

# EZ-PD™ PAG2S-AC integrated USB PD and secondary-side ACF controller

## General description

EZ-PD™ PAG2S-AC CYPAS212 is an integrated secondary-side PWM controller and USB Power Delivery (USB PD) controller, PAG2S-AC integrates secondary side synchronous rectifier (SR), pulse-width modulator (PWM) and active clamp flyback (ACF) control. PAG2S-AC is targeted towards USB-C power adapters; it fits well into high-efficiency AC-DC flyback designs with USB PD, Qualcomm Quick Charge, and other standard charging protocols. PAG2S-AC CYPAS212 also supports USB PD Extended Power Range (EPR) mode.

## Applications

- USB-C chargers and adapters
- USB-C chargers and adapters with EPR
- Power adapters supporting both USB PD and legacy charging

## Features

- Integrated secondary-side flyback controller and charging port controller
- Integrates secondary side synchronous rectifier (SR), PWM control with ACF support
- Supports synchronous rectification in critical conduction mode (CrCM), valley switching, discontinuous conduction mode (DCM), and continuous conduction mode (CCM) and supports switching frequency up to 300 kHz
- Supports burst mode for light load operations
- SR driver works with both standard MOSFET and logic level MOSFET
- USB PD 3.1 compliant with EPR support of up to 28 V VBUS
- Supports USB PD 2.0, PD 3.0 with Programmable Power Supply (PPS), QC5.0, QC4+, QC 4.0, QC 3.0, QC 2.0, Samsung AFC, Apple Charging, and BC v1.2 charging protocols
- Integrates low-side current sense amplifier (LSCSA), 2x VBUS discharge FETs, and an NFET gate driver to drive the load switch and VCONN FETs to support EMCA cables
- Configurable VBUS overvoltage protection (OVP), undervoltage protection (UVP), overcurrent protection (OCP), short-circuit protection (SCP), and system overtemperature protection (OTP)
- Protects against accidental VBUS to CC short; electrostatic discharge (ESD) protection on CC, VBUS, and DP/DM lines and overvoltage on DP/DM lines
- Integrates a 32-bit Cortex®-M0+ with 64-KB flash, 8-KB SRAM, and 64-KB ROM
- 32-pin QFN package with -40°C to +150°C junction temperature range



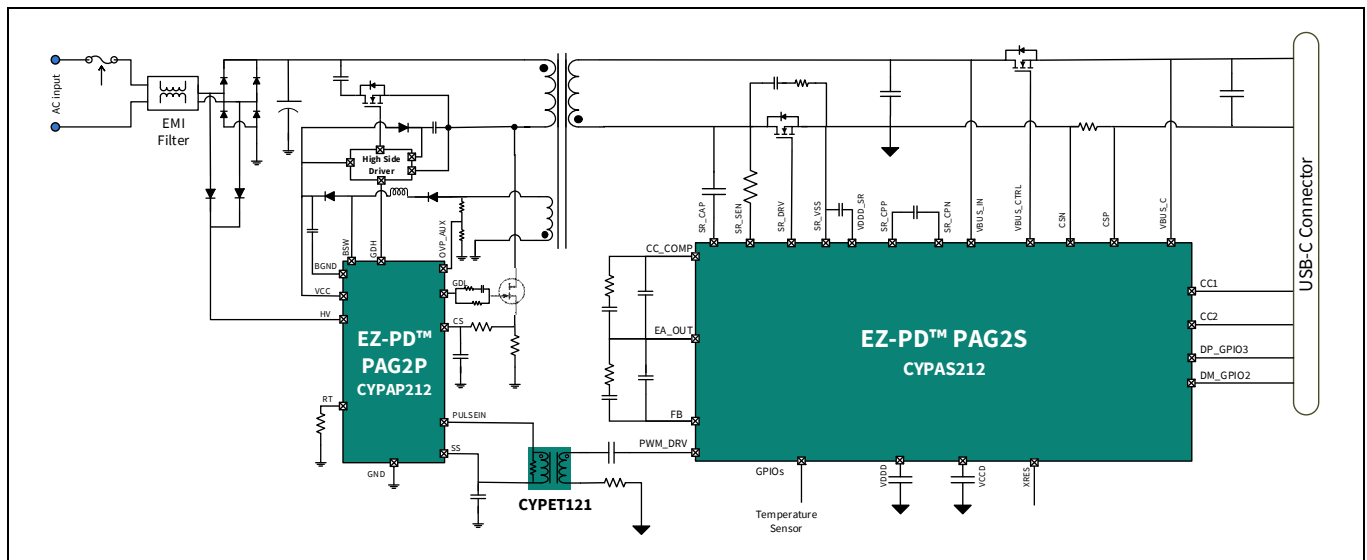
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## 1 Application overview

### 1.1 USB PD adapter – Secondary-side flyback control

**Figure 1** shows a power adapter application diagram implementing a secondary-side controlled synchronous flyback system. In this system, EZ-PD™ PAG2S-AC modulates the pulse width of the primary MOSFET in voltage control mode. PAG2S-AC engages the internal error amplifier (EA) and a programmable ramp generator to determine the pulse width of the PWM. This PWM signal is transferred from the secondary to the primary side through a pulse edge transformer, the same pulse transformer is used to transfer the ACF signal as well. In this topology, PAG2S-AC integrates three key features: secondary-side PWM control with ACF, charging protocol control, and fault protection. In the following example, EZ-PD™ PAG2P is used as the primary controller with PAG2S-AC.



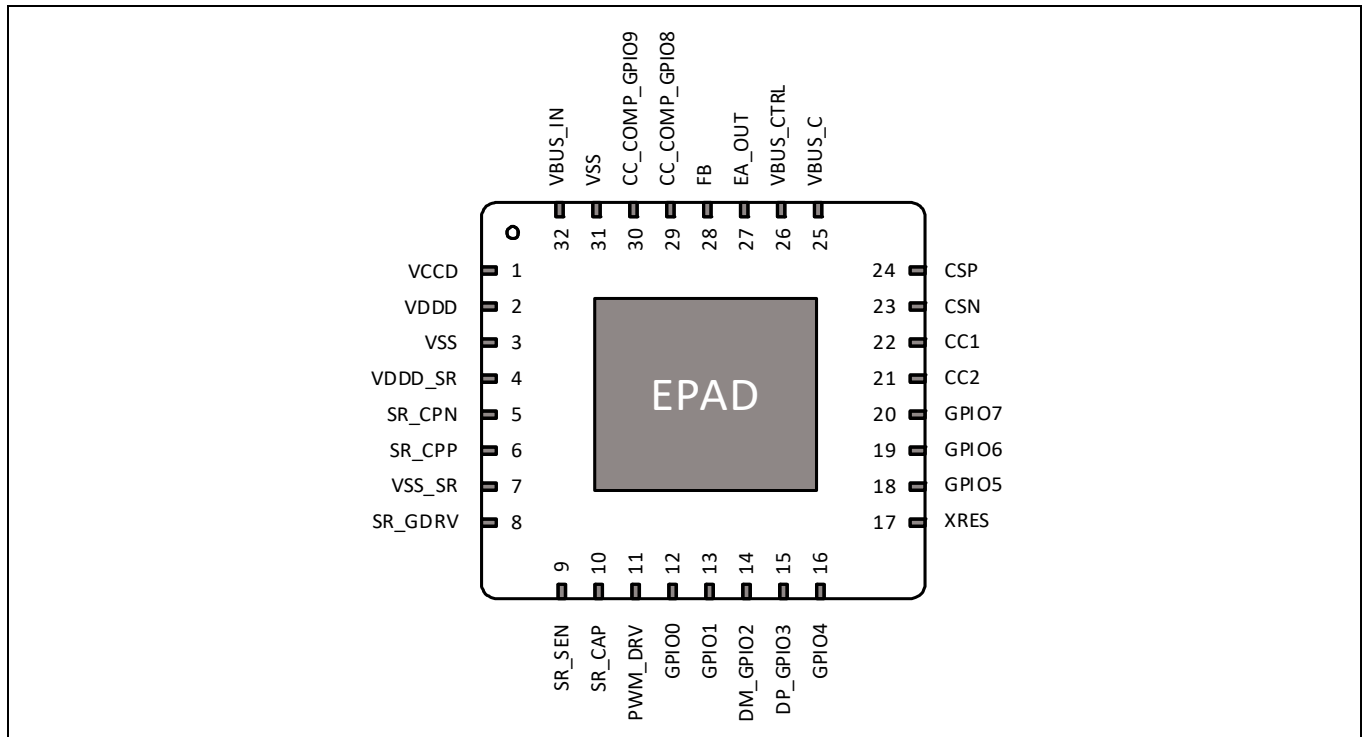
**Figure 1** USB PD adapter with secondary-side flyback control

## 2 Pinouts

### 2.1 Pin definitions

**Table 1** 32-pin QFN pin description

Pin number	Pin name	Pin description
1	VCCD	1.8-V core voltage LDO output
2	VDDD	3.0-V to 5.5-V internal LDO output
3	VSS	Ground
4	VDDD_SR	V <sub>DDD</sub> supply for sync rectifier driver
5	SR_CPN	Synchronous rectification doubler capacitor negative pin
6	SR_CPP	Synchronous rectification doubler capacitor positive pin
7	VSS_SR	Ground for synchronous rectifier driver
8	SR_GDRV	Synchronous rectifier NFET gate driver
9	SR_SEN	Synchronous rectifier NFET drain terminal sensing
10	SR_CAP	Synchronous rectifier NFET drain sensing for resonance frequency > 4 MHz
11	PWM_DRV	Pulse-edge transformer driver
12	GPIO0	GPIO
13	GPIO1	
14	DM_GPIO2	USB D-/GPIO/SWD_DAT
15	DP_GPIO3	USB D+/GPIO/SWD_CLK
16	GPIO4	Not connected
17	XRES	External reset input
18	GPIO5	GPIO
19	GPIO6	GPIO/TCPWM
20	GPIO7	GPIO
21	CC2	Power Delivery Communication Channel 2
22	CC1	Power Delivery Communication Channel 1
23	CSN	Low-side current sense amplifier negative input
24	CSP	Low-side current sense amplifier positive input
25	VBUS_C	USB Type-C VBUS monitor input
26	VBUS_CTRL	Load switch NFET gate control
27	EA_OUT	EA output
28	FB	EA feedback
29	CC_COMP_GPIO8	Pin for constant current mode compensation capacitor/GPIO/TCPWM
30	CC_COMP_GPIO9	
31	VSS	Ground
32	VBUS_IN	3.3-V to 30-V power source input for regulator



**Figure 2** 32-pin QFN pin map

## 2.2 Pin description

### 2.2.1 SR\_GDRV, SR\_VSS, SR\_SEN, SR\_CPP, SR\_CPN, SR\_CAP

EZ-PD™ PAG2S-AC senses the voltage across the synchronous rectifier NFET and appropriately controls the gate driver to achieve optimum efficiency. It supports both standard NFET and logic-level NFET. PAG2S-AC supports synchronous rectification in CrCM, valley switching, discontinuous conduction mode (DCM), and continuous conduction mode (CCM). The SR sense block supports negative sense detect and ZCD. For solution having resonance frequency on SR\_DRAIN > 4 MHz, peak-detect is sensed via the SR\_CAP pin by coupling SR\_DRAIN to SR\_CAP via a 10-pF capacitor. If resonance frequency < 4 MHz, SR\_CAP in must be left floating.

The gate driver (SR\_GDRV) can be driven to internal VDDD or twice the VDDD to achieve lower  $R_{DS(ON)}$  of the external NFET. The gate driver can be driven to twice the VDDD using an internal doubler circuit, with the doubler capacitor connected across the SR\_CPP and SR\_CPN pins. The source terminal of the SR FET must be connected to the SR\_VSS pin. The voltage at the drain node of the external NFET is sensed via SR\_SEN using a resistive divider.

### 2.2.2 FB, EA\_OUT, CC\_COMP\_GPIOx

PAG2S-AC integrates two error amplifier blocks which handle secondary-output sensing and regulation for both constant voltage and constant current modes of operation. The error-amplifier output feeds into the internal analog PWM block. The negative input of the error amplifier is the feedback (FB) pin and the positive input is an internal voltage reference. Based on the desired VBUS output, the voltage at the FB pin will be changed using internal current source/sink IDACs. An external compensation network is required between the FB and EA\_OUT pins, as shown in the application diagram (see [Figure 1](#)). Constant current operation makes use of an internal LSCSA, the output of which feeds into an independent error amplifier as shown in functional block diagram. Constant current mode regulation requires an external compensation network between CC\_COMP\_GPIOx and EA\_OUT as shown in [Figure 1](#).

### 2.2.3 PWM\_DRV

PAG2S-AC supports an analog PWM generator, which modulates the pulse width of the primary-side FET in voltage control mode. It generates a programmable ramp which is compared against the output of the error amplifier to determine the PWM pulse width. The ramp is generated by sourcing current into an internal capacitor; the source current is a programmable combination of a certain fixed current and the feed-forward current. The PWM signal is transferred from the secondary side to the primary side through an external pulse edge transformer. The same pulse edge transformer is used to transfer the ACF signal as well. PAG2S-AC CYPAS212 uses time division multiplexing (TDM) to differentiate between PWM and ACF signals. Complimentary primary side controller CYPAP212 decodes these signals accordingly.

### 2.2.4 VBUS\_IN, VDDD, VCCD

PAG2S-AC integrates a high-voltage regulator, which is powered from the VBUS\_IN rail, the output of the regulator powers the VDDD rail. The input to the regulator can range from 3.3-V minimum to 30-V maximum. This regulator is intended to deliver PAG2S-AC current consumption and is not expected to drive any external loads or ICs. PAG2S-AC also has an internal configurable discharge path for the VBUS\_IN rail, which is used to discharge the VBUS rail during negative voltage transitions. The discharge resistor strength is configurable through firmware settings.

The regulated VDDD supply, is either used to directly power some internal analog blocks or further regulated down to 1.8-V VCCD, which powers the majority of the core. VDDD and VCCD are brought out on to pins to connect external capacitors for regulator stability; these are not meant to be used as power supplies.

### 2.2.5 VBUS\_C, VBUS\_CTRL

VBUS\_C is used to monitor the voltage at the Type-C connector. VBUS\_C has an internal configurable discharge path, which is used to discharge the VBUS\_C rail during negative voltage transitions. The discharge resistor strength is configurable through firmware settings. The load switch is between VBUS\_IN and VBUS\_C. PAG2S-AC integrates an NFET gate driver to control this load switch. VBUS\_CTRL is the output of this gate driver. There is an optional slow turn-on feature which is meant to avoid sudden in-rush current.

### 2.2.6 CSP, CSN

PAG2S-AC integrates a LSCSA to monitor the load current. CSP is the positive input pin for the LSCSA and CSN is the negative input. Suggested Rsense for LSCSA is 5 mΩ.

### 2.2.7 CC1, CC2

CC1 and CC2 are the communication channels for USB PD protocol. PAG2S-AC integrates a USB PD transceiver consisting of a transmitter (TX) and receiver (RX) that communicate Biphase Mark Code (BMC)-encoded data over the Configuration Channel (CC) channels as per the USB PD standard. All communication is half-duplex. The physical layer implements collision avoidance to minimize communication errors on the channel. This block includes all termination resistors (Rp) and their switches as required by the USB PD specification.

To support active cable applications, PAG2S-AC also integrates VCONN FETs to power the CC lines. An external 390-pF capacitor is required on both the CC1 and CC2 pins.

### 2.2.8 DP\_GPIOx, DM\_GPIOx

The DP and DM lines are the standard USB D+ and D- lines. PAG2S-AC integrates a charge detect block, which handles legacy charging protocols such as BC 1.2, Quick Charge, Apple Charging, and Samsung AFC. This block integrates all the terminations required for these charging protocols; no external components are required. When legacy charging is not required in the system, the same DP and DM lines can be re-used as standard GPIOs. The charger detect block also supports impedance detection on DP/DM lines.

## 2.2.9 GPIOx, XRES

PAG2S-AC has multiple GPIOs, out of which some are dedicated GPIOs and the rest are multiplexed with other functionalities. These GPIOs support multiple drive modes and configurable threshold options. During power-on and reset, the GPIOs are forced to the tristate so as not to crowbar any inputs and/or cause excess turn-on current. The XRES pin can be used to initiate a reset; this pin is internally pulled HIGH and must be pulled LOW externally to trigger a reset.



## 3 Functional description

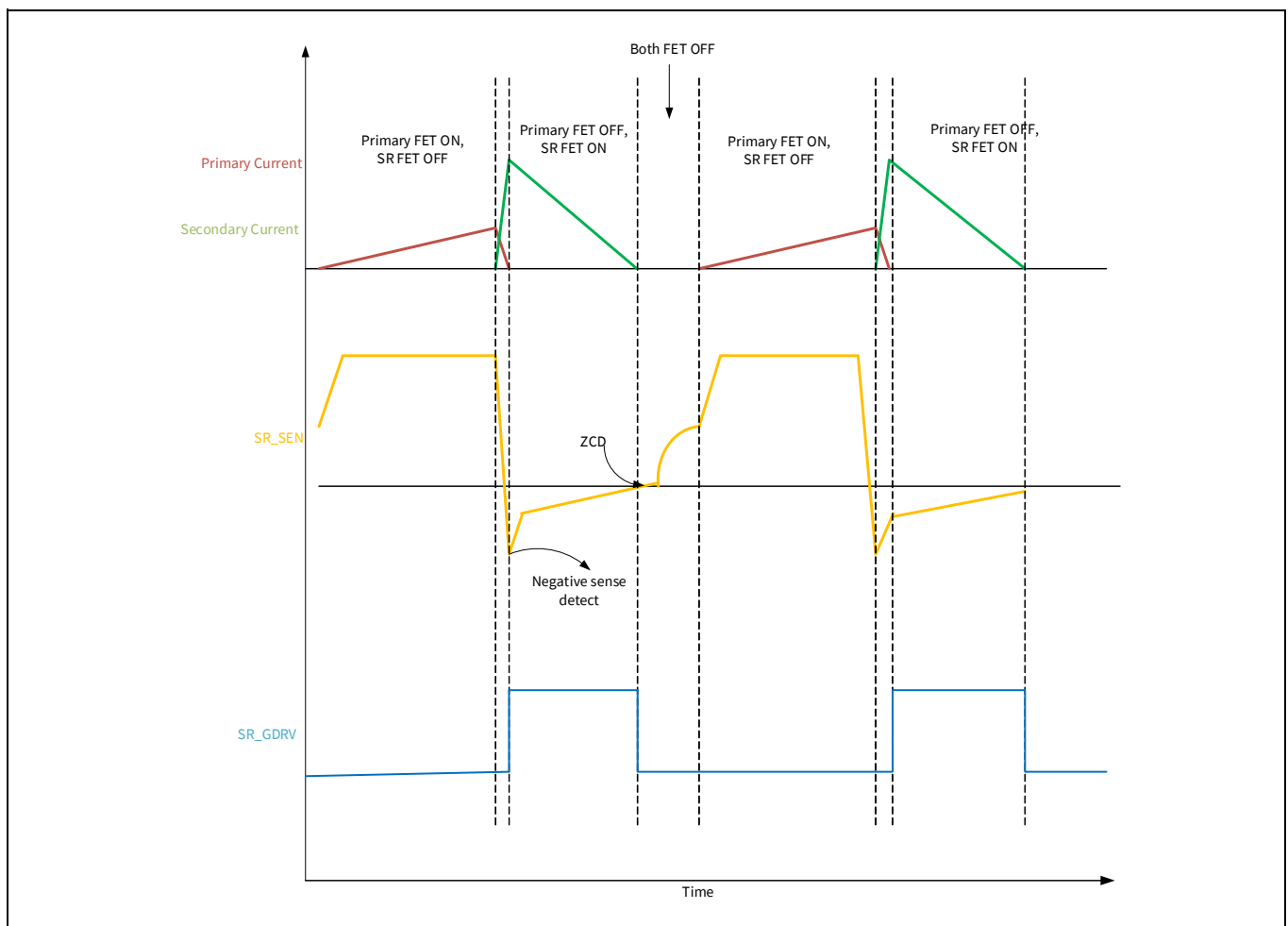
### 3.1 System start-up

On power-up, the primary side start-up controller must start controlling the primary switch using its soft start mechanism and provide sufficient current to charge the secondary-side output capacitor and the start-up current required for EZ-PD™ PAG2S-AC. The secondary output voltage is the input power supply source of PAG2S-AC. Once VBUS\_IN voltage exceeds 3.3-V, PAG2S-AC firmware will boot up and take control of the primary switch. The PAG2S-AC firmware boot up time is in the order of a few milliseconds.

Once the boot-up is complete, the firmware configures the error-amplifier to achieve the 5-V secondary output and PAG2S-AC will generate the PWM pulses accordingly. These pulses on PWM\_DRV are coupled to the primary start-up controller through a pulse transformer. On receiving the PWM pulses, the primary side start-up controller is expected to synchronize its internal oscillator with the PWM pulses and switch from start-up mode to secondary control mode. In secondary control mode, the primary switch is directly controlled by the PWM pulses generated by PAG2S-AC.

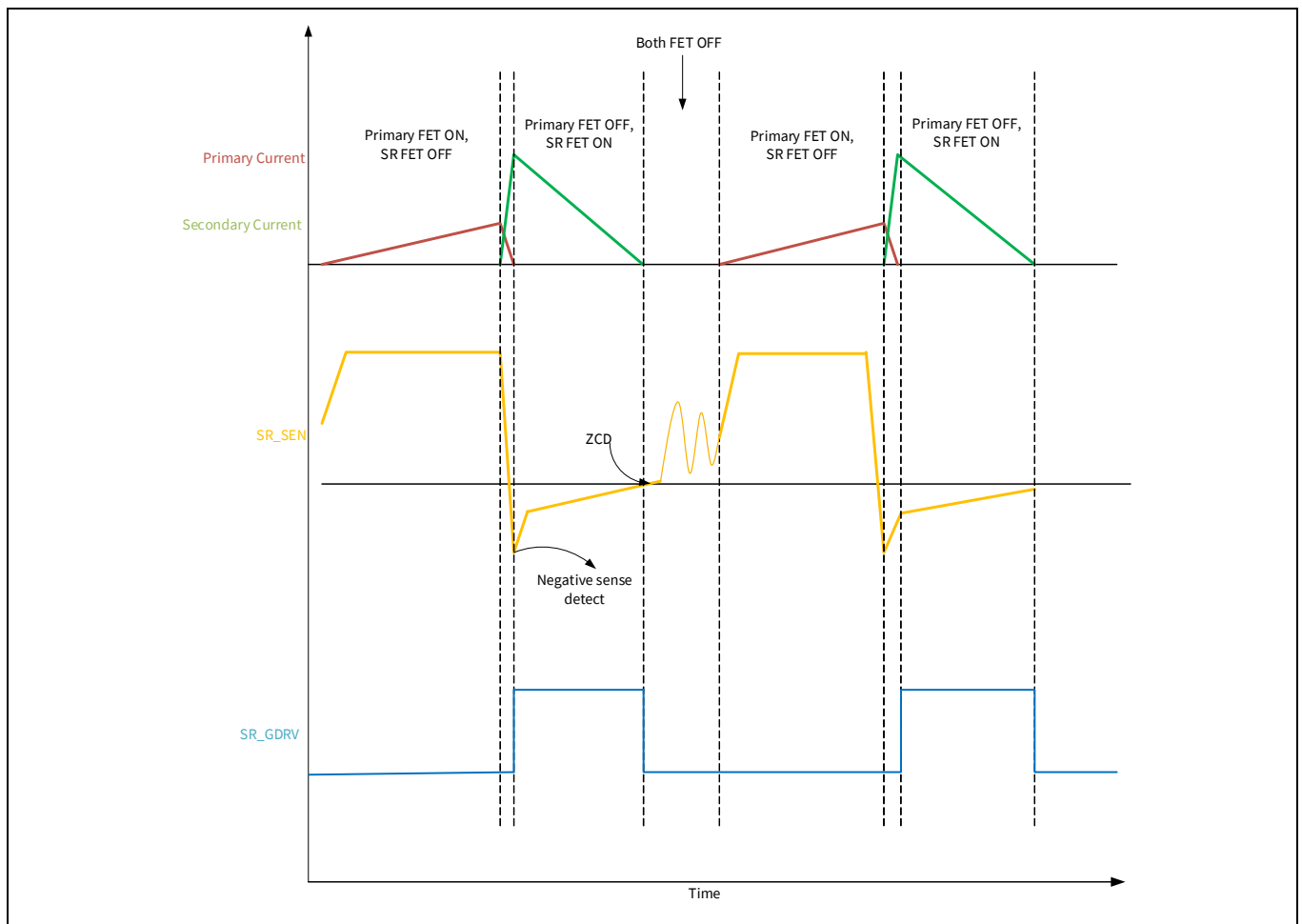
### 3.2 Modes of operation - SR

PAG2S-AC supports synchronous rectification (SR) in both DCM and CCM modes. The SR sense block supports negative sense detect and ZCD. **Figure 3** through **Figure 5** show the SR\_GDRV functionality in CrCM, valley switching, and CCM modes. The SR controller has a turn-on propagation delay of 40 ns (typ) and a turn-off propagation delay of 25 ns (typ).



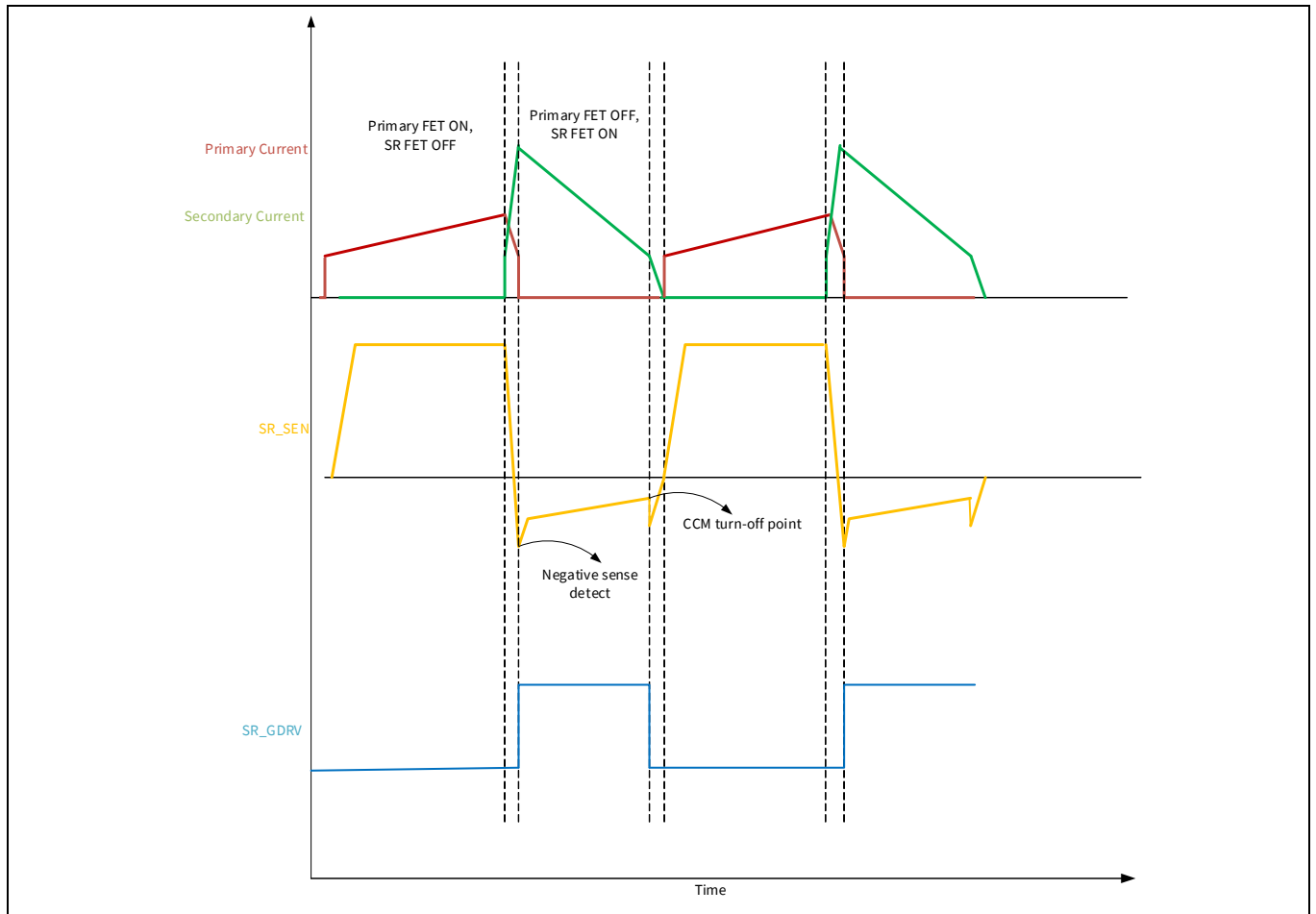
**Figure 3** SR\_SEN and SR\_GDRV in CrCM mode

## Functional description



**Figure 4** SR\_SEN and SR\_GDRV in DCM/valley switching mode

## Functional description



**Figure 5** SR\_SEN and SR\_GDRV in CCM mode

## Functional description

The voltage at the drain node of the external NFET is sensed on the SR\_SEN pin connected via an external resistor. The external resistor is required to restrict the voltage at the SR\_SEN pin below 34 V. The external resistance on the SR\_SEN pin depends on the turns ratio of the power transformer. [Table 2](#) provides the external resistor values required for different turns ratios.

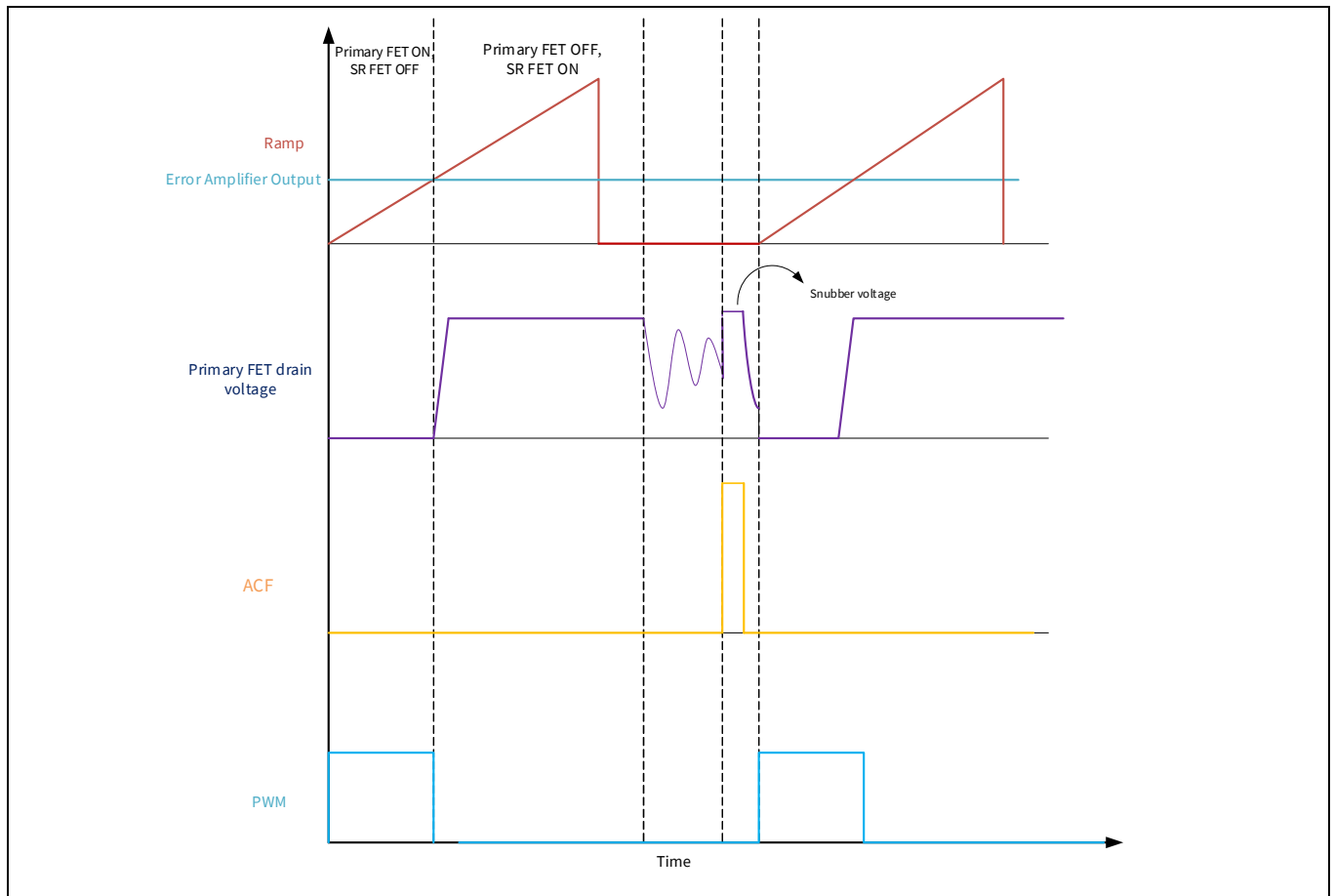
**Table 2** External resistance on SR\_SEN vs. turns ratio

Primary: Secondary turns ratio	Rext ( $\Omega$ )
3:1	20k
4:1	20k
5:1	20k
6:1	12k
7:1	12k
8:1	12k
9:1	12k
10:1	12k
11:1	12k
12:1	12k
13:1	12k
14:1	12k
15:1	12k

### 3.3 Modes of operation - PWM and ACF

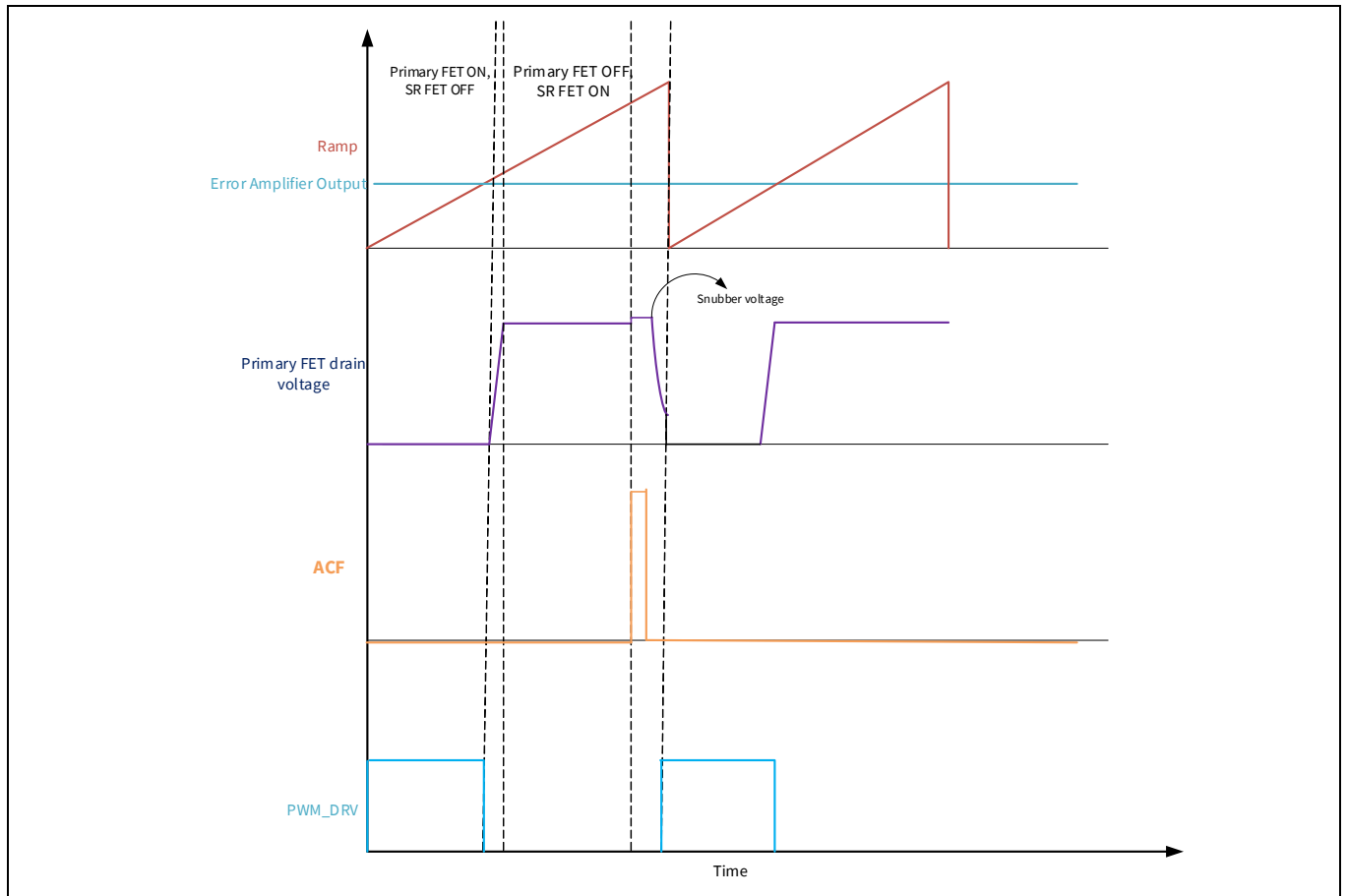
PAG2S-AC supports multiple modes of operation: CrCM, valley switching, DCM, CCM, and burst mode for light load operations. Firmware allows configurability for minimum/maximum pulse width, period, and pulse skip or burst levels. PAG2S-AC also supports Active Clamp Flyback control, where it sends an ACF signal for a short duration before sending the PWM signal. PAG2P uses the ACF signal to drive the high-side gate driver and the PWM signal to drive the low-side gate driver. ACF recycles the energy in the snubber capacitor, thereby improving system efficiency. ACF pulse-width is firmware configurable, which enables optimization for each design.

**Figure 6** and **Figure 7** show the PWM and ACF functionality in DCM and CCM modes respectively.



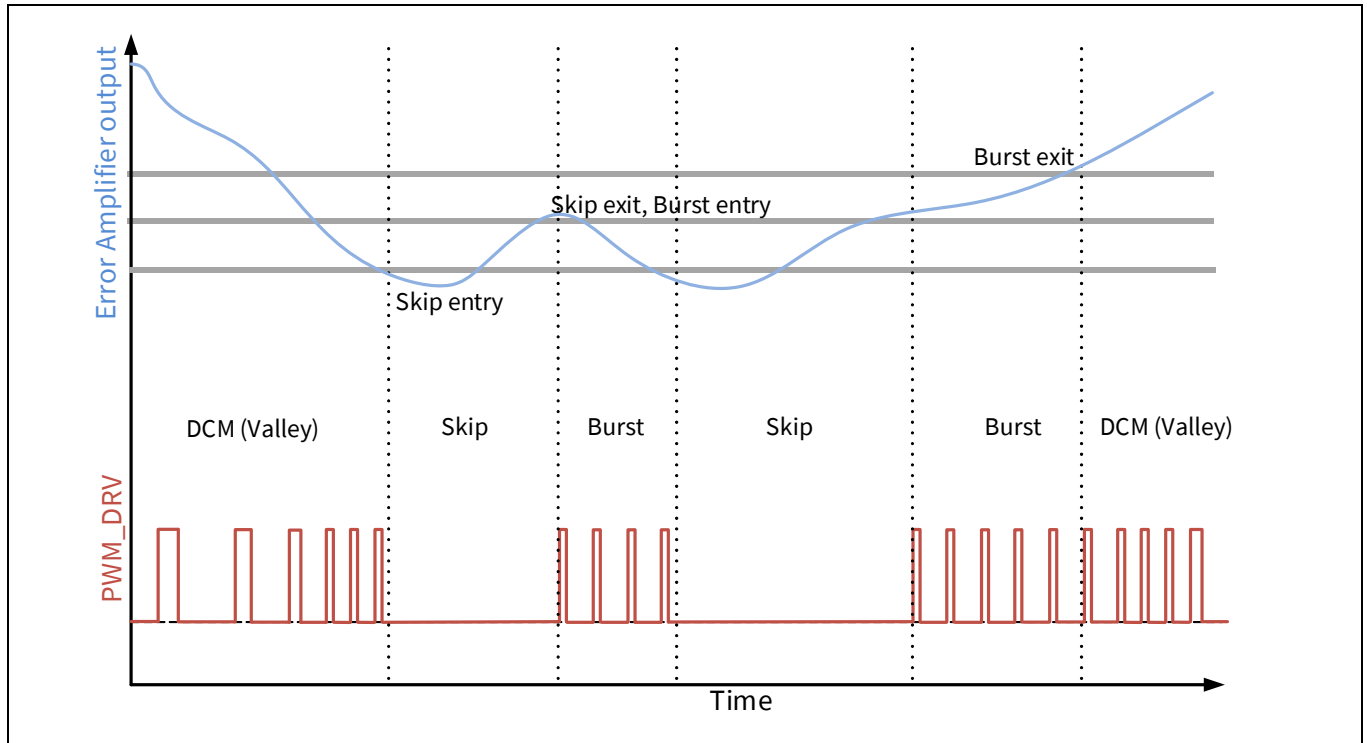
**Figure 6** PWM\_ACF in DCM mode

## Functional description



**Figure 7** PWM\_ACF in CCM mode

Analog PWM smart algorithm allows the operation to automatically transition between modes based on the output power requirement. The mode of operation stays in CrCM for higher loads, moves to DCM for medium loads, and switches to skip mode or burst mode for low- and ultra-low power loads (see [Figure 8](#)).



**Figure 8 Error amplifier output vs. modes of operation**

### 3.4 Fault protection

#### 3.4.1 VBUS OVP, UVP, OCP, and SCP

VBUS undervoltage and overvoltage faults are monitored using internal VBUS\_IN/VBUS\_C resistor dividers. VBUS overcurrent and short-circuit faults are monitored using internal current sense amplifiers (CSA). The fault thresholds and response mechanisms are firmware-configurable.

#### 3.4.2 Overtemperature protection

Over-temperature monitoring is done using an external thermistor and internal ADC. The thermistor can be connected to any free GPIO. PAG2S-AC has an integrated 8-bit SAR ADC, which is available for general purpose analog-to-digital conversions. The fault thresholds and response mechanisms are firmware-configurable.

#### 3.4.3 ESD, CC OVP, and DP/DM OVP

PAG2S-AC offers ESD protection on all pins. Further, the chip integrates protection against accidental short of CC pins to the high-voltage VBUS\_C rail and also protects against overvoltage on DP/DM pins.

### 3.5 Power modes

PAG2S-AC supports multiple power modes - Active, Sleep, and Deep Sleep. Transitions between these modes is handled by the application firmware depending on the operating conditions.

### 3.6 MCU subsystem

PAG2S-AC integrates a 32-bit Cortex®-M0+ MCU with 64-KB flash, 8-KB SRAM, and 64-KB ROM. PAG2S-AC also supports 1x TCPWM and 2x ADC.

Electrical specifications

## 4 Electrical specifications

### 4.1 Absolute maximum ratings

**Table 3 Absolute maximum ratings**

Parameter	Description	Min	Typ	Max	Unit
V <sub>BUS_IN_MAX</sub>	Maximum input supply voltage	-0.3		34	V
V <sub>DDD_MAX</sub>	V <sub>DDD</sub> supply voltage			6	
V <sub>SR_DRAIN_MAX</sub>	Voltage on SR_SEN pin	-		34	
V <sub>CC_PIN_ABS</sub>	Voltage on CC1, CC2 pins			V <sub>DDD</sub> + 0.5	
V <sub>GPIO_ABS</sub>	GPIO voltage	-0.5	-		mA
I <sub>GPIO_ABS</sub>	Current per GPIO	-		25	
I <sub>LU</sub>	Pin current for latch-up	-100		100	
ESD_HBM	Electrostatic discharge human body model			2000	V
ESD_CDM	ESD charged device model			500	

### 4.2 Device-level specifications

**Table 4 Device-level specifications**

Parameter	Description	Min	Typ	Max	Unit	Details/conditions
<b>Memory size</b>						
FLASH_SIZE	Flash memory size	-	64	-	KB	SONOS flash amount (bytes)
SRAM_SIZE	SRAM memory size		8			SRAM amount (bytes)
SROM_SIZE	SROM memory size		64			
<b>Silicon power</b>						
V <sub>DDD_REG</sub>	V <sub>DDD</sub> output with V <sub>BUS</sub> 5.5 V–30 V	4.6	5	5.4	V	-
V <sub>DDD_MIN</sub>	V <sub>DDD</sub> output with V <sub>BUS</sub> 3.15 V–5.5 V	V <sub>BUS</sub> - 0.33	-	-		
V <sub>BUS_IN</sub>	Power supply input voltage	3.15		30.0		
V <sub>CCD</sub>	Output voltage for core logic	-	1.8	-		
V <sub>DDWRITE</sub>	Supply voltage for flash write	3	-	5.5		
C <sub>EFC</sub>	External regulator voltage bypass for V <sub>CCD</sub>	80	100	120	nF	X5R ceramic or better
C <sub>EXC</sub>	Power supply capacitor for V <sub>DDD</sub>	4	4.7		μF	
C <sub>EXV</sub>	Power supply decoupling capacitor for V <sub>BUS_IN</sub>	-	1	-		
C <sub>EXCPP</sub>	Capacitor between SR_CPP and SR_CPN pins	0.1	-			
I <sub>GPIO_ABS</sub>	Current per GPIO	-		25	mA	Absolute maximum



## Electrical specifications

**Table 4** Device-level specifications (continued)

Parameter	Description	Min	Typ	Max	Unit	Details/conditions
T <sub>SLEEP</sub>	Wakeup from Sleep mode	-	0	-	μs	-
T <sub>DEEPSLEEP</sub>	Wakeup from Deep Sleep mode		35			
I <sub>DD_A</sub>	Active current from V <sub>BUS_IN</sub> (Type-C attached)		25.0		mA	V <sub>BUS_IN</sub> = 11 V, T <sub>A</sub> = 25°C, CC1/CC2 in Tx or Rx, CPU at 24 MHz, SR/PWM at 100 kHz EA/ADC/CSA/UVOV blocks ON
I <sub>DD_A1</sub>	Current from V <sub>BUS_IN</sub> (Type-C attached) in PWM mode		13.0			V <sub>BUS_IN</sub> = 28 V, T <sub>A</sub> = 25°C, Clock at 24 MHz, SR/PWM at 100 kHz, SR cap = 3 nF, No toggling on CC
I <sub>DD_A3</sub>	Current from V <sub>BUS_IN</sub> (Type-C attached) in low-power PWM mode		4			V <sub>BUS_IN</sub> = 28 V, T <sub>A</sub> = 25°C, Clock at 3 MHz, PWM mode, No toggling on CC
I <sub>DD_DS1_UA</sub>	Deep Sleep current from V <sub>BUS_IN</sub> (Type-C unattached) in PWM mode		350		μA	V <sub>BUS_IN</sub> = 5 V, T <sub>A</sub> = 25°C, Type-C unattached, PWM mode, downstream facing port (DFP) mode
L <sub>SEC</sub>	Secondary-side inductor	3	-	μH	Secondary-side inductor	

### 4.3 Functional block specifications

**Table 5 Functional block specifications**

Parameter	Description	Min	Typ	Max	Unit	Details/conditions
<b>Synchronous rectifier</b>						
VCPP1	Voltage doubler output voltage with $V_{BUS} = 3.3\text{ V} - 5.5\text{ V}$	5		-	V	
VCPP2	Voltage doubler output voltage with $V_{BUS} = 5.5\text{ V} - 30\text{ V}$	9		11		
TR_SR	Rise time (1 V to $V_{OH} - 1\text{ V}$ ) of sync-rectifier gate driver output with $C_L = 3\text{ nF}$ , including (with and without double bypass mode)		-	75	ns	
TF_SR1	Fall time ( $V_{OH} - 1\text{ V}$ to 1 V) of sync-rectifier gate driver output with $C_L = 3\text{ nF}$ (with doubler mode)	-	25	50		
TF_SR2	Fall time ( $V_{OH} - 1\text{ V}$ to 1 V) of sync-rectifier gate driver output with $C_L = 3\text{ nF}$ (with doubler bypass mode)		15	30		
VTRIP_NSN_100	Negative sense trip voltage to turn ON secondary switch	50	100	150	mV	
VTRIP_ZCD	Negative sense trip voltage to turn OFF secondary switch	-8	-5	-3		
VTRIP_ZCDF	Trip voltage to turn OFF secondary switch through fast ZCD	0	7	10		
TD_ON	Turn on propagation delay from SR_DRAIN at 100 mV to SR_GDRV reaching 1 V	-	40	80	ns	
IO_SRC_SNK	Output peak current (source and sink)	-	1	-	A	
TR_SR1	Rise time (1 V to $V_{OH} - 1\text{ V}$ ) of sync-rectifier gate driver output with $C_L = 3\text{ nF}$ , including (with doubler mode)	-	-	75	ns	

## Electrical specifications

**Table 5** Functional block specifications (continued)

Parameter	Description	Min	Typ	Max	Unit	Details/conditions			
TR_SR2	Rise time (1 V to $V_{OH} - 1$ V) of sync-rectifier gate driver output with $CL = 3$ nF, including (with doubler bypass mode)	–	–	30	ns	–			
<b>PWM</b>									
FSW	Switching frequency	20	–	300	kHz	–			
PWM_ON	Minimum controllable ON time	100	–	–	ns	–			
$V_{OL\_PTDR}$	Output LOW voltage at the output of pulse-edge transformer driver ( $I_{Sink} = 8$ mA)	–	–	0.5	V	$V_{DD} = 3$ V, $I_{ol} = 8$ mA			
<b>GPIO</b>									
I_LU	Latch up current limits	–100	–	100	mA	–			
RPU	Pull-up resistor value	3.5	5.6	8.5	k $\Omega$	–			
RPD	Pull-down resistor value								
$I_{IL}$	Input leakage current (absolute value)	–	–	2	nA	+25°C $T_A$ , 3 V $V_{DD}$			
$C_{PIN\_A}$	Maximum pin capacitance			22	pF	Capacitance on DP, DM pins			
$C_{PIN}$				3		7	All $V_{DD}$ , all other GPIOs		
$V_{OH}$	Output voltage HIGH level	$V_{DD} - 0.6$	–	–	V	$I_{oh} = -4$ mA			
$V_{OL}$	Output voltage LOW level	–		0.6		$I_{ol} = 10$ mA			
$V_{IH\_CMOS}$	Input voltage HIGH threshold	$0.7 \times V_{DD}$		–		–			
$V_{IL\_CMOS}$	Input voltage LOW threshold	–		$0.3 \times V_{DD}$					
$V_{IH\_TTL}$	LVTTL input	2		–					
$V_{IL\_TTL}$	LVTTL input	–		0.8					
$V_{HYSTTL}$	Input hysteresis LVTTL	80		–			mV		
$V_{HYS\_CMOS}$	Input hysteresis CMOS	$0.1 \times V_{DD}$		–					
IDIODE	Current through protection diode to $V_{DD}/V_{SS}$	–		–			100	$\mu$ A	–

## Electrical specifications

**Table 5** Functional block specifications (continued)

Parameter	Description	Min	Typ	Max	Unit	Details/conditions
$T_{RISEF}$	Rise time in Fast Strong mode	1	-	15	ns	$C_{LOAD} = 25 \text{ pF}$
$T_{FALLF}$	Fall time in Fast Strong mode			15		
$T_{RISES}$	Rise time in Slow Strong mode	10		70		
$T_{FALLS}$	Fall time in Slow Strong mode			70		
$F_{GPIO\_OUT1}$	GPIO $F_{OUT}$ ; $2.85 \text{ V} \leq V_{DD} \leq 5.5 \text{ V}$ . Fast Strong mode.	-	-	28	MHz	-
$F_{GPIO\_OUT2}$	GPIO $F_{OUT}$ ; $2.85 \text{ V} \leq V_{DD} \leq 5.5 \text{ V}$ . Slow Strong mode.	-	-	6		
$F_{GPIO\_IN}$	GPIO input operating frequency; $2.85 \text{ V} \leq V_{DD} \leq 5.5 \text{ V}$ .	-	-	28		

### Flash macro

FLASH_ERASE	Row erase time	-	-	15.5	ms	-
FLASH_WRITE	Row (block) write time (erase and program)	-	-	20		
FLASH_DR	Flash data retention	15	-	-	Years	$25^\circ\text{C}$ to $55^\circ\text{C}$ , all $V_{DD}$
FLASH_ENPB	Flash write endurance	100K	-	-	Cycles	$25^\circ\text{C}$ to $85^\circ\text{C}$ , all $V_{DD}$
FLASH_ENPB1	Flash write endurance	10K	-	-		$25^\circ\text{C}$ to $125^\circ\text{C}$ , all $V_{DD}$
FLASH_ROW_PGM	Row program time after erase	-	-	7	ms	-
$T_{BULKERASE}$	Bulk erase time (32 KB)	-	-	35		
$T_{DEVPROG}$	Total device program time	-	-	7.5	s	-
$F_{RET1}$	Flash retention, $T_A \leq 55^\circ\text{C}$ , 100k P/E cycles	15	-	-	Years	-
$F_{RET2}$	Flash retention, $T_A \leq 85^\circ\text{C}$ , 10k P/E cycles	10	-	-		
$F_{RET3}$	Flash retention, $T_A \leq 105^\circ\text{C}$ , 10k P/E cycles	3	-	-		

### SWD

$F_{SWDCLK1}$	All $V_{DD}$	-	-	14	MHz	-
$T_{SWDI\_SETUP}$	$T = 1/f_{SWDCLK}$	$0.25 \times T$	-	-	ns	-
$T_{SWDI\_HOLD}$				-		
$T_{SWDO\_VALID}$		-		$0.50 \times T$		
$T_{SWDO\_HOLD}$		1		-		

## Electrical specifications

**Table 5** Functional block specifications (continued)

Parameter	Description	Min	Typ	Max	Unit	Details/conditions	
<b>ILO / IMO / POR</b>							
F <sub>IMO</sub>	IMO frequency	24	36	48	MHz	–	
IMO_STL	IMO settling time when the trim register is changed	–	–	200	ns	25°C T <sub>A</sub> , All V <sub>DDD</sub> , 48 MHz ≥ F <sub>IMO</sub> ≥ 24 MHz	
F <sub>CPU</sub>	CPU input frequency			48	MHz		
F <sub>ILO</sub>	ILO frequency	15	40	80	kHz		
SR_POWER_UP	Power supply slew rate during power up	–		67	V/ms		
F <sub>IMOTOL</sub>	Frequency variation at 24 MHz and 48 MHz (trimmed)	–2		2	%		
T <sub>STARTIMO</sub>	IMO start-up time			7	µs		
T <sub>STARTILO1</sub>	ILO start-up time	–		2	ms		
EXTCLKFREQ	External clock input frequency			16	MHz		
EXTCLKDUTY	Duty cycle; measured at V <sub>DD</sub> /2	45	–	55	%		
TCLKSWITCH	System clock source switching time	3		4	Periods		
V <sub>RISEIPOR</sub>	Power-on-reset (POR) rising trip voltage	0.72		1.5	V	–	
V <sub>FALLIPOR</sub>	POR falling trip voltage	0.62		1.4			
V <sub>DDD_BOD</sub>	Brown-out detect (BOD) trip voltage active/ sleep modes	2.34		3			
V <sub>CCD_BOD</sub>		1.64		2			
V <sub>CCD_BOD_DPSLP</sub>		1.1		2			
<b>Timer</b>							
SYS_TIM_RES	Sys timer resolution	–	16	–	bits		–
WDT_RES	WDT resolution		16				
<b>TCPWM</b>							
TCPWM <sub>FREQ</sub>	Operating frequency	–		F <sub>c</sub>	MHz		F <sub>c</sub> max = CLK_SYS
T <sub>PWMEXT</sub>	Output trigger pulse widths	2/F <sub>c</sub>	–	–	ns	Minimum possible width of overflow, underflow, and CC (counter equals compare value) outputs	
T <sub>CRES</sub>	Resolution of counter	1/F <sub>c</sub>				Minimum time between successive counts	
PWM <sub>RES</sub>	PWM resolution					Minimum pulse width of PWM output	

## Electrical specifications

**Table 5 Functional block specifications** (continued)

Parameter	Description	Min	Typ	Max	Unit	Details/conditions
<b>PD transceiver</b>						
vSwing	Transmitter output HIGH voltage	1.05	-	1.2	V	-
vSwing_low	Transmitter output LOW voltage	-		0.075		
zDriver	Transmitter output impedance	33		75	Ω	
Idac_std	Source current for USB standard advertisement	64		96	μA	
Idac_1p5a	Source current for 1.5 A @ 5-V advertisement	166		194		
Idac_3a	Source current for 3 A @ 5-V advertisement	304		356	μA	
zOPEN	CC impedance to ground when disabled	108		-	kΩ	
DFP_default_0p2	CC voltages on DFP side-Standard USB	0.15		0.25	V	
DFP_1.5A_0p4	CC voltages on DFP side - 1.5 A	0.35		0.5		
DFP_3A_0p8	CC voltages on DFP side - 3 A	0.75		0.85		
DFP_3A_2p6	CC voltages on DFP side - 3 A	2		2.75		
Vattach_ds	Deep Sleep attach threshold	0.30		0.6	-	
Rattach_ds	Deep Sleep pull-up resistor	10		50	kΩ	
<b>LSCSA DC specifications</b>						
Csa_Acc1	CSA accuracy with 5 mV < Vsense < 10 mV	-0.75	-	0.75	mV	-
Csa_Acc2	CSA accuracy with 10 mV < Vsense < 15 mV					
Csa_Acc3	CSA accuracy with 15 mV < Vsense < 25 mV					
Csa_Acc4	CSA accuracy with Vsense = 50 mV					
SCP_6A	Short circuit current detect @ 6 A	5.4	6	6.6	A	-
SCP_10A	Short circuit current detect @ 10 A	9	10	11		
SCP_20A	Short circuit current detect @ 20 A	18	20	22		
OCP threshold	OCP trip with 5 mΩ and current > 4 A	117	130	143		
Av	Nominal gain values supported: 40, 60	30	-	60	V/V	

## Electrical specifications

**Table 5 Functional block specifications** (continued)

Parameter	Description	Min	Typ	Max	Unit	Details/conditions
<b>LSCSA AC specifications</b>						
T <sub>SCP_GATE</sub>	Delay from SCP threshold trip to external NFET power gate turn off	–	2.5	–	μs	1 nF NFET gate capacitance, V <sub>BUS_IN</sub> = 28 V
T <sub>SCP_GATE_1</sub>			7.5			3 nF NFET gate capacitance, V <sub>BUS_IN</sub> = 28 V
<b>UVOV</b>						
VTHOV	Overvoltage threshold accuracy, 4 V–30 V	–3	–	3	%	–
VTHUV1	Undervoltage threshold accuracy, 3 V–4 V	–4		4		
VTHUV2	Undervoltage threshold accuracy, 4 V–30 V	–3		3		
<b>VBUS gate driver DC specifications</b>						
GD_VGS	Gate to source overdrive during ON condition	5	–	10	V	NFET driver is ON
GD_Rpd	Resistance when pull-down enabled	–		2	KΩ	Applicable on VBUS_CTRL to turn-off external NFET
GD_drv	Programmable typical gate current	0.3		9.75	μA	Gate driver output current
<b>VBUS gate driver AC specifications</b>						
T <sub>ON</sub>	VBUS_ctrl LOW to HIGH (1 V to V <sub>BUS</sub> + 1 V) with 3 nF external capacitance	2	5	10	ms	V <sub>BUS_IN</sub> = 5 V
T <sub>OFF</sub>	VBUS_ctrl HIGH to LOW (90% to 10%) with 3 nF external capacitance	–	7.5	–	μs	V <sub>BUS_IN</sub> = 28 V
<b>VBUS discharge</b>						
R1	NMOS ON resistance for DS = 1 on V <sub>BUS_IN</sub>	1000	–	4000	Ω	Measured at 0.5 V
R2	NMOS ON resistance for DS = 2 on V <sub>BUS_IN</sub>	500		2000		
R4	NMOS ON resistance for DS = 4 on V <sub>BUS_IN</sub>	250		1000		
R8	NMOS ON resistance for DS = 8 on V <sub>BUS_IN</sub>	125		500		
R16	NMOS ON resistance for DS = 16 on V <sub>BUS_IN</sub>	62.5		250		

## Electrical specifications

**Table 5 Functional block specifications** (continued)

Parameter	Description	Min	Typ	Max	Unit	Details/conditions
R32	NMOS ON resistance for DS = 32 on V <sub>BUS_IN</sub>	31.25		150	–	Measured at 0.5 V
Vbus_stop_error	Error percentage of final VBUS value from setting	–	–	10	%	When VBUS is discharged to 5 V
R1A	NMOS ON resistance for DS = 1 on V <sub>BUS_C</sub>	1000		2000	Ω	Measured at 0.5 V
R127A	NMOS ON resistance for DS = 127 on V <sub>BUS_C</sub>	6.5		38		
<b>Voltage regulation DC specifications</b>						
V <sub>OUT</sub>	Typical V <sub>BUS_IN</sub> output voltage range	3.3	–	28	V	
VR	VBUS voltage regulation accuracy	–	±3	±5	%	–
I <sub>ka_off</sub>	Off-state cathode current	–	2.2	10	μA	
<b>VBUS regulator specifications</b>						
VOLTAGE_DETECT	Voltage detect threshold voltage on V <sub>BUS_IN</sub>	1.65	2.1	2.4	V	
T <sub>START</sub>	Total startup time for the regulator supply outputs with 4.7-μF load capacitance	–	50	200	μs	–
<b>ADC DC specifications</b>						
Resolution	ADC resolution	–	8	–	bits	–
INL	Integral non linearity	–2.5	–	2.5	LSB	Reference voltage generated from V <sub>DDD</sub>
INL	Integral non linearity	–1.5	–	1.5		Reference voltage generated from bandgap
VREF_ADC1	Reference voltage of ADC	V <sub>DDDmin</sub>	–	V <sub>DDDmax</sub>	V	Reference voltage generated from V <sub>DDD</sub>
VREF_ADC2		1.96	2	2.04		Reference voltage generated from bandgap
<b>VCONN switch specifications</b>						
VCONN_OUT	VCONN minimum output voltage with 20 mA load current with Vbus = 5 V–30 V	4.5	–	–	V	–
I <sub>LEAK</sub>	Connector side pin leakage current	–	–	10	μA	
<b>VCONN switch AC specifications</b>						
T <sub>ON</sub>	Switch turn-on time	–	–	600	μs	–
T <sub>OFF</sub>	Switch turn-off time	–	–	10		



## 5 Ordering information

**Table 6** PAG2S-AC ordering information

MPN	Application	Package type	Si ID	Si Rev
CYPAS212A1-32LQXQ	USB PD adapter – Secondary-side flyback control with ACF	32-pin QFN	3B11	A1
CYPAS212A1-32LQXQT				

### 5.1 Ordering code definitions

CY	PA	S	X	XX	XX	-	XX	XX	X	X	XX	X
<p>T = Tape and reel</p> <p>ES (optional field) = Pre-production engineering samples only. Non orderable.</p> <p>Temperature range: Q = Extended industrial (-40°C to +105°C)</p> <p>X = Pb-free</p> <p>Package type: LQ = QFN; S = SOIC</p> <p>Number of pins in the package</p> <p>Si Rev</p> <p>Application and feature combination designation</p> <p>Product type: 2 = Second-generation product family</p> <p>Product type: S = Secondary-side controller</p> <p>Marketing code: PA = Power adapter</p> <p>Company ID: CY = CYPRESS (an Infineon company)</p>												

Packaging

## 6 Packaging

**Table 7 Package characteristics**

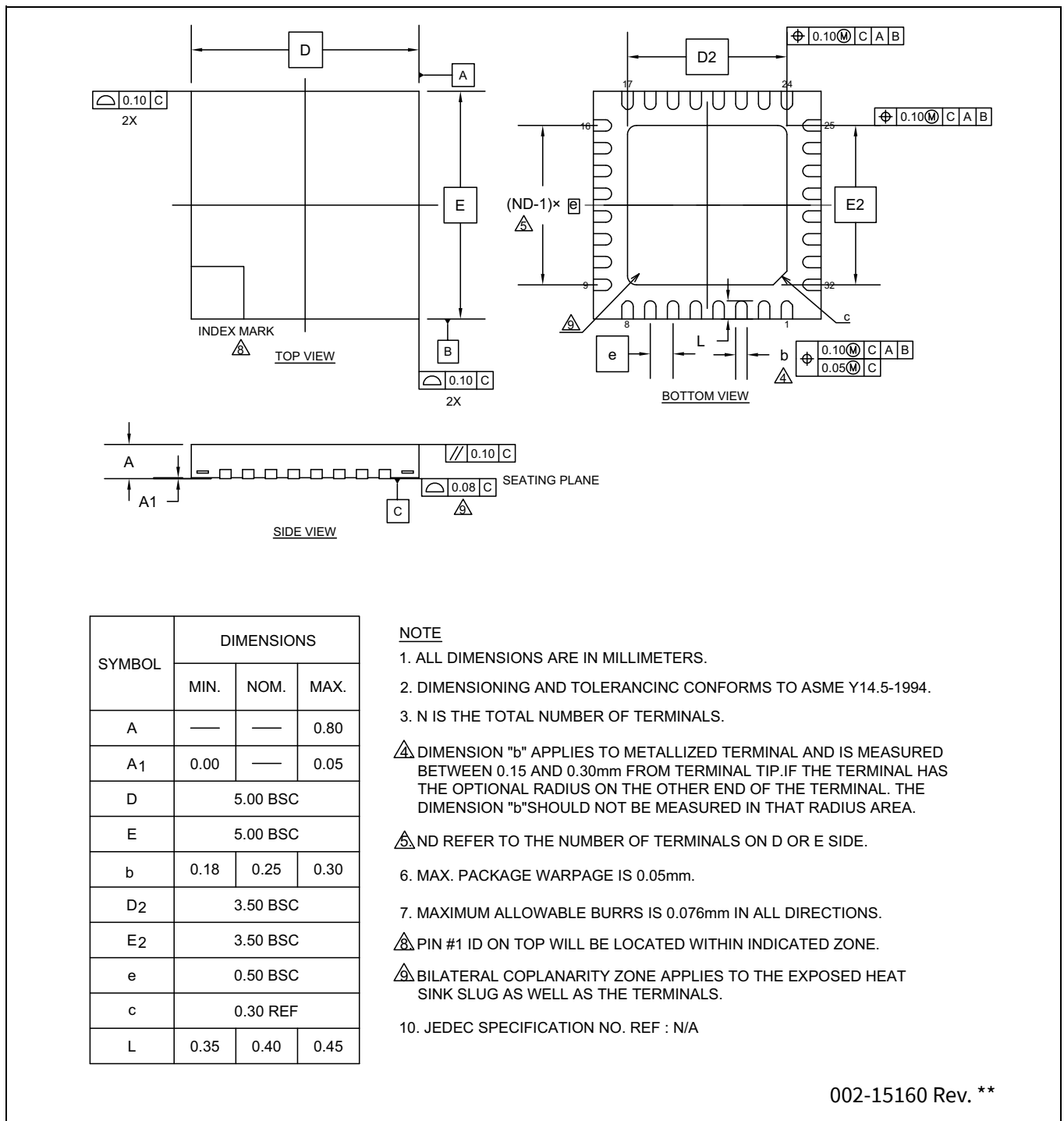
Parameter	Description	Conditions	Min	Typ	Max	Unit
T <sub>A</sub>	Operating ambient temperature	Extended industrial	-40	-	105	°C
T <sub>J</sub>	Operating junction temperature				150	
T <sub>JA</sub>	Package $\theta_{JA}$ for 32-QFN	-	-	23.4	-	°C/W
T <sub>JB</sub>	Package $\theta_{JB}$ for 32-QFN			4.85		
T <sub>JC</sub>	Package $\theta_{JC}$ for 32-QFN			27.2		

**Table 8 Solder reflow peak temperature**

Package	Maximum peak temperature	Maximum time within 5°C of peak temperature
32-pin QFN	260°C	30 seconds

**Table 9 Package moisture sensitivity level (MSL), IPC/JEDEC J-STD-2**

Package	MSL
32-pin QFN	MSL3



**Figure 9** 32-lead QFN ((5.0 × 5.0 × 0.8 mm) WNP032 3.5 × 3.5 mm E-Pad (Sawn)) package outline (PG-VQFN-32), 002-15160

## 7 Acronyms

**Table 10 Acronyms used in this document**

<b>Acronym</b>	<b>Description</b>
ACF	active clamp flyback
ADC	analog-to-digital converter
Arm®	advanced RISC machine, a CPU architecture
BOD	brown-out detect
BMC	biphase mark code
CC	constant current
CCM	continuous conduction mode
CPU	central processing unit
CrCM	critical conduction mode
CS	current sense
CSA	current sense amplifier
CSN	current sense negative
CSP	current sense positive
DCM	discontinuous conduction mode
DFP	downstream facing port
DM	data minus
DP	data plus
DS	drive strength
EA	error amplifier
EMI	electromagnetic interference
EPR	extended power range
ESD	electrostatic discharge
ESD-HBM	electro static discharge human body model
FB	feedback
FS	full-speed
GPIO	general-purpose input/output
ILO	internal low-speed oscillator, see also IMO
IMO	internal main oscillator, see also ILO
I/O	input/output, see also GPIO
LDO	low-dropout regulator
LSCSA	low-side current sense amplifier
LVTTTL	low-voltage transistor-transistor logic
NFET	N-channel field effect transistor
NMOS	N-type metal-oxide-semiconductor
OCP	overcurrent protection
OVP	overvoltage protection

## Acronyms

**Table 10** Acronyms used in this document (continued)

Acronym	Description
OTP	over-temperature protection
PD	power delivery
PHY	physical layer
POR	power-on reset
PPS	programmable power supply
PSM	pulse-skipping mode
PWM	pulse-width modulator
RAM	random-access memory
RISC	reduced-instruction-set computing
RMS	root-mean-square
RX	receive
SAR	successive approximation register
SCL	I <sup>2</sup> C serial clock
SCP	short-circuit protection
SDA	I <sup>2</sup> C serial data
SPI	Serial Peripheral Interface, a communications protocol
SR	synchronous rectifier
SRAM	static random access memory
SWD	Serial Wire Debug, a test protocol
SWDCLK	serial wire debug clock
TCPWM	timer/counter/PWM
TX	transmit
Type-C	a new standard with a slimmer USB connector and a reversible cable, capable of sourcing up to 100 W of power
USB	Universal Serial Bus
USB PD	USB Power Delivery
WDT	watchdog timer
XRES	external reset I/O pin
ZCD	zero crossing defect

## 8 Document conventions

### 8.1 Units of measure

**Table 11** Units of measure

Symbol	Unit of measure
°C	degrees Celsius
Hz	hertz
KB	1024 bytes
kHz	kilohertz
kΩ	kilo ohm
Mbps	megabits per second
MHz	megahertz
MΩ	mega-ohm
Msp	megasamples per second
μA	microampere
μF	microfarad
μs	microsecond
μV	microvolt
μW	microwatt
mA	milliampere
ms	millisecond
mV	millivolt
nA	nanoampere
ns	nanosecond
Ω	ohm
pF	picofarad
ppm	parts per million
ps	picosecond
s	second
sps	samples per second
V	volt

Revision history

## Revision history

Document revision	Date	Description of changes
*B	2023-10-10	Post to external web.
*C	2023-12-20	Updated TR_SR from 60 ns to 75 ns in <a href="#">Table 5</a> Functional block specifications.

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