incorporates the back-to-back N-channel MOSFET on two low-on-resistance power paths, in order to prevent the current flow from OUT to IN when OUT is externally forced to a higher voltage than IN.

### 1. I²C Compatible Interface

The SY20816C integrates an I²C-compatible interface. The I²C interface supports clock speeds of up to 400kHz ("Fast-Mode") and uses standard I²C commands to ensure compatibility with a wide range of system processors. The SY20816C always operates as a slave device. It is addressed using a 7-bit slave address followed by an 8th bit, which indicates whether the transaction is a read-operation or a write-operation.

The I²C interface is fully functional after the power supply exceeds the UVLO threshold.

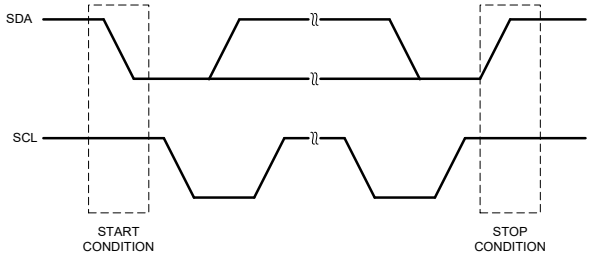
**I²C Device Address**

When communicating with multiple devices through the I²C interface, each device must have a unique address, allowing the host to differentiate between them. In the case of the SY20816C, the most significant 5-bits of its device address are fixed at '10000,' while the 6th and 7th bits can be selected using the ADDR pin. A total of 4 distinct addresses are provided, and can be configured using the RADDR input pin.

| RADDR | Device Address |
|---|---|
| ADDR short to GND | 1000000 |
| 44.2k | 1000001 |
| 200k | 1000010 |
| ADDR tie to VCC | 1000011 |

**START and STOP Conditions**

The START condition is a HIGH to LOW transition of the SDA line, while SCL is HIGH. The STOP condition is a LOW to HIGH transition on the SDA line, while SCL is HIGH. A STOP condition must be sent before each START condition. The I²C master always generates the START and STOP conditions.




**Data Validity**

The data on the SDA line must be stable during the HIGH period of the SCL unless generating a START or STOP condition. The HIGH or LOW state of the data line can only change when the clock signal on the SCL line is LOW.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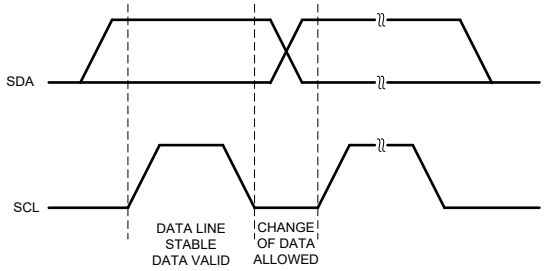
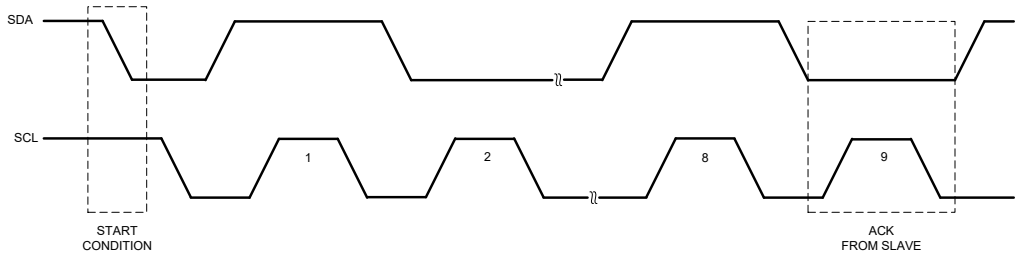



**Acknowledge**

Each address and data transmission uses 9-clock pulses. The ninth pulse is the acknowledge bit (ACK). After the START condition, the master sends 7-slave address bits and an R/ bit during the subsequent 8-clock pulses. During the ninth clock pulse, the device that recognizes its own address holds the data line low to acknowledge. Both the master and the slave also use the acknowledge bit to acknowledge receipt of register addresses and data.

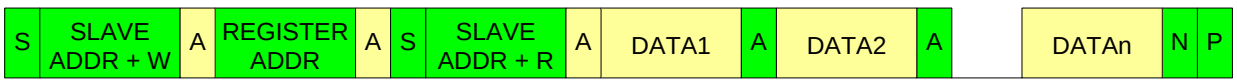


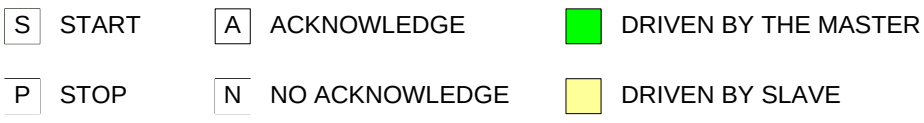

**Data Transactions**

All transactions start with a control byte sent from the $I^2C$ master device. The control byte begins with a START condition, followed by 7-bits of slave address, followed by the R/ bit. The R/ bit is 0 for a write or 1 for a read. If any slave devices on the $I^2C$ bus recognize their address, they will acknowledge by pulling the SDA line low for the last clock cycle in the control byte. If no slave devices exist at that address or are not ready to communicate, the data line will be 1, indicating a Not Acknowledge condition. Once the control byte is sent, and the SY20816C acknowledges it, the 2nd byte sent by the master must be a register address byte. The register address byte tells the SY20816C which register the master will write or read. Once the SY20816C receives a register address byte, it responds with an acknowledgement. If a STOP condition is detected after the register address byte is received, the SY20816C takes no further action but stores the register address byte. The register address byte auto increases when multiple data bytes are transmitted.

Write

Random Read





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**Register Map**

**Status register:** 0x00

| Bit 7 | | | | | | | Bit 0 |
|---|---|---|---|---|---|---|---|
| OC_HV | RVS | OC_5V | OVP | FRS | TSD | Vsafe5V | Vsafe0V |
| R | R | R | R | R | R | R | R |

**Bit 7 OC_HV:** Over current indicator for the high-voltage power path. When the load current exceeds the current limit value for longer than Toc, this bit will be set and power FET is turned off. This bit will be cleared when read if the error condition has been removed. This bit will cause the ALERT_L pin to be asserted.

1 = Load current exceeds the current limit value.

0 = High voltage power path not over current.

**Bit 6 RVS:** Reverse Block indicator for selected power path. When OUT is higher than IN by more than 50mV, this bit will be set to 1. This bit will be cleared when read if the error condition has been removed. This bit will cause the ALERT_L pin to be asserted

- High voltage path is enabled, source mode.

1 = VBUS > VCHG +50mV

0 = Reverse block is not triggered.

- High voltage path is enabled, sink mode.

1 = VCHG > VBUS +50mV

0 = Reverse block is not triggered.

- 5V voltage path is selected.

1 = VBUS > V5V +50mV

0 = Reverse block is not triggered

**Bit 5 OC_5V:** Over current indicator for 5V voltage power path. This bit will be cleared when read if the error condition has been removed. This bit will cause the ALERT_L pin to be asserted

1 = Load current exceeds the current limit value.

0 = 5V voltage power path not over current

**Bit 4 OVP:** Over Voltage Protection for the selected channel. When 5V channel is selected, SY20816C will detect the VBUS voltage. When VBUS is higher than 6V, this bit will be set to 1 and the power MOSFET will be turned off. When HV channel is selected, SY20816C will detect the VBUS voltage. When the VBUS is higher than the OVP_SET configured threshold, this bit will be set to 1, and power MOSFET will be turned off.

1 = VBUS OVP is triggered

0 = OVP is not triggered

**Bit 3 FRS:** Fast role swap triggered. The bit is set when VBUS is lower than 4.75V and the fast role swap is triggered. The HV channel power path is shut down and the V5V path is turned on in 100us. This bit will be cleared when read. This bit will cause the ALERT_L pin to be asserted.

1 = FRS is triggered

0 = FRS is not triggered

**Bit 2 TSD:** Thermal shutdown indicator. When the junction temperature exceeds 150℃, this bit is set to 1, and the Power MOSFET is turned off. This bit will be cleared when read if the temperature of the die is below $T_{SD}$ - $T_{HYS}$. This bit will cause the ALERT_L pin to be asserted.

1 = The junction temperature exceeds 150℃.


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0 = The junction temperature is within safe range.

**Bit 1 Vsafe5V**: Indicator VBUS is at Vsafe5V range.

1 = 4.0V< VBUS < 5.5V

0 = VBUS is out of Vsafe5V range.

**Bit 0 Vsafe0V:** Indicator VBUS is at Vsafe0V range.

1 = VBUS < 0.8V

0 = VBUS >0.8V

**Control Register 1:** 0x01

| Bit 7 | | | | | | | Bit 0 |
|---|---|---|---|---|---|---|---|
| Power_ENB | HV_ILIM | | 5V_ILIM | | HV_DR | CH_SEL | Reserved |
| W/R | W/R | W/R | W/R | W/R | W/R | W/R | W/R |

**Bit 7 Power_ENB**: Power delivery enable control. Default: 0. This bit will be set to 1 when OC_HV, OVP or TSD are set.

1 = Both channels are turned off.

0 = High voltage channel or 5V voltage channel are active. The active channel is determined by the CH_SEL bit.

**Bit 6-5 HV_ILIM:** High-voltage power path source current limit control bit. Default value: 10.

00 = 1.25A

01 = 1.75A

10 = 3.3A

11 = 5.5A

**Bit 4-3 5V_ILIM:** 5V voltage power path source current limit control bit. Default value: 11.

00 = 1.25A

01 = 1.75A

10 = 2.25A

11 = 3.3A

**Bit 2 HV_DR:** High-voltage path power delivery direction control. Default value: 0.

1 = Source mode, Delivery power from VCHG to VBUS.

0 = Sink mode, Delivery power from VBUS to VCHG.

**Bit 1 CH_SEL:** Channel selection bit. Default: 1.

1 = High voltage power path is selected.

0 = 5V voltage power path is selected.

**Bit 0 Reserved.**

**Control Register 2:** 0x02

| Bit 7 | | | | | | | Bit 0 |
|---|---|---|---|---|---|---|---|
| OC_DELAY | | DSG_TIME | | DSG_RON | | SDSG | FDSG |
| W/R | W/R | W/R | W/R | W/R | W/R | W/R | W/R |


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**Bit 7-6 OC_DELAY:** Program the over-current response delay time. Default value: 01.

00: 1ms

01: 10ms

10: 50ms

11: 100ms

**Bit 5-4 DSG_TIME:** Program the discharge time. Default value: 10.

00: 50ms

01: 100ms

10: 200ms

11: 400ms

**Bit 3-2 DSG_RON:** Program the discharge resistor. Default value: 00.

00: 200Ω

01: 400Ω

10: 800Ω

11: 1600Ω

**Bit 1 SDSG**: Smart discharge mode. Default value: 1.

0: Discharge FET ON/OFF is controlled by only the FDSG bit.

1: SY20816C worked at smart discharge function.

**Bit 0 FDSG:** Force discharge mode. Default value: 0.

0: Discharge FET is controlled by SDSG.

1: Discharge FET is turned on.

**Control Register 3:** 0x03

| Bit 7 | | | | | | | Bit 0 |
|---|---|---|---|---|---|---|---|
| BUSY | OVP_SET | | | RVS_MASK | Reserved | Reserved | RST_REG |
| R | W/R | W/R | W/R | W/R | W/R | W/R | W/R |

**Bit 7 BUSY:** I²C busy indicate. When SY20816C is in a channel transition state or count discharge time period, this bit will be set to 1. After this channel transition or discharge timer expires, the bit will be set to 0 automatically.

1: I²C busy, the command of I²C will be ignored.

0: Receive I²C command normally.

**Bit 6-4 OVP_SET:** Over-voltage protection setting for HV channel. Default value: 000.

000: 5V power profile application, typical OVP value is 6V.

001: 7V power profile application, typical OVP value is 8.4V.

010: 9V power profile application, typical OVP value is 11.1V.

011: 10V power profile application, typical OVP value is 12.1V.

100: 12V power profile application, typical OVP value is 14.2V.

101: 15V power profile application, typical OVP value is 17.9V.


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110: 18V power profile application, typical OVP value is 21.6V.

111: 20V power profile application, typical OVP value is 23.7V.

**Bit 3 RVS_MASK:** LV and HV reverse blocking protection interrupt mask. Default value: 0.

1: ALERT_L does not respond when LV or HV reverse blocking protection is triggered.

0: ALERT_L is pulled low immediately when LV or HV reverse blocking protection is triggered.

**Bit 0 RST_REG:** Reset all $I^2C$ registers to default value.

1: Reset all $I^2C$ registers to the default value.

0: Default value. No action.

**Control Register 4:** 0x04

| Bit 7 | | | | | | | Bit 0 |
|---|---|---|---|---|---|---|---|
| CC1_BPS | CC2_BPS | VCONN1 | VCONN2 | VBAT_OVP | VCONN_OC | CC_FRS | Reserved |
| W/R | W/R | W/R | W/R | R | R | W/R | W/R |

**Bit 7 CC1_BPS:** Combine HOST_CC1 to CONN_CC1. Before combining HOST_CC1 to CONN_CC1, the exposed Rd should be removed first. Default: 0.

1 = HOST_CC1 and CONN_CC1 are internal connected.

0 = HOST_CCx and CONN_CCx are isolated.

**Bit 6 CC2_BPS:** Combine HOST_CC2 to CONN_CC2. Before combining HOST_CC2 to CONN_CC2, the exposed Rd should be removed first. Default: 0.

1 = HOST_CC2 and CONN_CC2 are internal connected.

0 = HOST_CCx and CONN_CCx are isolated.

**Bit 5 VCONN1:** VCONN select bit. Default: 0.

1 = Select CONN_CC1 as VCONN. CC1_BPS is set to 0. CONN_CC1 is connected to the VBAT.

0 = CONN_CC1 is not selected as VCONN.

**Bit 4 VCONN2:** VCONN select bit. Default: 0.

1 = Select CONN_CC2 as VCONN. CC2_BPS is set to 0. CONN_CC2 is connected to the VBAT.

0 = CONN_CC2 is not selected as VCONN.

**Bit 3 VBAT_OVP:** When VBAT is over 6V, VBAT_OVP is set to 1. This bit will be cleared when read if the error condition has been removed. This bit will cause the ALERT_L pin to be asserted.

1 = VBAT_OVP triggered.

0 = VBAT_OVP not triggered.

**Bit 2 VCONN_OC:** VCONN channel over-current indication. Once the load current is larger than ICONN, the VCONN channel will be turned off, and the VCONNx bit is set to 0. If the error condition has been removed, this bit will be cleared when read. This bit will cause the ALERT_L pin to be asserted.

1 = Over current on VCONN.

0 = load is normal on VCONN.

**Bit 1 CC_FRS:** Fast role swap signal detect and enable pin. Default: 0.

0: Fast role swap signal detection is enabled on the CC pin.

1: Fast role swap signal detection is not enabled. FRS is controlled by FRS_EN and VBUS detection.


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## 2. Channel Transition Sequence

The SY20816C integrates a smooth channel transition control to match the USB PD specifications. The positive transition sequence (from a low voltage to a higher voltage) is shown below. The voltage ramp remains monotonic until the voltage reaches the final voltage. At the onset of transition, the old voltage should not drop more than 150mV. During the transition, load power consumption shall not be over 150mW.

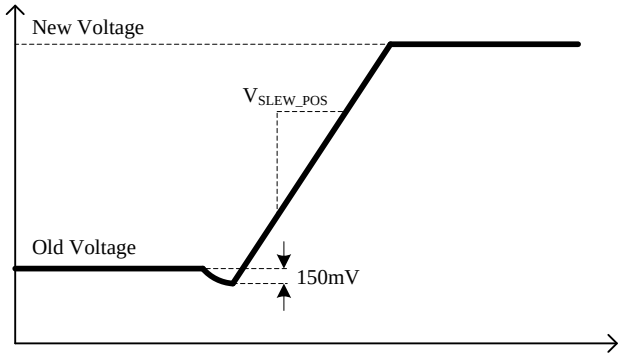


*Figure 3. Positive Transition*

The waveform for a negative voltage transition is shown in Figure 4. The voltage ramp remains monotonic until the voltage reaches the final voltage. At the end of the transition, the old voltage should not drop more than 150mV. During the transition, load power consumption shall not be over 150mW.

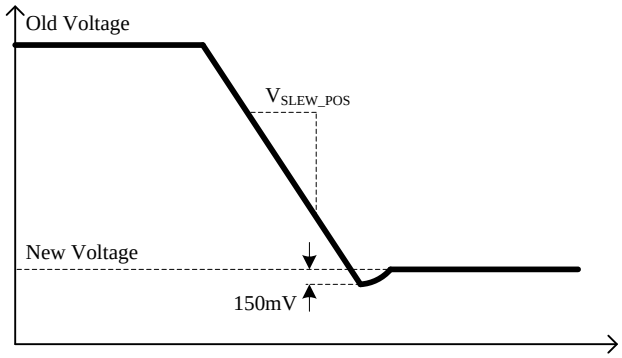


*Figure 4. Negative Transition*

## 3. EN Control

The EN pin enables or disables the power segment of the device. When VCHG, V5V, or VBAT are present, and EN is high, the power MOSFET can be configured on and off using the $I^2C$ interface. Otherwise, the power MOSFET is kept off. To wake up a dead battery system, the EN state will be ignored once VCHG, V5V, and VBAT are under UVLO and VBUS is at Vsafe5V. The HV channel will be turned on to deliver power to the dead battery system.


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## 4. Dead Battery Wake Up

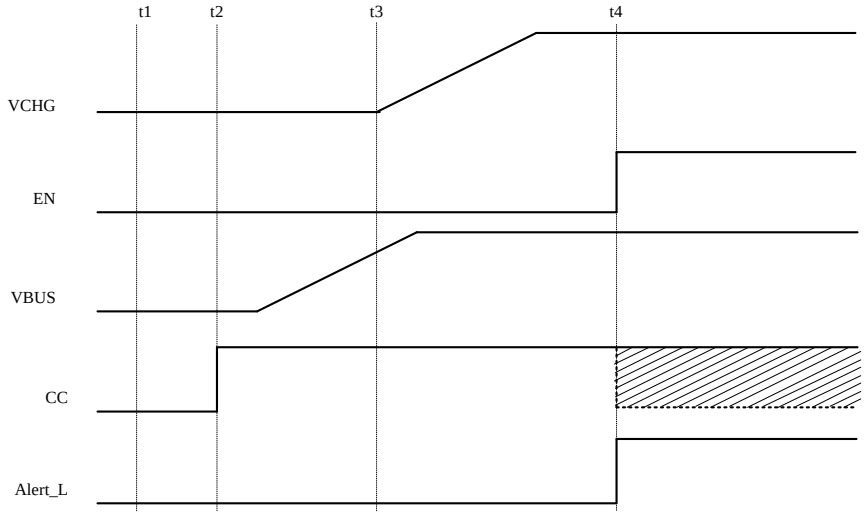


*Figure 5. Dead Battery Mode Timing Diagram*

t1: The system is in a dead battery condition. The CCs presents a Rd resistor to GND to signal an upstream-facing port (UFP).

t2: A USB type C downstream-facing port (DFP) is connected. Rd is detected by the DFP.

t3: VBUS is powered on by DFP. Once VBUS is higher than 4.5V, the HV power path is turned on. VCHG starts to rise.

t4: System logic circuit is supplied by VCHG. EN may be set high after VCHG is high. Once the EN is high, CC pins are connected to HOST_CC pins. The host controls the CC state. Alert_L is pulled high.

The VBUS pin voltage must be greater than VCHG, V5V, and VBAT pins to automatically start the device in the dead battery mode. Otherwise, the HV sink path will remain turned off.

## 5. Fast Role Swap

The SY20816C integrates a fast role swap function, which can support swap from UFP to DFP in 150μs to meet USB PD 3.0 specifications. Set CC_FRS to 0 and CCx_BPS to 1. When CCx is lower than 0.52V for longer than 30μs, the VCHG channel stops sinking current. Meanwhile, VBUS will decrease as DFP does not provide power anymore. When VBUS drops below V5V-40mV, the V5V channel will be turned on immediately and pull VBUS above 4.75V within 100μs.

If CC_FRS is set to 1, the SY20816C won't detect CC voltage. During the VCHG channel working at sink mode, when VBUS drops below V5V-40mV, the VCHG channel is shut down, and the V5V channel is turned on within 100μs.


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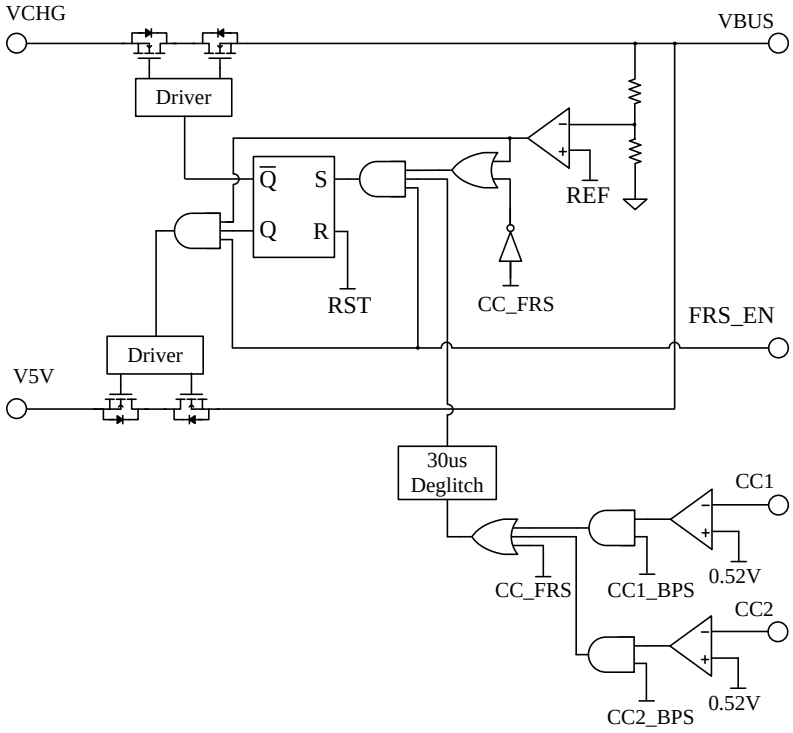


*Figure 6. Fast Role Swap Block Diagram*

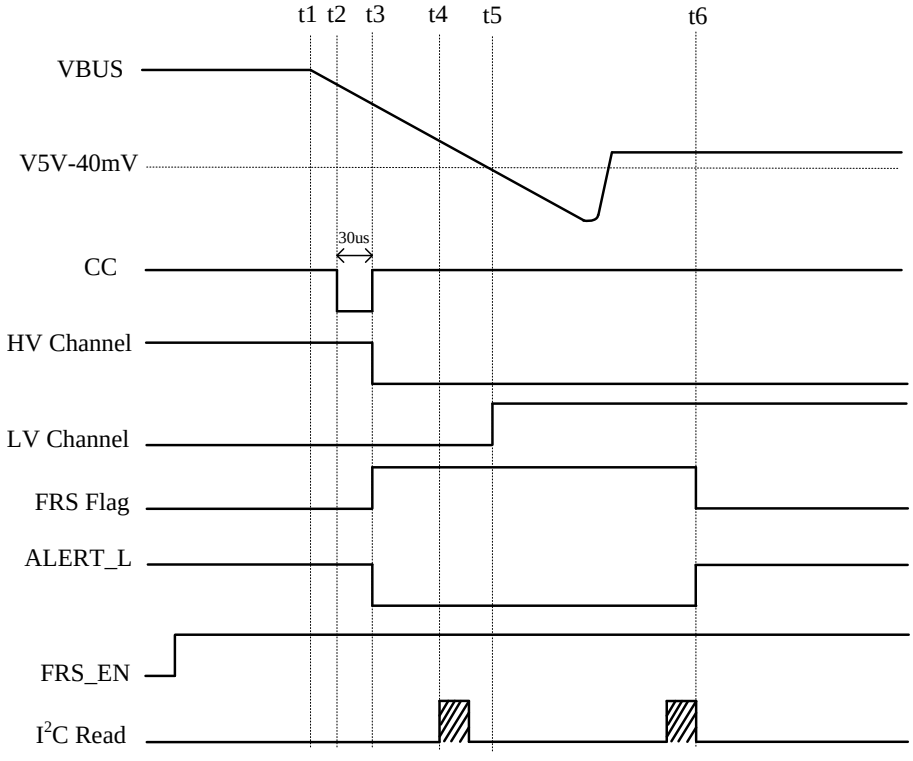


*Figure 7. Timing Diagram on CC_FRS=0*


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t1: VBUS power supply is detached.

t2: Hub sends FRS signal on CC to pull low.

t3: CC deglitch time is done, HV sink channel is turned off. Fast role swap is detected, and ALERT_L is pulled low.

t4: I²C read the FRS bit. ALERT_L keeps low, and the FRS flag remains high unless the FRS status is removed.

(1. FRS_EN disable, 2. CC_FRS disable, 3. LV channel has already been turned on).

t5: When VBUS drops below V5V-40mV, the V5V channel is enabled to drive VBUS.

t6: FRS flag is pulled down and ALERT_L is pulled high after I²C read.

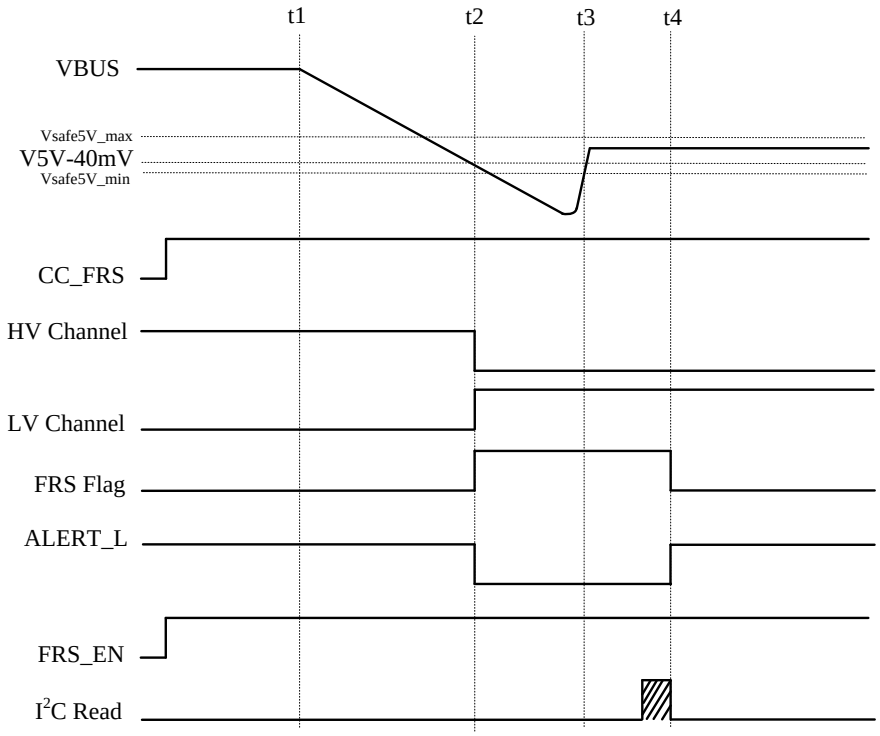


*Figure 8. Timing Diagram on CC_FRS=1*

t1: VBUS power supply is detached.

t2: When VBUS drops below V5V-40mV, the HV sink channel is turned off, and then the V5V channel is enabled to drive VBUS. Fast role swap is detected, and ALERT_L is pulled low. (This situation is applied for CC_FRS is disabled).

t3: VBUS back to Vsafe5V range. ALERT_L remains low, and the FRS flag remains high unless FRS has been read.

t4: FRS flag is pulled down and ALERT_L is pulled high after I²C read.

## 6. Smart Discharge Function

Automatic Discharge: When SDSG is set to 1, and the SY20816C operates in source mode, VBUS will automatically discharge under the following conditions: UVLO, channel shutdown, OCP, OVP, and TSD. The discharge time can be programmed by configuring DSG_TIME [1:0], and the discharge FET's $R_{DS\ (ON)}$ by configuring DSG_RON [1:0].

Manual Discharge (Forced Discharge Mode): SY20816C can operate in a forced discharge mode for VBUS. By setting SDSG to 0, the discharge FET can be independently controlled using the FDSG bit. When FDSG is set to 1, the discharge FET is turned on; when FDSG is set to 0, the discharge FET is turned off. The RDS(ON) of the discharge FET can be configured by writing to DSG_RON [1:0].


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## 7. I²C Busy

The BUSY bit is set to a high state during channel transitions or while counting the discharge time. When the BUSY bit is high, writing I²C commands to registers 0x01, 0x02, and 0x03 is not permitted. However, write I2C commands write commands to register 0x04 are still possible during this time.

## 8. Over Current Protection

The SY20816C supports current limit programming by I²C control for the CHG/V5V power path. The current limit of the VCONN path is fixed at 660mA. The current limit of CHG/V5V channel can be set using the control register 1(0x01).
Bit 6-5 is the CHG power path source and sink current limit control bit (Default value:10).
00 = 1.25A
01 = 1.75A
10 = 3.3A
11 = 5.5A
Bit 4-3 is the V5V power path source current limit control bit (Default value:11).
00 = 1.25A
01 = 1.75A
10 = 2.25A
11 = 3.3A
For the V5V or VCONN channels, once the load current exceeds the current limit threshold, the gate of the pass switch is modulated to achieve a constant output current. If the over-current condition persists for a long time, the junction temperature may exceed 150°C, and over-temperature protection will shut down the part. Once the device temperature drops below 130°C, the part will restart.

For the CHG channel, once the load current is over the current limit threshold, the power path will be shut down after $t_{OC}$. Furthermore, once the load current is greater than 2.7 times the current limit threshold, the power path would be shut down immediately.

## 9. Fault Flag (ALERT_L)

The ALERT_L pin is an open drain output to signal interrupts. The ALERT_L output is asserted (active low) when the over current on the LV or HV channels is detected after a $t_{OC}$ delay. The ALERT_L output is asserted immediately when thermal shutdown protection, over-voltage protection, reverse blocking, or fast role swap is triggered. The output remains asserted until the interrupt flags are read using the I²C bus.

## 10. Over Voltage Protection

The SY20816C integrates an over-voltage protection for the V5V and VBAT pins. When V5V exceeds 6V (typ.), the power FET of the LV channel will be turned off to protect the low voltage input stage during reverse blocking, and ALERT_L is pulled low to indicate a fault condition. When VBAT exceeds 6V (typ.), the VCONN1/2 switch will be disabled to protect the low voltage input stage during reverse blocking on CONN_CC1/2 pins.

The SY20816C also integrates an over-voltage protection for VCHG and VBUS pins for the HV power path. The power FET of the HV channel will be turned off rapidly when VCHG or VBUS exceed the OVP_SET value.

## 11. Reverse Block Function

The SY20816C integrates a reverse blocking protection on the VCHG to VBUS power path (HV source path), the VBUS to VCHG power path (HV sink path), and the V5V to VBUS power path (LV source path). When the voltage between the OUT and IN pins of the above paths exceeds 50mV, reverse blocking is triggered. The corresponding switch power FET will be turned off in around 1μs to block the reverse current flow from OUT to IN. The power FET will auto restart if the voltage at the OUT pin becomes less than the voltage at the IN input.

## 12. CC Line Capacitance

USB PD specifies the total amount of capacitance allowed on the CC lines. The specification from section 5.8.6 of the USB PD specification is shown in Table 1.


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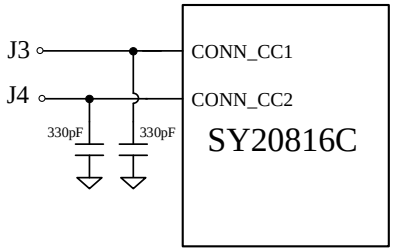
**Table1. USB PD cReceiver Specification**

| Name | Description | Min | Max | Unit | Comment |
|---|---|---|---|---|---|
| cReceiver | CC receiver capacitance | 200 | 600 | pF | The DFP or UFP system shall have capacitance within this range when not transmitting on the line. |

A 330pF ceramic capacitor is recommended to be used on each CC line as shown below:




## 13. CC Dead Battery Mode

When the device is unpowered, the SY20816C presents a 5.1k resistor to GND on CONN_CCx. Once the power adaptor detects the pull-down resistor, it applies 5V on the VBUS pin. As VBUS exceeds UVLO, the CHG path is turned on. Thus, the system is powered and can wake up, even when in a dead battery condition.

After the system wakes up, the PD controller could write CCx_BPS to 1 to take over the CC line control for higher power delivery. Once HOST_CCx is bypassed to CONN_CCx, the pull-down resistor is removed, and the PD controller should also present a 5.1k resistor to keep VBUS present. Table 2 shows the CONN_CCx connection state results.

**Table 2. CONN_CCx Connection State**

| CCx_BPS | VCONNx | CONN_CCx STATE |
|---|---|---|
| 0 | 0 | Present a Rd resistor |
| 0 | 1 | Connect to the VBAT |
| 1 | 0 | Connect to the Host_CCx |
| 1 | 1 | Connect to the VBAT |

## 14. V5V Capacitor

A 1μF ceramic capacitor from V5V to GND is strongly recommended to prevent the input voltage from dropping during hot-plug events. However, higher capacitor values could further reduce the voltage drop on the V5V. Furthermore, a VBUS short will cause ringing on the input without the input capacitor. This could destroy the internal circuitry when the input transient exceeds the absolute maximum supply voltage, even for a short duration.

## 15. VBUS Capacitor

A 1μF ceramic capacitor is recommended to be placed close to the device and the output connector to reduce voltage drop during load transients. Higher ceramic capacitor values can further reduce the drop during high-current applications.

A high-voltage spike could occur during an unexpected plug into a USB type-C port. Adding a TVS like SYS12V20SLC between VBUS to GND is strongly recommended to clamp the voltage spike to a lower level than the absolute voltage rating.

During high voltage transient conditions, VBUS might be exposed to negative voltages due to the resonance of leakage-inductance of cable wire and output cap. This negative voltage may lead to abnormal IC operation and even permanent damage. A Schottky diode is recommended to clamp VBUS at a safe voltage range.

## 16. VCHG Capacitor

A 10μF or larger input ceramic capacitor is strongly recommended to be placed close to the device. Furthermore, a VBUS short will cause ringing on the VCHG without the VCHG capacitor. It could destroy the internal circuitry when the VCHG transient exceeds the absolute maximum voltage rating, even for a short duration.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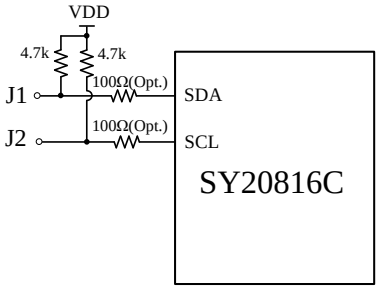
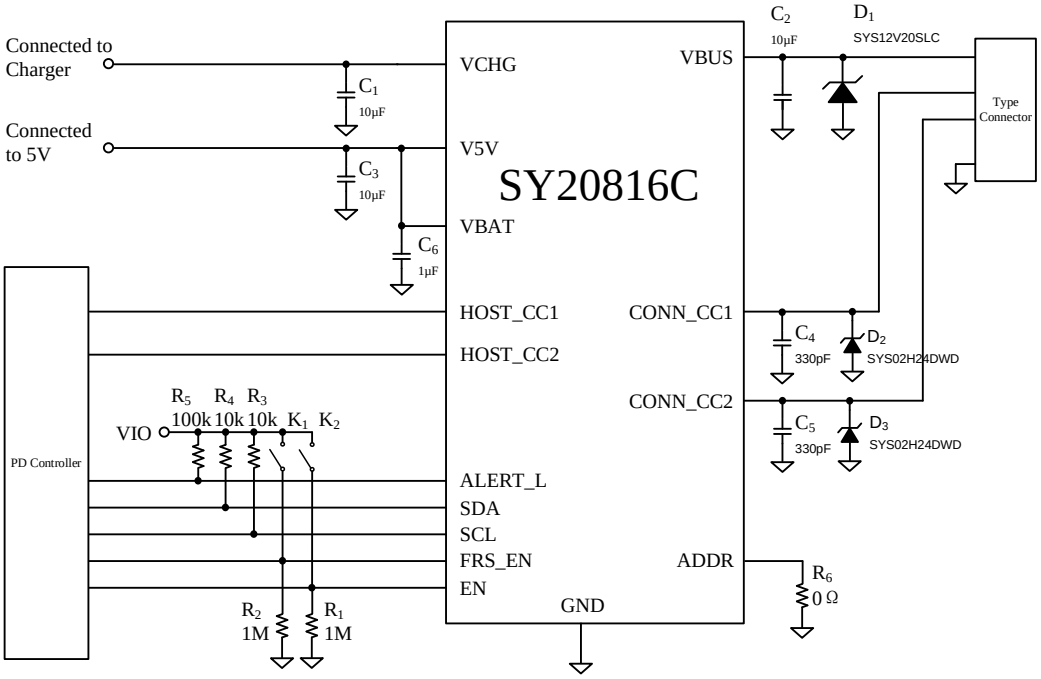
The USB PD 3.0 specification defines a sink bulk capacitance that shall not exceed 100μF so that the transient charging or discharging of the total bulk capacitance on VBUS can be accounted for during voltage transitions.

## 17. Signal Integrity

A 100Ω resistor from SDA/SCL to J1/J2 is recommended to improve signal integrity.




## 18. Application Schematic




## 19. BOM List

| Reference Designator | Description | Part Number | Manufacturer |
|---|---|---|---|
| $C_1$ | 10μF/50V, 1206 | GRM31CR61H106KA12L+A01 | Murata |
| $C_2$ | 10μF/50V, 1206 | GRM31CR61H106KA12L+A01 | Murata |
| $C_3$ | 10μF/10V, 0805 | GRM21BR71A106KA73L+A01 | Murata |
| $C_4$ | 330pF/50V, 0603 | GCG1885G1H331GA01# | Murata |
| $C_5$ | 330pF/50V, 0603 | GCG1885G1H331GA01# | Murata |
| $C_6$ | 1μF/50V, 0603 | GRM31MR71H105KA88L+A01 | Murata |
| $R_1$ | 1MΩ, 0603 | RC0603FR-071ML | YAGEO |
| $R_2$ | 1MΩ, 0603 | RC0603FR-071ML | YAGEO |
| $R_3$ | 10kΩ,0603 | RC0603FR-0710KL | YAGEO |
| $R_4$ | 10kΩ, 0603 | RC0603FR-0710KL | YAGEO |
| $R_5$ | 100kΩ, 0603 | RC0603FR-07100KL | YAGEO |
| $R_6$ | 0Ω, 0603 | | |
| $D_1$ | 20V, TVS | SYS12V20SLC | Silergy |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## 20. PCB Layout Guide

For best performance of the SY20816C, the following guidelines must be strictly followed:

1. Keep all VBUS traces as short and wide as possible and use at least 2-ounce copper.
2. Place the output capacitor as close to the connectors as possible to lower the impedance between the port and the capacitor and to improve transient performance.
3. Input and output capacitors should be placed close to the device and connected to the ground plane to reduce noise coupling.
4. The VBUS, CONN_CC1, and CONN_CC2 pins are exposed externally, and adding a TVS to each is necessary to prevent surge voltage.

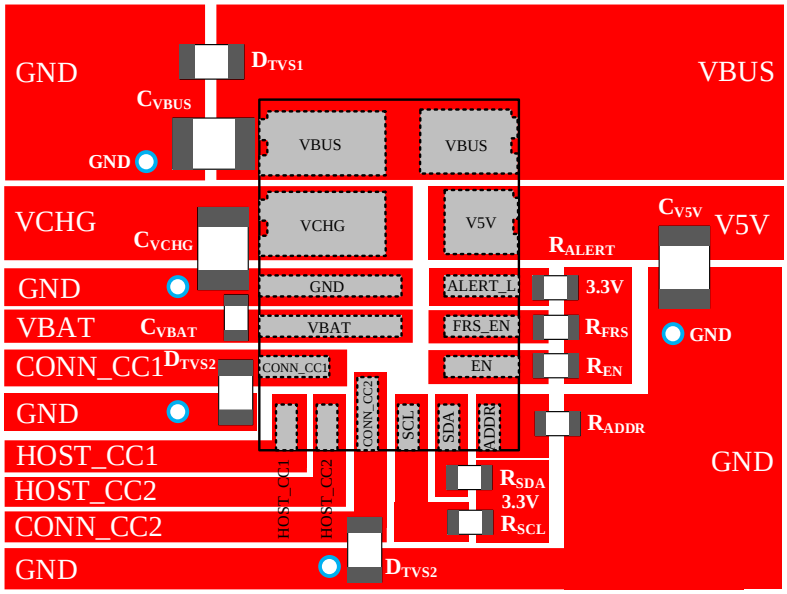


*Figure 9. PCB Layout Example*


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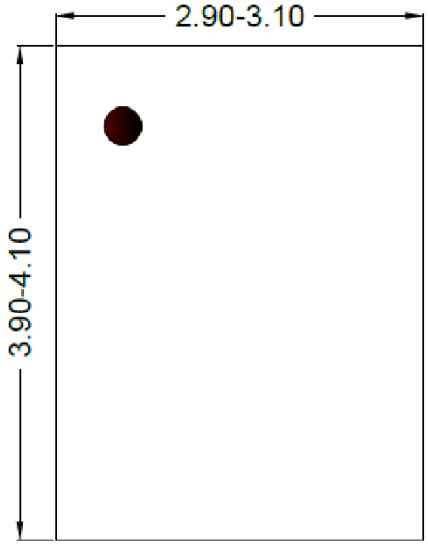
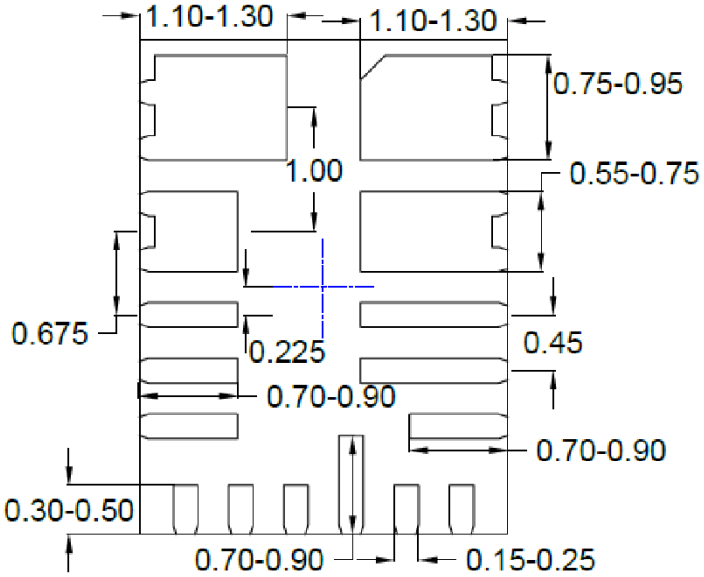
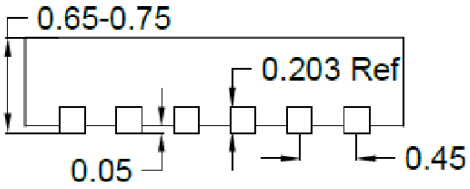
## QFN3×4-16 Package Outline Drawing



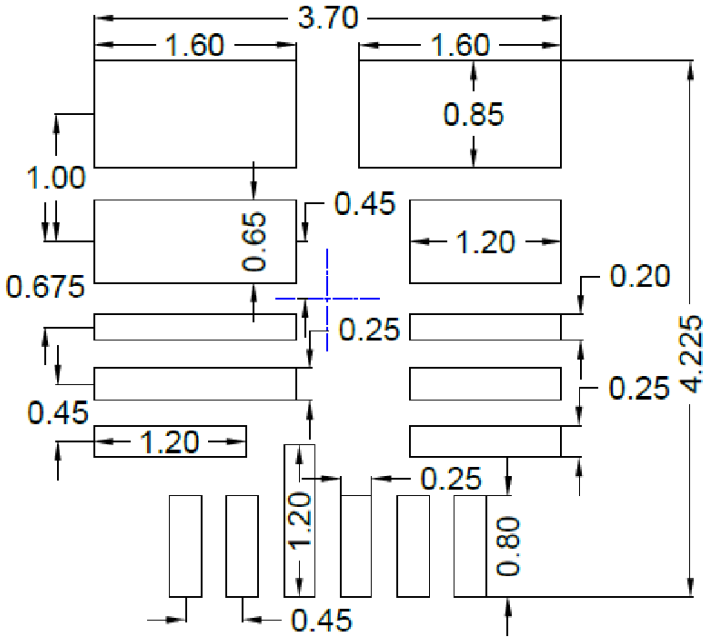

Top View




Bottom View




Side View




Recommended PCB Layout
(Reference only )

*Note 1: All dimensions are in millimeters and exclude mold flash and metal burr.*
*Note 2: Center of PCB refers to the chip body center.*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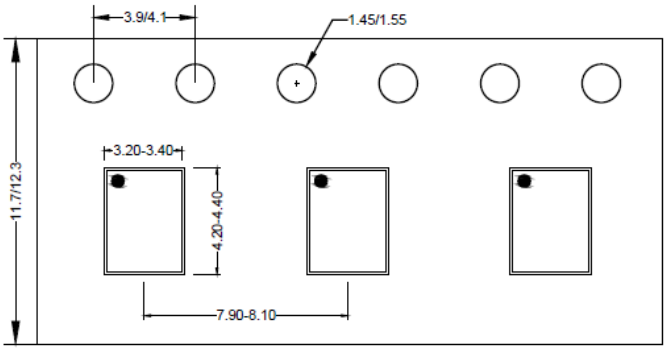
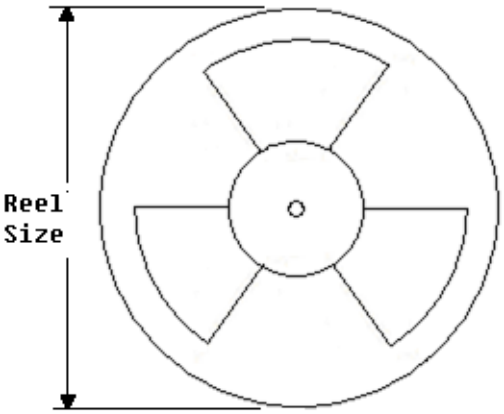
# Taping & Reel Specification

## QFN3x4 Taping orientation




Feeding direction ⟶

## Carrier Tape & Reel Specification for Packages




| Package type | Tape width (mm) | Pocket pitch (mm) | Reel size (Inch) | Trailer length (mm) | Leader length (mm) | Qty per reel |
|---|---|---|---|---|---|---|
| QFN3×4 | 12 | 8 | 13" | 400 | 400 | 5000 |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## Revision History

| Date | Revision | Change |
|---|---|---|
| Mar. 22, 2022 | Revision 1.0 | 1. Update the ON resistance (pages 5-6);<br>2. Add Max. value of "On Resistance of CC Bypass" (page 6);<br>3. Add Note 4 in EC table (page 7). |
| Dec. 23, 2021 | Revision 0.9A | 1. Update the schematic diagram (page 1);<br>2. Update the PCB Layout Guide (page 26) |
| Mar. 11, 2021 | Revision 0.9 | Initial Release |

The revision history provided is for informational purposes only and is believed to be accurate; however, it is not warranted. Please make sure that you have the latest revision.


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