

High-Efficiency Qi v1.1-Compliant Wireless Power Receiver and Battery Charger

Check for Samples: [bq51050B](#), [bq51051B](#)

FEATURES

- **Single-Stage Wireless Power Receiver and Li-Ion/Li-Pol Battery Charger**
 - Combines Wireless Power Receiver, Rectifier and Battery Charger in a Single Small Package
 - 4.2V and 4.35V Output Voltage Options
 - Supports up to 1.5A Charging Current
 - 93% Peak AC-DC Charging Efficiency
- **Robust Architecture**
 - 20V Maximum Input Voltage Tolerance, with Input OV Protection Clamp
 - Thermal Shutdown and Over Current Protection
 - Temperature Monitoring and Fault Detection

- **Compatible with WPC v1.1 “Qi” Industry Standard**
- **Power Stage Output Tracks Rectifier and Battery Voltage to Ensure Maximum Efficiency Across the Full Charge Cycle**
- **Available in small WCSP and QFN packages**

APPLICATIONS

- **Battery Packs**
- **Cell Phones, Smart Phones**
- **Headsets**
- **Portable Media Players**
- **Other Hand-Held Devices**

DESCRIPTION

The bq5105x is a high efficiency, wireless power receiver with Li-Ion/Li-Pol battery charge controller for portable applications. The bq5105x device provides efficient AC/DC power conversion, integrates digital controller required to comply with Qi v1.1 communication protocol and all necessary control algorithms needed for efficient and safe Li-Ion and Li-Pol battery charger. Together with bq500210 transmitter-side controller, the bq5105x enables a complete wireless power transfer system for direct battery charger solution. By utilizing near-field inductive power transfer, the receiver coil embedded in the portable device can pick up the power transmitted by transmitter coil. The AC signal from the receiver coil is then rectified and conditioned to apply power directly to the battery. Global feedback is established from the receiver to the transmitter in order to stabilize the power transfer process. This feedback is established by utilizing the Qi v1.1 communication protocol.

The bq5105x devices integrate a low-impedance synchronous rectifier, low-dropout regulator, digital control, charger controller, and accurate voltage and current loops in a single package. The entire power stage (rectifier and LDO) utilize low resistive N-MOSFET's (100mΩ typical R_{ds(on)}) to ensures high efficiency and low power dissipation.

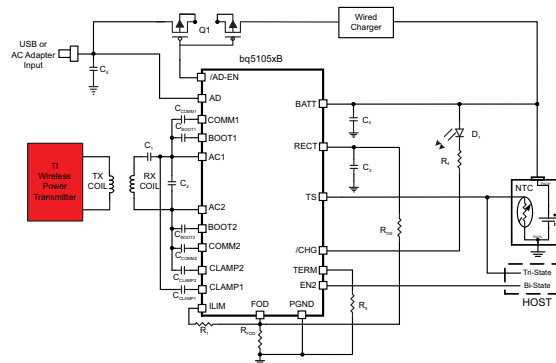


Figure 1. Typical System Blocks Show bq5105xB Used as a Wireless Power Li-Ion/Li-Pol Battery Charger

Note: Visit ti.com/wirelesspower for product details and design resources



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

ORDERING INFORMATION

PART NO.	IC MARKING	PACKAGE	ORDERING NUMBER (TAPE AND REEL)	QUANTITY
bq51050B	bq51050B	WCSP-28	bq51050BYFPR bq51050BYFPT	3000 250
	bq51050B	VQFN-20	bq51050BRHLR bq51050BRHLT	3000 250
bq51051B	bq51051B	WCSP-28	bq51051BYFPR bq51051BYFPT	3000 250
	bq51051B	VQFN-20	bq51051BRHLR bq51051BRHLT	3000 250

AVAILABLE OPTIONS

DEVICE	FUNCTION	V _{RECT-OVP}	V _{RECT(REG)}	V _{BAT(REG)}	NTC MONITORING
bq51050B	4.2V Li-Ion Wireless Battery Charger	15V	Track	4.2V	JEITA
bq51051B	4.35V Li-Ion Wireless Battery Charger	15V	Track	4.35V	JEITA

ABSOLUTE MAXIMUM RATINGS⁽¹⁾⁽²⁾

over operating free-air temperature range (unless otherwise noted)

		VALUES		UNITS
		MIN	MAX	
Input voltage	AC1, AC2, RECT, COMM1, COMM2, BAT(OUT), $\overline{\text{CHG}}$, CLAMP1, CLAMP2	-0.3	20	V
	AD, AD-EN	-0.3	30	V
	BOOT1, BOOT2	-0.3	26	V
	EN2, TERM, FOD, TS-CTRL, ILIM	-0.3	7	V
Input current	AC1, AC2		2	A(RMS)
Output current	BAT(OUT)		1.5	A
Output sink current	$\overline{\text{CHG}}$		15	mA
	COMM1, COMM2		1.0	A
Junction temperature, T _J		-40	150	°C
Storage temperature, T _{STG}		-65	150	°C
ESD Rating	Human body model (HBM)(100pF, 1.5kΩ)		2	kV
	Charged device model (CDM)		500	V

- (1) Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltages are with respect to the VSS terminal, unless otherwise noted.

THERMAL INFORMATION

THERMAL METRIC ⁽¹⁾		YFP	RHL	UNITS
		28-PINS	20-PINS	
θ_{JA}	Junction-to-ambient thermal resistance	58.9	37.7	°C/W
θ_{JCTop}	Junction-to-case (top) thermal resistance	0.2	35.5	
θ_{JB}	Junction-to-board thermal resistance	9.1	13.6	
Ψ_{JT}	Junction-to-top characterization parameter	1.4	0.5	
Ψ_{JB}	Junction-to-board characterization parameter	8.9	13.5	
θ_{JCbott}	Junction-to-case (bottom) thermal resistance	n/a	2.7	

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

RECOMMENDED OPERATING CONDITIONS

over operating free-air temperature range (unless otherwise noted)

			MIN	MAX	UNIT
V_{IN}	Input voltage range	RECT	4.0	10.0	V
I_{IN}	Input current	RECT		1.5	A
I_{BAT}	BAT(output) current	BAT		1.5	A
I_{AD-EN}	Sink current	AD-EN		1	mA
I_{COMM}	COMM sink current	COMM		500	mA
T_J	Junction temperature		0	125	°C

TYPICAL APPLICATION SCHEMATIC

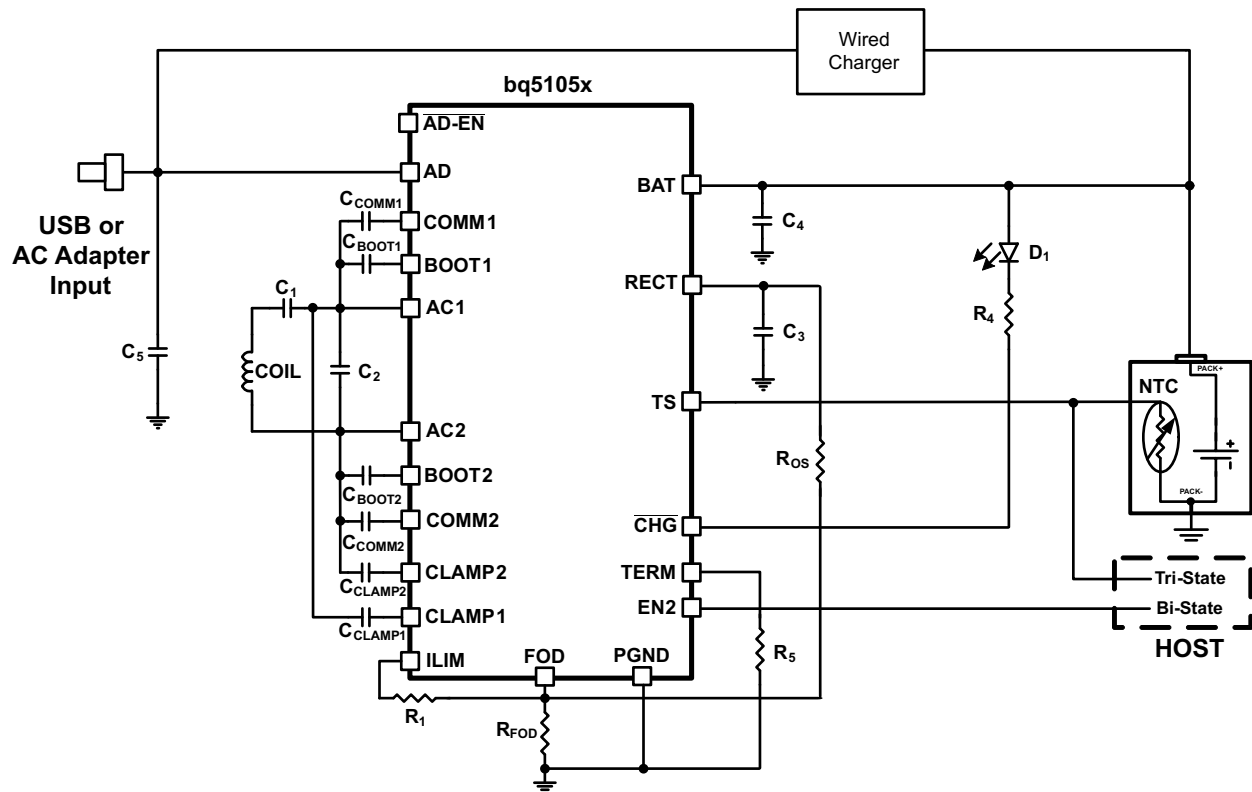


Figure 2. bq5105x Used as a Wireless Power Receiver and Li-Ion/Li-Pol Battery Charger

ELECTRICAL CHARACTERISTICS

Over junction temperature range $0^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ and recommended supply voltage (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{UVLO}	Under-voltage lock-out	$V_{RECT}: 0\text{V} \rightarrow 3\text{V}$	2.6	2.7	2.8	V
$V_{HYS-UVLO}$	Hysteresis on UVLO	$V_{RECT}: 3\text{V} \rightarrow 2\text{V}$		250		mV
	Hysteresis on OVP	$V_{RECT}: 16\text{V} \rightarrow 5\text{V}$		150		mV
V_{RECT}	Input over-voltage threshold	$V_{RECT}: 5\text{V} \rightarrow 16\text{V}$	14.5	15	15.5	V
$V_{RECT-REG}^{(1)}$	V_{RECT} regulation voltage			5.11		V
I_{LOAD}	I_{LOAD} Hysteresis for dynamic V_{RECT} thresholds as a % of I_{LIM}	I_{LOAD} falling		5%		
V_{TRACK}	Tracking V_{RECT} regulation above V_{BAT}	$V_{BAT} = 3.5\text{V}$, $I_{BAT} \geq 500\text{mA}$		300		mV
$V_{RECT-REV}$	Rectifier reverse voltage protection at the BAT(output)	$V_{RECT-REV} = V_{BAT} - V_{RECT}$, $V_{BAT} = 10\text{V}$		8.3	9	V
$V_{RECT-DPM}$	Rectifier under voltage protection, restricts I_{BAT} at $V_{RECT-DPM}$		3	3.1	3.2	V
QUIESCENT CURRENT						
I_{RECT}	Active chip quiescent current consumption from RECT (in the prswireless power is present)	$I_{BAT} = 0$, $0^{\circ}\text{C} \leq T_J \leq 85^{\circ}\text{C}$		8	10	mA
		$I_{BAT} = 300\text{mA}$, $0^{\circ}\text{C} \leq T_J \leq 85^{\circ}\text{C}$		2	3	mA
I_Q	Quiescent current at the BAT when wireless power is disabled(Standby)	$V_{BAT} = 4.2\text{V}$, $0^{\circ}\text{C} \leq T_J \leq 85^{\circ}\text{C}$		12	20	μA
ILIM SHORT PROTECTION						
$R_{ILIM-SHORT}$	Highest value of I_{LIM} resistor considered a fault (short). Monitored for $I_{BAT} > 100\text{mA}$	$R_{ILIM}: 200\Omega \rightarrow 50\Omega$. I_{BAT} latches off, cycle power to reset			120	Ω
$t_{DGL-Short}$	Deglint time transition from I_{LIM} short to I_{BAT} disable			1		ms
I_{LIM_SC}	$I_{LIM-SHORT_OK}$ enables the I_{LIM} short comparator when I_{BAT} is greater than this value	$I_{BAT}: 0 \rightarrow 200\text{mA}$	110	145	165	mA
$I_{LIM-SHORT_OK}$ HYSTERESIS	Hysteresis for $I_{LIM-SHORT_OK}$ comparator	$I_{BAT}: 200 \rightarrow 0\text{mA}$		30		mA
I_{BAT-CL}	Maximum output current limit	Maximum I_{BAT} that will be delivered for 1 ms when I_{LIM} is shorted			2.4	A
BATTERY SHORT PROTECTION						
$V_{BAT(SC)}$	BAT pin short-circuit detection/pre-charge threshold	$V_{BAT}: 3\text{V} \rightarrow 0.5\text{V}$, no deglitch	0.75	0.8	0.85	V
$V_{BAT(SC)-HYS}$	$V_{BAT(SC)}$ hysteresis	$V_{BAT}: 0.5\text{V} \rightarrow 3\text{V}$		100		mV
$I_{BAT(SC)}$	Source current to BAT pin during short-circuit detection	$V_{BAT} = 0\text{V}$	12	18	22	mA
PRECHARGE						
V_{LOWV}	Pre-charge to fast charge transition threshold	$V_{BAT}: 2\text{V} \rightarrow 4\text{V}$	2.9	3.0	3.1	V
K_{PRECHG}	Pre-charge current as a percentage of I_{BAT}	$V_{LOWV} > V_{BAT} > V_{BAT(SC)}$, $I_{BAT}: 50 - 300\text{mA}$	18%	20%	23%	
$t_{pre-charge}$	Pre-charge timeout	$V_{BAT} < V_{LOWV}$		30		min
$t_{DGL1(LOWV)}$	De-glitch time, pre- to fast-charge			25		ms
$t_{DGL2(LOWV)}$	De-glitch time, fast- to pre-charge			25		ms
TIMERS						
$T_{fast-charge}$	Fast-charge timer	$V_{LOWV} < V_{BAT} < V_{BAT(REG)}$		36000		sec
$T_{pre-charge}$	Pre-charge timer	$V_{BAT-SHORT} < V_{BAT} < V_{LOWV}$		1800		sec
OUTPUT						
V_{OREG}	Regulated BAT(output) voltage	$I_{BAT} = 1000\text{mA}$	bq51050B	4.16	4.2	4.22
			bq51051B	4.30	4.35	4.37
V_{DO}	Drop-out voltage, RECT to BAT	$I_{BAT} = 1\text{A}$		110	190	mV
K_{LIM}	Current programming factor	$R_{LIM} = K_{LIM} / I_{LIM}$		290	300	320
I_{BAT}	Battery charge current limit programming range				1500	mA
$I_{COMM-CL}$	Current limit during communication			330	390	420

(1) $V_{RECT(REG)}$ is over ridden when rectifier fold back mode is active ($V_{RECT(REG)-TRACKING}$).

ELECTRICAL CHARACTERISTICS (continued)

Over junction temperature range $0^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ and recommended supply voltage (unless otherwise noted)

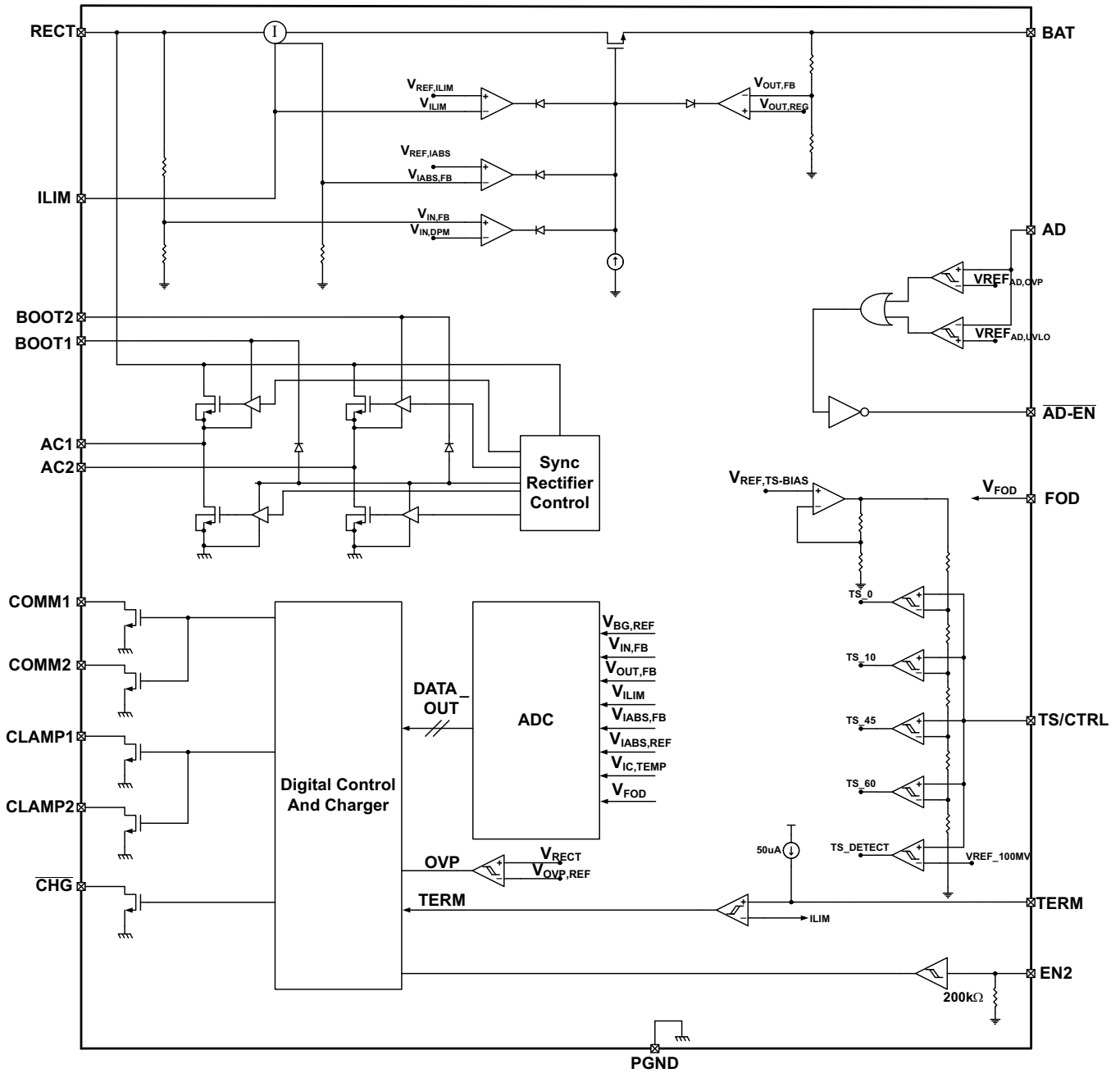
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
TERMINATION							
K _{TERM}	Programmable termination current as a percentage of I _{LIM}	R _{TERM} = %I _{LIM} x K _{TERM}		200	240	280	Ω/%
I _{TERM}	Constant current at the TERM pin to bias the termination reference			40	50	55	μA
V _{RECH}	Recharge threshold	bq51050B	V _{BAT(REG)} –135mV	V _{BAT(REG)} –110mV	V _{BAT(REG)} –90mV	V	
		bq51051B	V _{BAT(REG)} –125mV	V _{BAT(REG)} –95mV	V _{BAT(REG)} –70mV		
TS / CTRL							
V _{TS}	Internal TS bias voltage	I _{TS-Bias} < 100 μA (periodically driven see t _{TS/CTRL-Meas})		2	2.2	2.4	V
V _{OC}	Rising threshold	V _{TS} : 50% → 60%		57	58.7	60	%V _{TSB}
	Falling threshold	V _{TS} : 60% → 50%		55	56.3	57	
	Hysteresis on 0C Comparator	V _{TS} : 60% → 50%			2.4		
V _{10C}	Rising threshold	V _{TS} : 40% → 50%		46	47.8	49	%V _{TSB}
V _{10C-Hyst}	Hysteresis on 10C Comparator	V _{TS} : 50% → 40%			2		%V _{TSB}
V _{45C}	Falling threshold	V _{TS} : 25% → 15%		18	19.6	21	%V _{TSB}
V _{45C-Hyst}	Hysteresis on 45C Comparator	V _{TS} : 15% → 25%			3		%V _{TSB}
V _{60C}	Falling threshold	V _{TS} : 20% → 5%		12	13.1	14	%V _{TSB}
V _{60C-Hyst}	Hysteresis on 60C Comparator	V _{TS} : 5% → 20%			1		%V _{TSB}
I _{45C}	I _{LIM} reduction percentage at 45c	V _{TS} : 25% → 15%, I _{LOAD} = I _{LIM}		45	50	55	%
V _{CTRL-HI}	CTRL pin threshold for a high	V _{TS/CTRL} : 50 → 150 mV		80	100	130	mV
V _{CTRL-LOW}	CTRL pin threshold for a low	V _{TS/CTRL} : 150 → 50 mV		50	80	100	mV
T _{TS/CTRL-Meas}	Time period of TS/CTRL measurements--when VT _{SB} is being driven	TS bias voltage is only driven when communication packets are sent			24		ms
t _{TS-Deglitch}	Deglitch time for all TS comparators				10		ms
NTC-Pullup	Pull-up resistor for the NTC network. Pulled up to the TS bias LDO.			18	20	22	kΩ
NTC-R _{NOM}	Nominal resistance requirement at 25c of the NTC resistor				10		kΩ
NTC-Beta	Beta requirement for accurate temperature sensing via the above specified thresholds				3380		Ω
THERMAL PROTECTION							
T _J	Thermal shutdown temperature				155		°C
	Thermal shutdown hysteresis				20		°C
OUTPUT LOGIC LEVELS ON /CHG							
V _{OL}	Open drain CHG pin	I _{SINK} = 5 mA				500	mV
I _{OFF,CHG}	CHG leakage current when disabled	V _{CHG} = 20 V, 0°C ≤ T _J ≤ 85°C				1	μA
COMM PIN							
R _{DS-ON(COMM)}	Comm1 and Comm2	V _{rect} = 2.6V			1		Ω
f _{COMM}	Signaling frequency on COMM pin				2.00		Kb/s
I _{OFF,Comm}	Comm pin leakage current	V _{COMM1} = 20 V, V _{COMM2} = 20 V				1	μA
CLAMP PIN							
R _{DS-ON(CLAMP)}	Clamp1 and Clamp2				0.75		Ω

ELECTRICAL CHARACTERISTICS (continued)Over junction temperature range $0^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ and recommended supply voltage (unless otherwise noted)

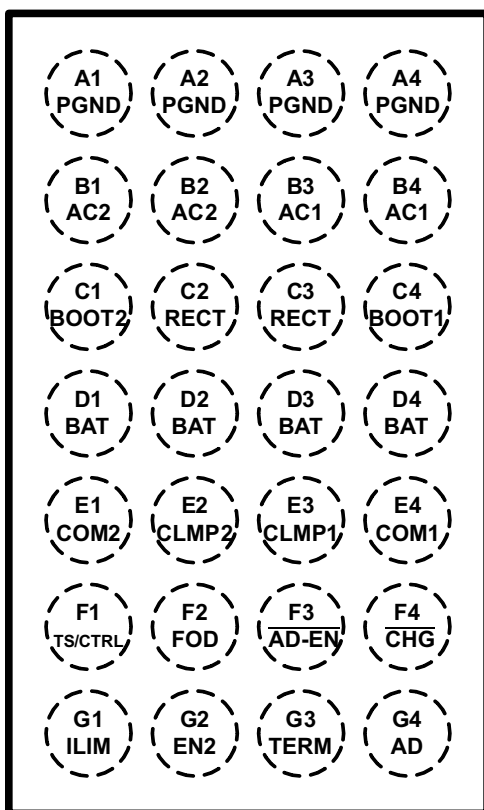
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SYNCHRONOUS RECTIFIER						
I_{BAT}	I_{BAT} at which the synchronous rectifier enters half synchronous mode, SYNC_EN	$I_{\text{BAT}} 200 \rightarrow 0 \text{ mA}$	80	115	140	mA
	Hysteresis for $I_{\text{BAT,RECT-EN}}$ (full-synchronous mode enabled)	$I_{\text{BAT}} 0 \rightarrow 200 \text{ mA}$		25		
$V_{\text{HS-DIODE}}$	High-side diode drop when the rectifier is in half synchronous mode	$I_{\text{AC-VRECT}} = 250 \text{ mA}$, and $T_J = 25^{\circ}\text{C}$		0.7		V
EN2						
V_{IL}	Input low threshold for EN2				0.4	V
V_{IH}	Input high threshold for EN2		1.3			V
$R_{\text{PD, EN}}$	EN2 pull down resistance			200		k Ω
ADC						
P_{powerREC}	Received power measurement	0W – 5W received power after calibration of Rx magnetics losses		0.25		W

DEVICE INFORMATION

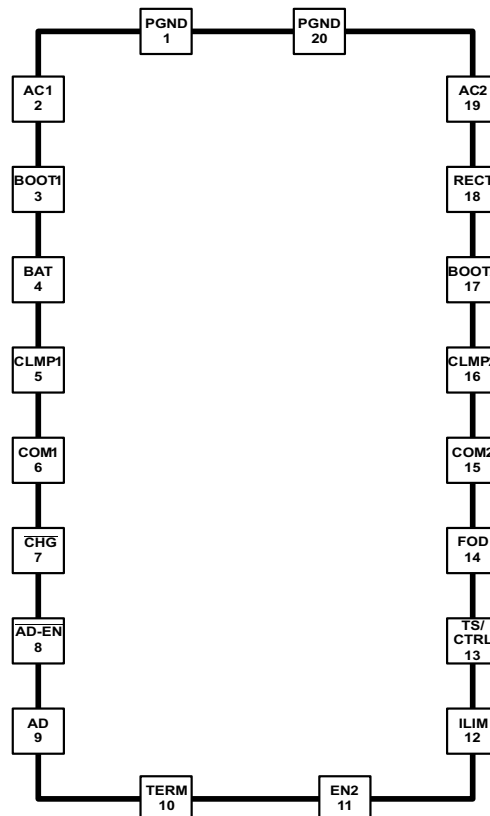
SIMPLIFIED BLOCK DIAGRAM



YFP Package
3.0mm x 1.9mm 28-Pin WCSP
(TOP VIEW)



RHL Package
4.35mm x 3.35mm 20-Pin QFN
(TOP VIEW)



PIN FUNCTIONS

NAME	WCSP	QFN	I/O	DESCRIPTION
AC1	B3, B4	2	I	Input power from receiver coil.
AC2	B1, B2	19	I	
BOOT1	C4	3	O	Bootstrap capacitors for driving the high-side FETs of the synchronous rectifier. Connect a 10nF ceramic capacitor from BOOT1 to AC1 and from BOOT2 to AC2.
BOOT2	C1	17	O	
RECT	C2, C3	18	O	Filter capacitor for the internal synchronous rectifier. Connect a ceramic capacitor to PGND. Depending on the power levels, the value may be 4.7µF to 22µF.
BAT	D1, D2, D3, D4	4	O	Output pin, delivers power to the battery while applying the internal charger profile.
COM1	E4	6	O	Open-drain output used to communicate with primary by varying reflected impedance. Connect through a capacitor to either AC1 or AC2 for capacitive load modulation (COMM2 must be connected to the alternate AC1 or AC2 pin). For resistive modulation connect COMM1 and COMM2 to RECT via a single resistor; connect through separate capacitors for capacitive load modulation.
COM2	E1	15	O	Open-drain output used to communicate with primary by varying reflected impedance. Connect through a capacitor to either AC1 or AC2 for capacitive load modulation (COMM1 must be connected to the alternate AC1 or AC2 pin). For resistive modulation connect COMM1 and COMM2 to RECT via a single resistor; connect through separate capacitors for capacitive load modulation.
CLMP1	E3	5	O	Open drain FETs which are utilized for a non-power dissipative over-voltage AC clamp protection. When the RECT voltage goes above 15 V, both switches will be turned on and the capacitors will act as a low impedance to protect the IC from damage. If used, Clamp1 is required to be connected to AC1, and Clamp2 is required to be connected to AC2 via 0.47µF capacitors.
CLMP2	E2	16	O	
PGND	A1, A2, A3, A4	1, 20	–	Power ground

PIN FUNCTIONS (continued)

NAME	WCSP	QFN	I/O	DESCRIPTION
ILIM	G1	12	I/O	Programming pin for the battery charge current. Connect external resistor to VSS. Size R_{ILIM} with the following equation: $R_{ILIM} = 300 / I_{ILIM}$ where I_{ILIM} is the desired battery charge current.
AD	G4	9	I	Connect this pin to the wired adapter input. When a voltage is applied to this pin wireless charging is disabled and AD_EN is driven low. Connect to GND through a 1 μ F capacitor. If unused, capacitor is not required and should be grounded directly.
AD-EN	F3	8	O	Push-pull driver for external PFET when wired charging is active.
TS/CTRL	F1	13	I	Must be connected to ground via a NTC resistor. If an NTC function is not desired, connect to GND with a 10 k Ω resistor. As a CTRL pin pull to ground to send end power transfer (EPT) fault to the transmitter or pull-up to an internal rail (i.e. 1.8 V) to send EPT termination to the transmitter.
TERM	G3	10	I	Input that allows the termination threshold to be programmable. $K_{TERM} = 240 \Omega/\%$. Set the termination threshold by applying the following equation $R_{TERM} = \%I_{ILIM} \times K_{TERM}$ where $\%I_{ILIM}$ is the desired percentage of fast charge current when termination should occur.
EN2	G2	11	I	EN2=0 enables wired charging source if AD input voltage is above 3.6V, wireless charging is enabled if AD input voltage is < 3.6V, EN2=1 disables wired charging source; wireless power is always enabled if present.
FOD	F2	14	I	Input for the rectified power measurement. Connect to GND with a 188 Ω resistor.
CHG	F4	7	O	Open-drain output – active when charging of the battery is active.

TYPICAL CHARACTERISTICS

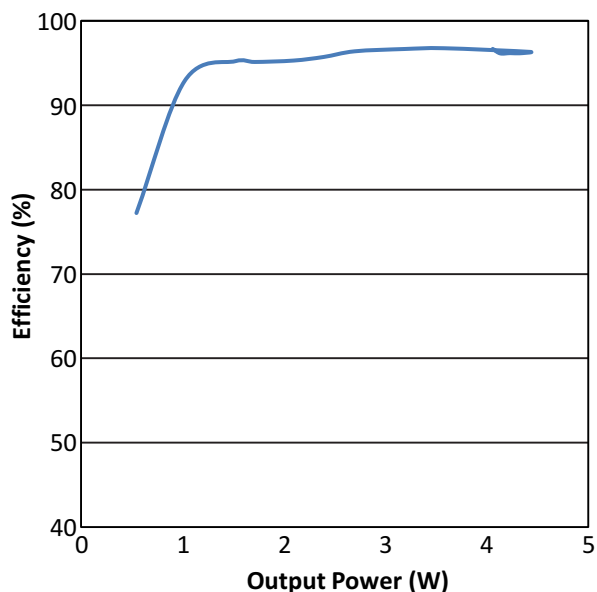


Figure 3. Rectifier Efficiency

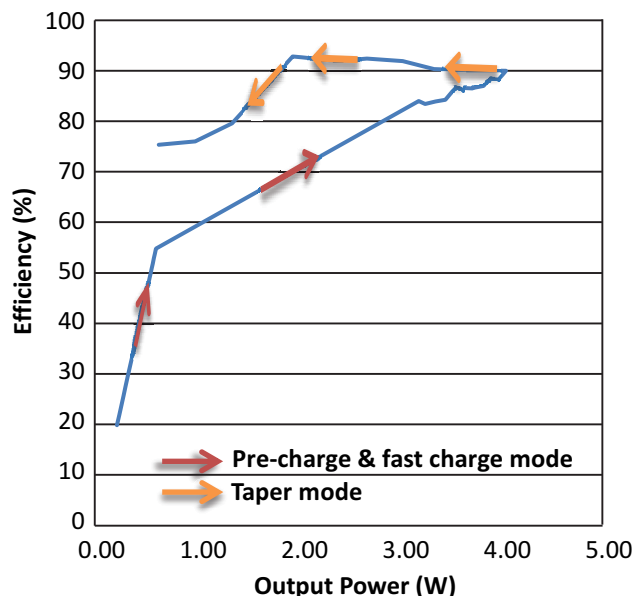


Figure 4. IC Efficiency (AC input to DC output)

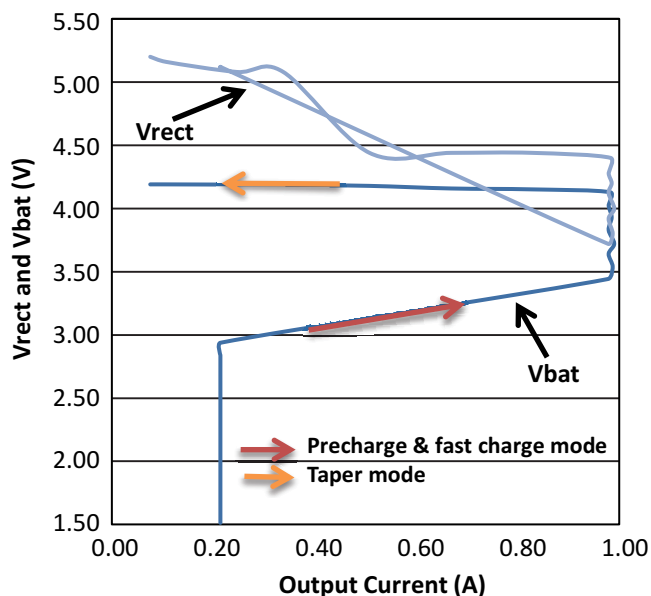


Figure 5. Vrect, Vbat Vs Output Current

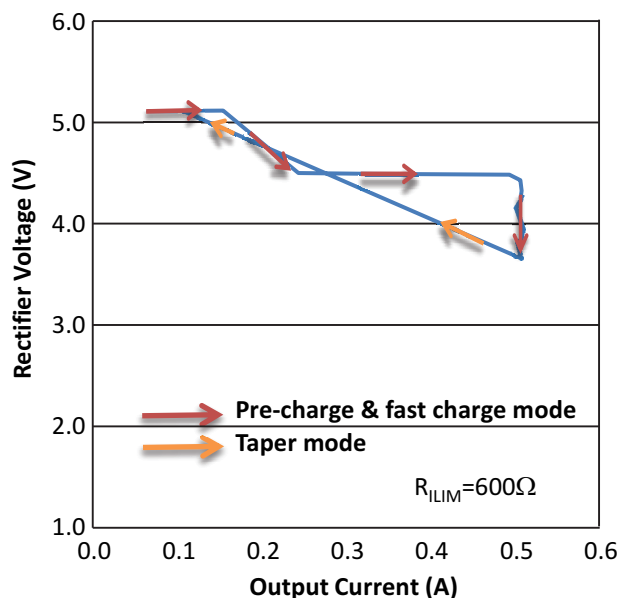


Figure 6. Vrect vs Output Current at $R_{ILIM}=600\Omega$

TYPICAL CHARACTERISTICS (continued)

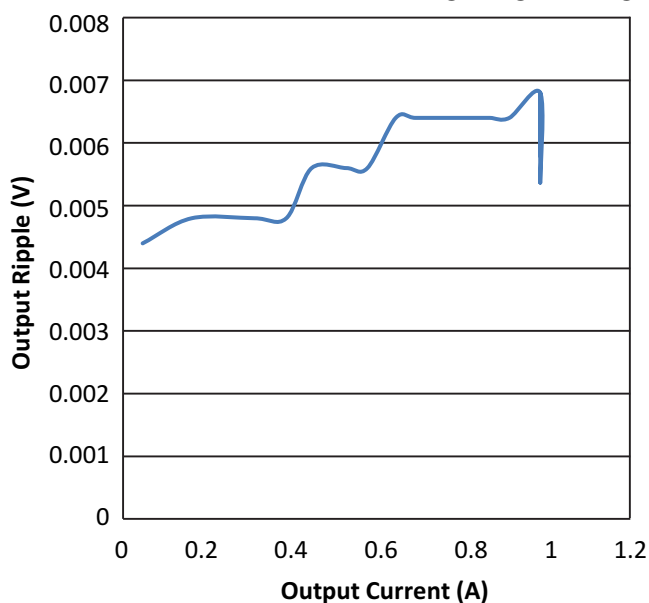


Figure 7. Output Ripple vs Output Current

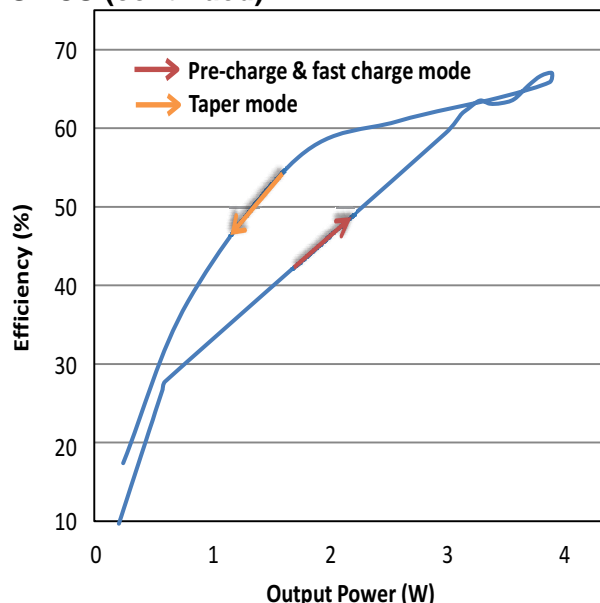


Figure 8. System Efficiency (DC input to DC output)

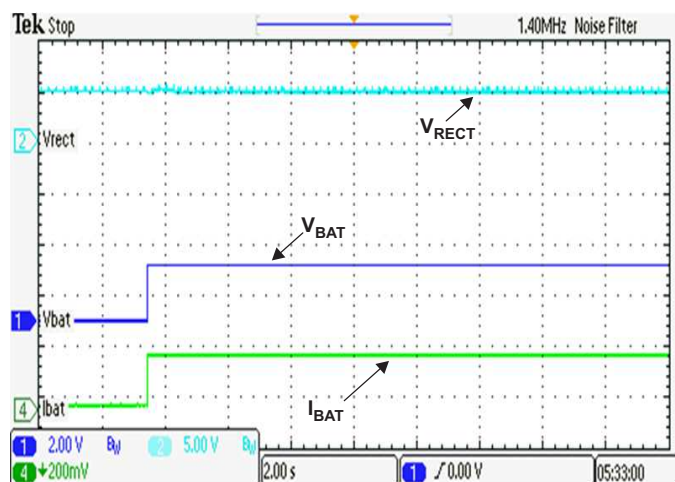


Figure 9. Battery Insertion in Pre-Charge Mode

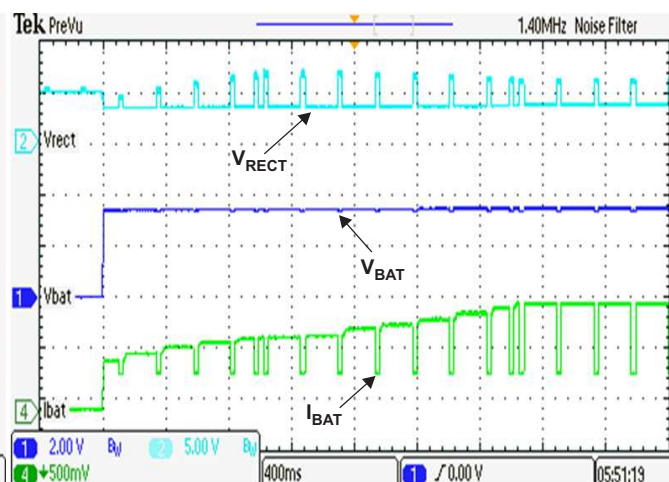


Figure 10. Battery Insertion in Fast-Charge Mode

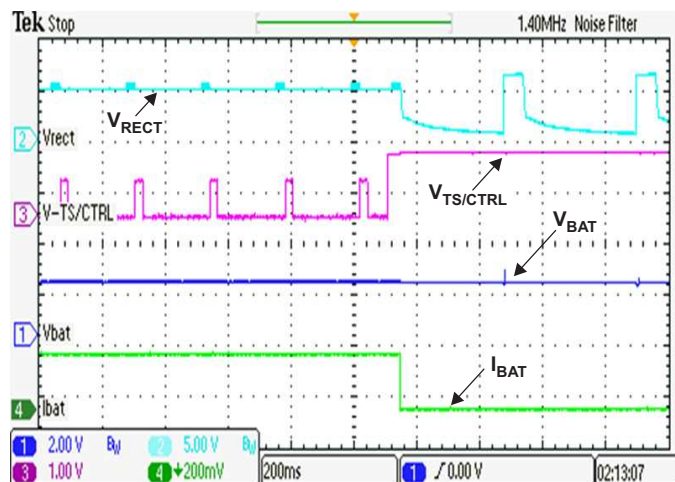


Figure 11. TS Fault

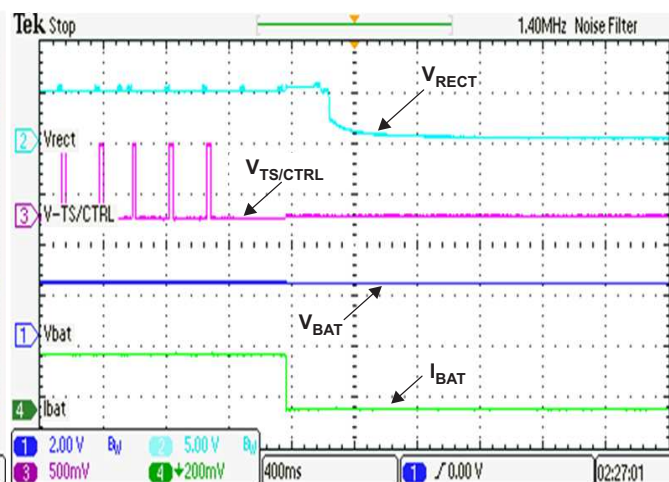


Figure 12. TS Ground Fault

TYPICAL CHARACTERISTICS (continued)

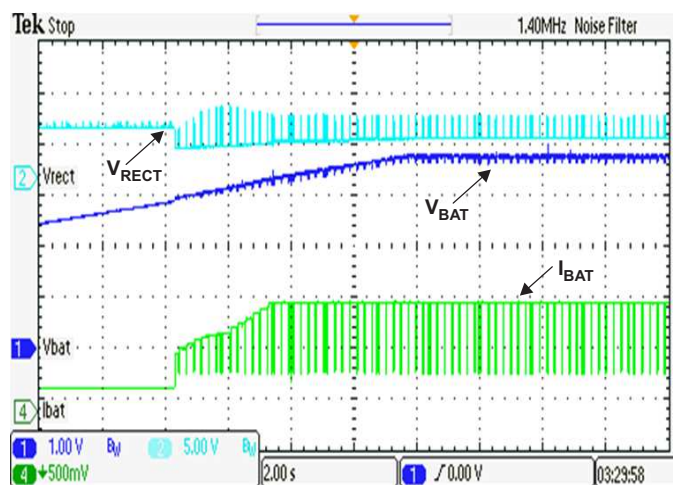


Figure 13. Pre-Charge to Fast Charge Transition

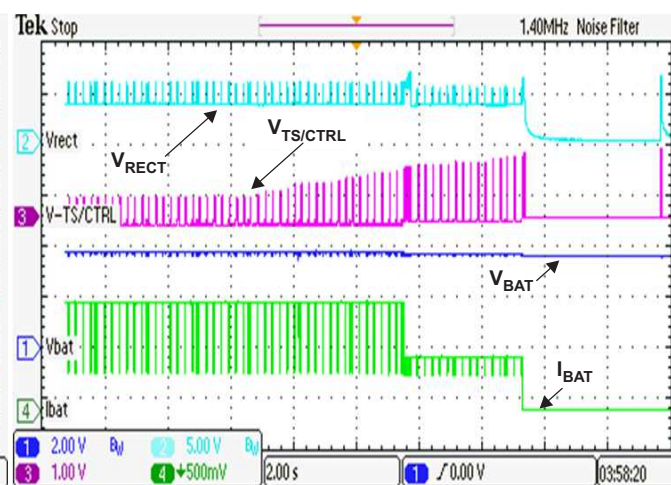


Figure 14. JEITA Functionality (Rising Temp)

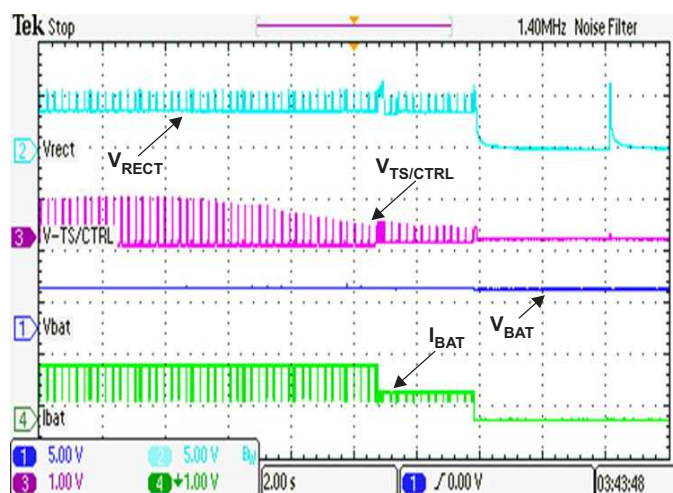


Figure 15. JEITA Functionality (Falling Temp)

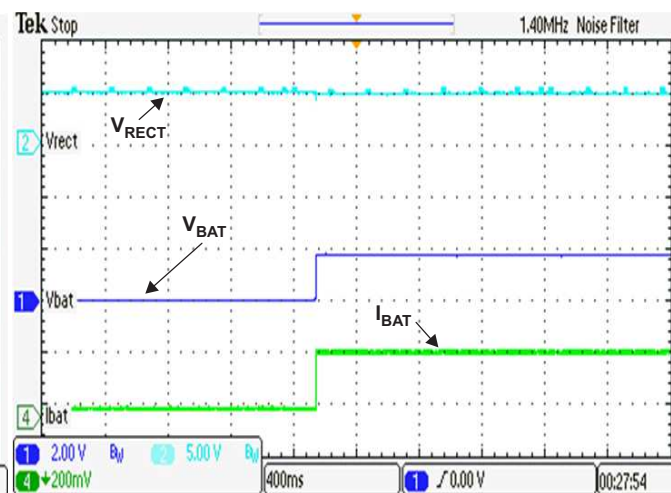


Figure 16. Battery Short to Pre-Charge Mode Transition

PRINCIPLE OF OPERATION

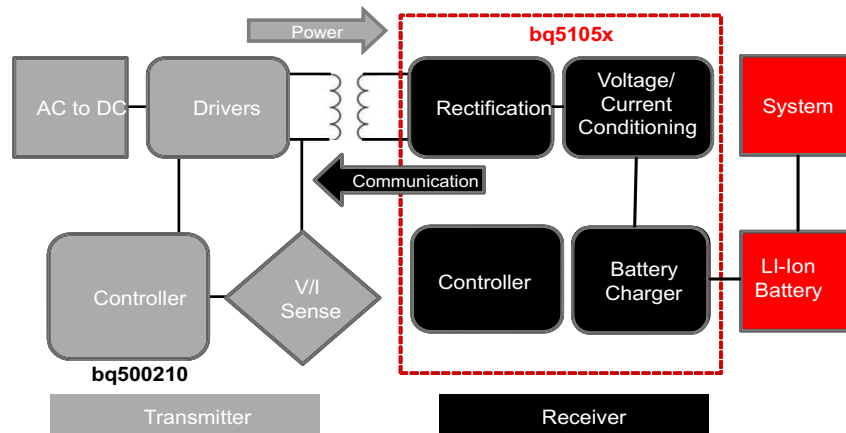


Figure 17. WPC Wireless Power Charging System Indicating the Functional Integration of the bq5105x

A Brief Description of the Wireless System

A wireless system consists of a charging pad (primary, transmitter) and the secondary-side equipment. There are coils in the charging pad and in the secondary equipment which magnetically coupled to each other when the equipment is placed on the charging pad. Power is transferred from the primary to the secondary by transformer action between the coils. Control over the amount of power transferred is achieved by changing the frequency of the primary drive.

The secondary can communicate with the primary by changing the load seen by the primary. This load variation results in a change in the primary coil current, which is measured and interpreted by a processor in the charging pad. The communication is digital - packets are transferred from the secondary to the primary. Differential Bi-phase encoding is used for the packets. The bit rate is 2Kbits / second.

Various types of communication packets have been defined. These include identification and authentication packets, error packets, control packets, power usage packets, end of power packet and efficiency packets.

The primary coil is powered off most of the time. It wakes up occasionally to see if a secondary is present. If a secondary authenticates itself to the primary, the primary remains powered up. The secondary maintains full control over the power transfer using communication packets.

Using the bq5105x as a Wireless Li-Ion/Li-Pol Battery Charger (With reference to [Figure 2](#))

[Figure 2](#) is the schematic of a system which uses the bq5105x as direct battery charger. When the system shown in [Figure 2](#) is placed on the charging pad (transmitter), the receiver coil couples to the magnetic flux generated by the coil in the charging pad which consequently induces a voltage in the receiver coil. The internal synchronous rectifier feeds this voltage to the RECT pin which has the filter capacitor C3.

The bq5105x identifies and authenticates itself to the primary using the COM pins by switching on and off the COM FETs and hence switching in and out C_{COMM} . If the authentication is successful, the transmitter will remain powered on. The bq5105x measures the voltage at the RECT pin, calculates the difference between the actual voltage and the desired voltage $V_{RECT-REG}$ and sends back error packets to the primary. This process goes on until the RECT voltage settles at $V_{RECT-REG}$.

During power-up, the LDO is held off until the $V_{RECT-REG}$ threshold converges. The voltage control loop ensures that the output (BAT) voltage is maintained at $V_{BAT-REG}$ to power the system depends on the battery charge mode. The bq5105x continues to monitor the V_{RECT} and V_{BAT} and maintains sending error packets to the primary every 250ms. The bq5105x regulates the V_{RECT} voltage very close to battery voltage, this voltage tracking process minimizes the voltage difference across the internal LDO and maximize the charging efficiency. If a large transient occurs, the feedback to the primary speeds up to every 32ms in order to converge on an operating point in less time.

Battery Charge Profile

The bq5105x charger monitors the battery current at all times and reduces the charge current when the system load requires current above the input current limit. The charge profile is shown in Figure 18.

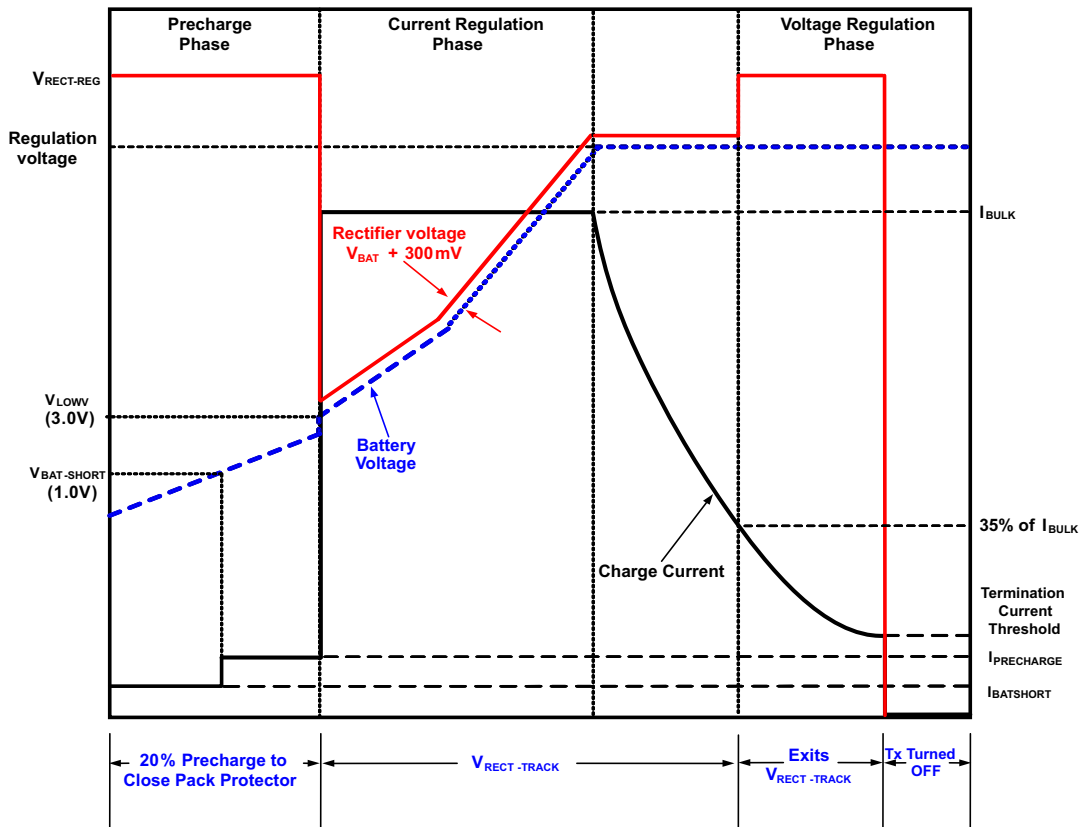


Figure 18. Li-Ion Battery Charger Profile

This allows for proper charge termination and timer operation. Under normal battery charging conditions, the system voltage is approximately equal to the battery voltage, however if the battery is deeply discharged, the system voltage does not drop below 3.5V. This minimum system voltage support enables the system to run with a defective or absent battery pack and enables instant system turn-on even with a totally discharged battery or no battery.

The battery is charged in three phases: precharge, fast-charge constant current and constant voltage. In all charge phases, an internal control loop monitors the IC junction temperature and reduces the charge current if the internal temperature threshold is exceeded. Additionally, a voltage-based battery pack thermistor monitoring input (TS) is included that monitors battery temperature for safe charging. The TS function for bq5105x is JEITA compatible.

Battery Charging Process

Precharge Mode ($V_{BAT} \leq V_{LOWV}$)

The bq5105X enters pre-charge mode when $V_{BAT} \leq V_{LOWV}$. Upon entering precharge mode, battery charge current limit is set to $I_{PRECHARGE}$. During pre-charge mode, the charge current is regulated to 20% of the fast charge current (I_{BULK}) setting.

If the battery is deeply discharged or shorted ($V_{BAT} < V_{BAT-SHORT}$), the bq5105X applies $I_{BAT-SHORT}$ current to bring the battery voltage up to acceptable charging levels. Once the battery rises above $V_{BAT-SHORT}$, the charge current is regulated to $I_{PRECHARGE}$.

Under normal conditions, the time spent in this pre-charge region is a very short percentage of the total charging time and this does not affect the overall charging efficiency for very long.

Fast Charge Mode /Constant Voltage Mode

Once $V_{BAT} > V_{LOWV}$, the bq5105x enters fast charge mode (Current Regulation Phase) where charge current is regulated using the internal MOSFETs between RECT and BAT. Once the battery voltage charges up to $V_{BAT-REG}$, the bq5105x enters constant voltage (CV) phase and regulates battery voltage to $V_{BAT(REG)}$ and the charging current is reduced.

Once the input current falls below the termination threshold (I_{TERM}), the charger goes into high impedance.

Battery Charge Current Setting Calculations

R_{ILIM} Calculations

The bq5105x includes a means of providing hardware overcurrent protection by means of an analog current regulation loop. The hardware current limit provides an extra level of safety by clamping the maximum allowable output current (e.g., a current compliance). The calculation for the total R_{ILIM} resistance is as follows:

$$R_1 = \frac{300}{I_{BULK}} - R_{FOD} \quad R_{ILIM} = R_1 + R_{FOD} \quad (1)$$

Where I_{BULK} is the expected maximum battery charge current during fast charge mode and I_{BULK} is the hardware over current limit. When referring to the application diagram shown in [Figure 2](#), R_{ILIM} is the sum of R_{FOD} (188Ω) and the resistance from the I_{LIM} pin to GND).

Termination Calculations

The bq5105X includes a programmable upper termination threshold. This pin can be used to send the charge status 100% packet (CS100) to the transmitter in order to indicate a full charge status. The header for this packet is 0x05. Note that this packet does not turn off the transmitter and is only used as an informative indication of the mobile device's charge status. The upper termination threshold is calculated using [Equation 2](#):

$$R_{TERM} = K_{TERM} \times \%I_{BULK} \quad (2)$$

The K_{TERM} constant is specified in the datasheet as 240. The upper termination threshold is set as a percentage of the ILIM setting.

For example, if the ILIM resistor is set to 300 Ω the ILIM current will be 1A ($300 \div 300$). If the upper termination threshold is desired to be 100 mA, this would be 10% of ILIM. The R_{TERM} resistor would then equal 2.4 kΩ (240×10).

Battery-Charger Safety and JEITA Guidelines

The bq5105x continuously monitors battery temperature by measuring the voltage between the TS pin and GND. A negative temperature coefficient thermistor (NTC) and an external voltage divider typically develop this voltage. The bq5105x compares this voltage against its internal thresholds to determine if charging is allowed. To initiate a charge cycle, the voltage on TS pin must be within the V_{T1} to V_{T4} thresholds. If V_{TS} is outside of this range, the bq5105x suspends charge and waits until the battery temperature is within the V_{T1} to V_{T4} range.

If V_{TS} is within the range of V_{T1} and V_{T2} , the charge current is reduced to $I_{BULK}/2$. If V_{TS} is within the range of V_{T2} and V_{T3} , the maximum charge voltage regulation is 4.25V. If V_{TS} is within V_{T3} and V_{T4} , the maximum charge voltage regulation is reduced back to 4.10V and charge current is reduced to $I_{BULK}/2$. [Figure 19](#) summarizes the operation.

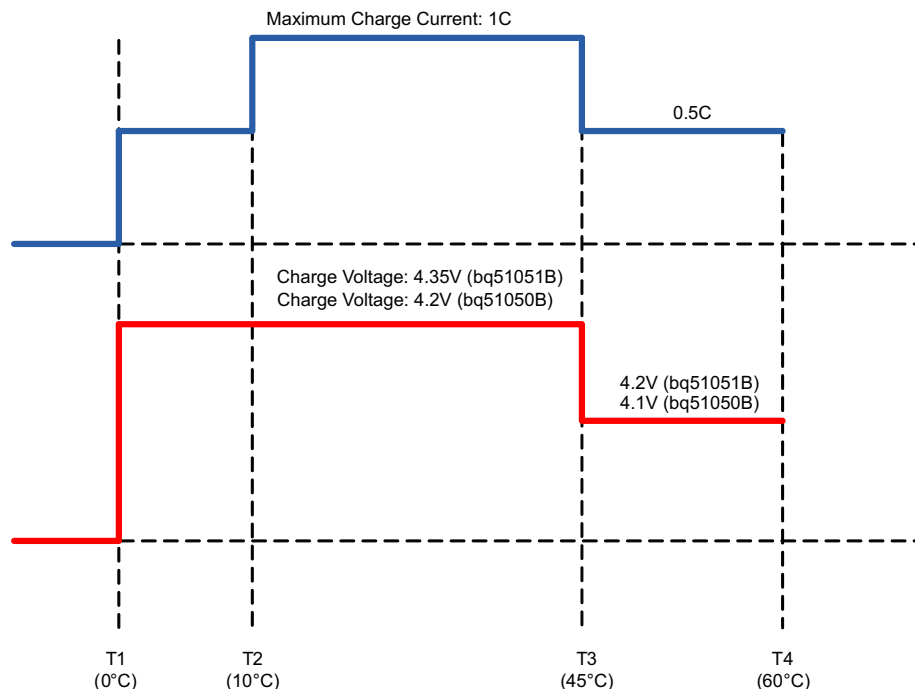


Figure 19. JEITA Compatible TS Profile

Input over-voltage

If, for some condition (e.g., a change in position of the equipment on the charging pad), the rectifier voltage suddenly increases in potential, the voltage-control loop inside the bq5105x becomes active, and prevents the output from going beyond $V_{BAT-REG}$. The receiver then starts sending back error packets every 30ms until the RECT voltage comes back to an acceptable level, and then maintains the error communication every 250ms.

If the input voltage increases in potential beyond V_{OVP} , the IC switches off internal FET and tells the primary to bring the voltage back to $V_{RECT(REG)}$. In addition a proprietary voltage protection circuit is activated by means of C_{clamp1} and C_{clamp2} that protects the IC from voltages beyond the maximum rating of the IC (e.g., 20V).

End Power Transfer Packet (WPC Header 0x02)

The WPC allows for a special command to terminate power transfer from the TX termed End Power Transfer (EPT) packet. The v1.1 specifies the below reasons and their responding data field value. The *Condition* column corresponds to the case where the bq5101x device will send this command.

REASON	VALUE	CONDITION
Unknown	0x00	$AD > 3.6V$
Charge Complete	0x01	$TS/CTRL = 1$
Internal Fault	0x02	$T_J > 150^{\circ}C$ or $R_{ILIM} < 100\Omega$
Over Temperature	0x03	$TS < V_{HOT}$, $TS > V_{COLD}$, or $TS/CTRL < 100mV$
Over Voltage	0x04	Not Sent
Over Current	0x05	Not Sent
Battery Failure	0x06	Not Sent
Reconfigure	0x07	Not Sent
No Response	0x08	V_{RECT} target does not converge

Status Outputs

The bq5105x provides one status output, $\overline{\text{CHG}}$. This output is an open-drain NMOS device that is rated to 20 V. The open-drain FET connected to the $\overline{\text{CHG}}$ pin will be turned on whenever the output (BAT) of the charger is enabled. As a note, the output of the charger supply will not be enabled if the $V_{\text{RECT(REG)}}$ does not converge at the no-load target voltage.

Communication Modulator

The bq5105x provides two identical, integrated communication FETs which are connected to the pins COM1 and COM2. These FETs are used for modulating the secondary load current which allows bq5105x to communicate error control and configuration information to the transmitter. Figure 20 shows how the COMM pins can be used for resistive load modulation. Each COMM pin can handle at most a 24Ω communication resistor. Therefore, if a COMM resistor between 12Ω and 24Ω is required COM1 and COM2 pins must be connected in parallel. bq5105x does not support a COMM resistor less than 12Ω .

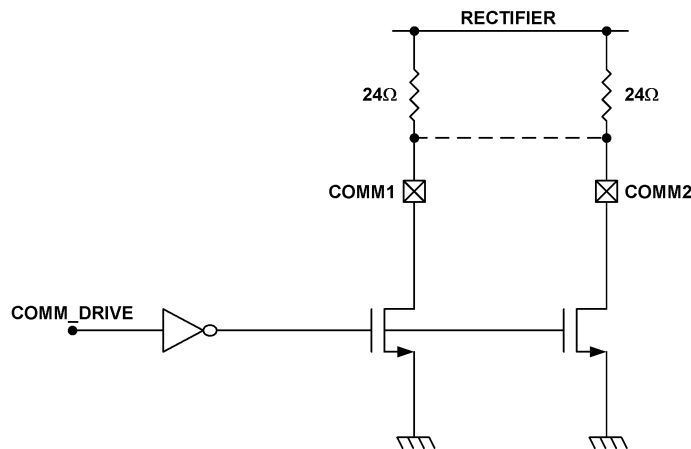


Figure 20. Resistive Load Modulation

In addition to resistive load modulation, the bq5105x is also capable of capacitive load modulation as shown in Figure 21. In this case, a capacitor is connected from COM1 to AC1 and from COM2 to AC2. When the COMM switches are closed there is effectively a 22 nF capacitor connected between AC1 and AC2. Connecting a capacitor in between AC1 and AC2 modulates the impedance seen by the coil, which will be reflected in the primary as a change in current.

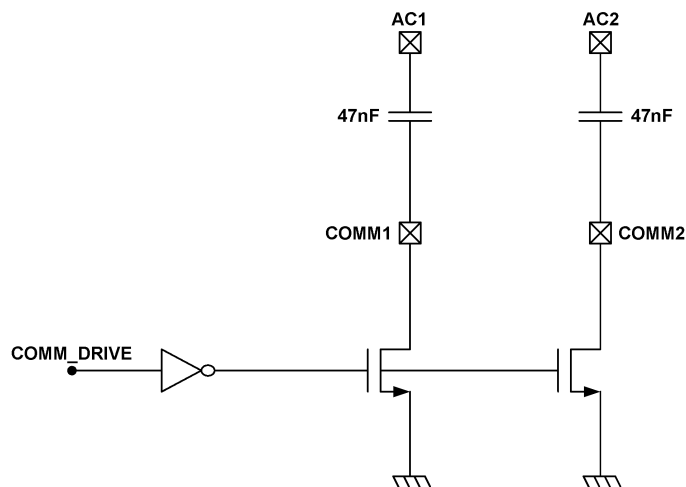


Figure 21. Capacitive Load Modulation

Synchronous Rectification

The bq5105x provides an integrated, self-driven synchronous rectifier that enables high-efficiency AC to DC power conversion. The rectifier consists of an all NMOS H-Bridge driver where the back gates of the diodes are configured to be the rectifier when the synchronous rectifier is disabled. During the initial startup of the WPC system the synchronous rectifier is not enabled. At this operating point, the DC rectifier voltage is provided by the diode rectifier. Once VRECT is greater than UVLO, half synchronous mode will be enabled until the load current surpasses 140 mA. Above 140 mA the full synchronous rectifier stays enabled until the load current drops back below 100 mA where half synchronous mode is enabled instead.

Internal Temperature Sense (TS)

The bq5105x includes a ratiometric battery temperature sense circuit. The temperature sense circuit has two ratiometric thresholds which represent a hot and cold condition. An external temperature sensor is recommended to provide safe operating conditions to the receiver product. This pin is best utilized when monitoring the surface that can be exposed to the end user.

The circuit in [Figure 22](#) allows for any NTC resistor to be used with the given V_{HOT} and V_{COLD} thresholds.

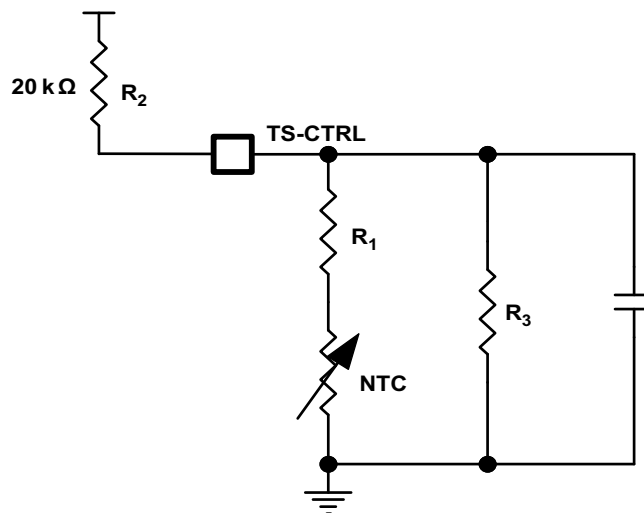


Figure 22. NTC Circuit used for Safe Operation of the Wireless Receiver Power Supply

The resistors R2 and R3 can be solved by resolving the system of equations at the desired temperature thresholds. The two equations are:

$$\%V_{\text{COLD}} = \frac{\left(\frac{R_3 R_{\text{NTC}}|_{\text{TCOLD}}}{R_3 + R_{\text{NTC}}|_{\text{TCOLD}}} \right)}{\left(\frac{R_3 R_{\text{NTC}}|_{\text{TCOLD}}}{R_3 + R_{\text{NTC}}|_{\text{TCOLD}}} \right) + R_2} \times 100 \quad (3)$$

$$\%V_{\text{HOT}} = \frac{\left(\frac{R_3 R_{\text{NTC}}|_{\text{THOT}}}{R_3 + R_{\text{NTC}}|_{\text{THOT}}} \right)}{\left(\frac{R_3 R_{\text{NTC}}|_{\text{THOT}}}{R_3 + R_{\text{NTC}}|_{\text{THOT}}} \right) + R_2} \times 100 \quad (4)$$

Where:

$$R_{\text{NTC}}|_{\text{TCOLD}} = R_0 e^{\beta \left(\frac{1}{\text{TCOLD}} - \frac{1}{T_0} \right)}$$

$$R_{\text{NTC}}|_{\text{THOT}} = R_0 e^{\beta \left(\frac{1}{\text{THOT}} - \frac{1}{T_0} \right)}$$

T_{COLD} and T_{HOT} are the desired temperature thresholds in degrees Kelvin. R_0 is the nominal resistance and β is the temperature coefficient of the NTC resistor. An example solution for part number ERT-JZEG103JA is:

$$R_2 = 7.81 \text{ k}\Omega$$

$$R_3 = 13.98 \text{ k}\Omega$$

Where,

$$T_{\text{COLD}} = 0^\circ\text{C}$$

$$T_{\text{HOT}} = 0^\circ\text{C}$$

$$\beta = 4500$$

$$R_0 = 10 \text{ k}\Omega$$

The plot of the percent V_{TSB} vs temperature is shown in Figure 23:

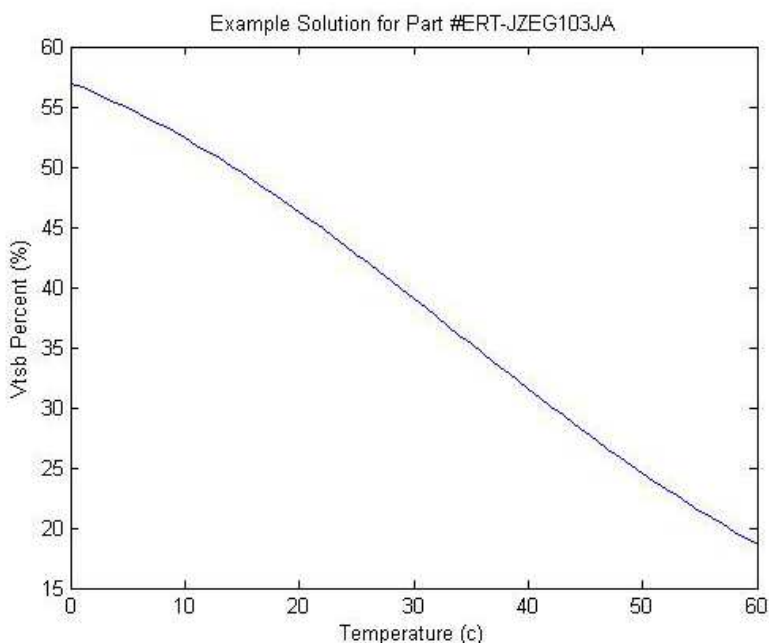


Figure 23. Example Solution for Panasonic Part # ERT-JZEG103JA

Figure 24 illustrates the periodic biasing scheme used for measuring the TS state. The TS_READ signal enables the TS bias voltage for 25 ms. During this period the TS comparators are read (each comparator has a 10 ms deglitch) and appropriate action is taken based on the temperature measurement. After this 25 ms period has elapsed the TS_READ signal goes low, which causes the TS-Bias pin to become high impedance. During the next 100 ms period the TS voltage is monitored and compared to 100 mV. If the TS voltage is greater than 100 mV then a secondary device is driving the TS/CTRL pin and a CTRL = '1' is detected.

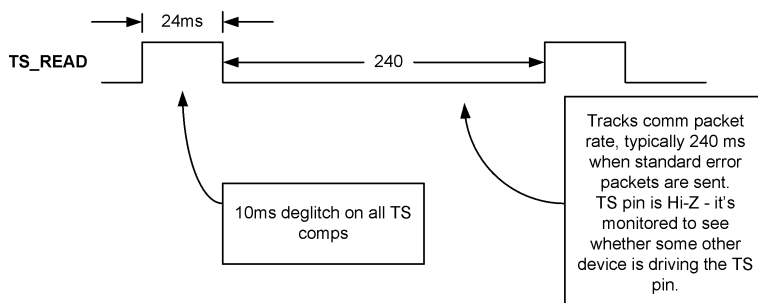


Figure 24. Timing Diagram for TS Detection Circuit

TS/CTRL Function:

The TS-CTRL pin offers three functions:

1. NTC temperature monitoring,
2. Charge done indication,
3. Fault indication

When NTC is connected between TS/CTRL pin and the GND, the NTC is function is allowed to operate. If the TS/CTRL pin is pulled to the battery voltage, the Rx is shutdown with the indication of a charge complete condition. If the TS-CTRL pin is pulled to GND, The Rx is shutdown with the indication of a fault.

Thermal Protection

The bq5105x includes a thermal shutdown protection. If the die temperature reaches TJ(OFF), the LDO is shut off to prevent any further power dissipation.

WPC 1.1 Compatibility

The bq5105x is a WPC 1.1 compatible device, In order to enable a Power Transmitter to monitor the power loss across the interface as one of the possible methods to limit the temperature rise of Foreign Objects, the bq51050B reports its Received Power to the Power Transmitter. The Received Power equals the power that is available from the output of the Power Receiver plus any power that is lost in producing that output power. For example, the power loss includes (but is not limited to) the power loss in the Secondary Coil and series resonant capacitor, the power loss in the Shielding of the Power Receiver, the power loss in the rectifier, the power loss in any post-regulation stage, and the eddy current loss in metal components or contacts within the Power Receiver. In WPC1.1 specification, foreign object detection (FOD) is enforced, that means the bq51050B will send received power information with known accuracy to the transmitter.

WPC 1.1 defines Received Power is “the average amount of power that the Power Receiver receives through its Interface Surface, in the time window indicated in the Configuration Packet”.

A Receiver will be certified as WPC 1.1 only after meeting following requirement The DUT (Device Under Test) is tested on a Reference Transmitter whose transmitted power is calibrated, the receiver must send a received power such that:

$$0 < (TX\ PWR)\ REF - (RX\ PWR\ out)\ DUT < 250mW$$

This 250mW bias ensures that system will remain interoperable.

WPC 1.1 Transmitter will be tested to see if they can detect reference Foreign Objects with a Reference receiver. WPC1.1 Specification will allow much more accurate sensing of Foreign Objects.

A Transmitter can be certified as a WPC 1.1 only after meeting the following requirement- A Transmitter is tested to see if it can prevent some reference Foreign Objects (disc, coin, foil) from exceeding their threshold temperature (60°C, 80°C).

Series and Parallel Resonant Capacitor Selection

Shown in [Figure 2](#), the capacitors C1 (series) and C2 (parallel) make up the dual resonant circuit with the receiver coil. These two capacitors must be sized correctly per the WPC v1.1 specification. [Figure 25](#) illustrates the equivalent circuit of the dual resonant circuit:

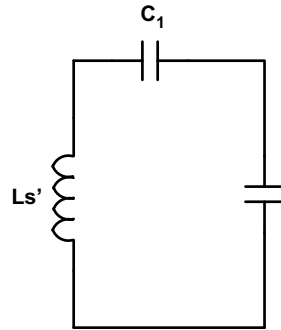


Figure 25. Dual Resonant Circuit with the Receiver Coil

Section 4.2 (Power Receiver Design Requirements) in volume 1 of the WPC v1.1 specification highlights in detail the sizing requirements. To summarize, the receiver designer will be required take inductance measurements with a fixed test fixture. The test fixture is shown in [Figure 26](#):

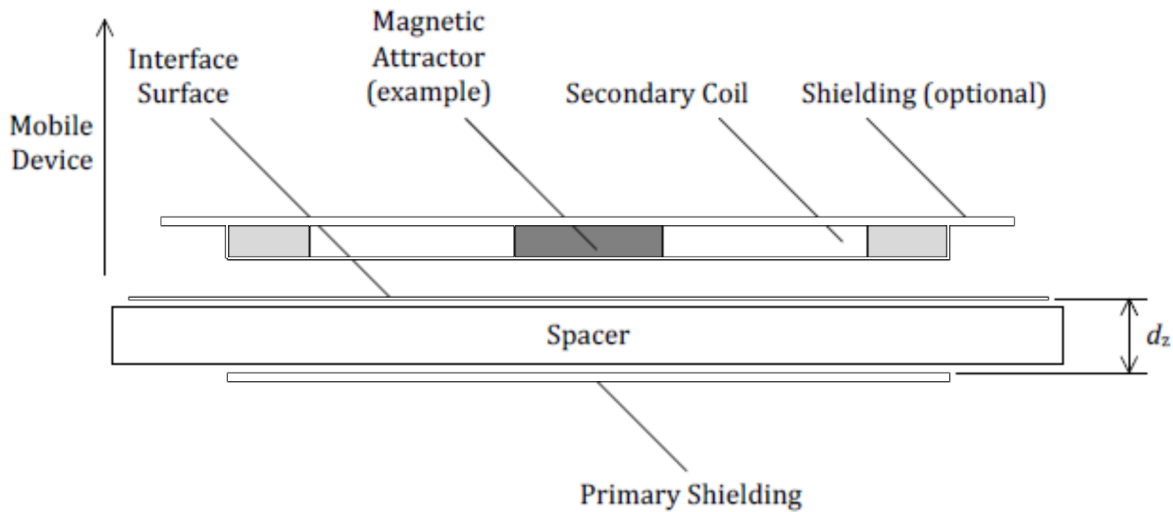


Figure 26. WPC v1.1 Receiver Coil Test Fixture for the Inductance Measurement L_s'

The primary shield is to be 50 mm x 50 mm x 1 mm of Ferrite material PC44 from TDK Corp. The gap d_z is to be 3.4 mm. The receiver coil, as it will be placed in the final system (e.g. the back cover and battery must be included if the system calls for this), is to be placed on top of this surface and the inductance is to be measured at 1-V RMS and a frequency of 100 kHz. This measurement is termed L_s' . This measurement is termed L_s or the free-space inductance. Each capacitor can then be calculated using [Equation 5](#):

$$C_1 = \frac{1}{(2\pi \times f_s)^2 \times L_s'}$$

$$C_2 = \frac{1}{(2\pi \times f_D)^2 \times \left(L_s - \frac{1}{C_1} \right)}$$
(5)

Where f_s is 100 kHz +5/–10% and f_D is 1 MHz ±10%. C_1 must be chosen first prior to calculating C_2 . The quality factor must be greater than 77 and can be determined by [Equation 6](#):

$$Q = \frac{2\pi \times f_D \times L_s}{R}$$
(6)

Where R is the DC resistance of the receiver coil. All other constants are defined above.

REVISION HISTORY

Changes from Original (August 2012) to Revision A	Page
• Changed bq51051B from product preview to production data	2
• Changed Regulated BAT(output) voltage	4
• Changed Recharge threshold	5
• Deleted $I_{TS-Bias-Max}$	5
• Changed V_{COLD} to V_{OC} and values	5
• Changed V_{45C} values	5
• Changed V_{60C} values	5
• Changed Figure 19	16
Changes from Revision A (August 2012) to Revision B	Page
• Changed last features bullet from: 1.9 x 3.0mm WCSP and 4.5 x 3.5mm QFN Package Options to: Available in small WCSP and QFN packages	1
• Changed Figure 1 and changed caption from: Wireless Power Consortium (WPC or Qi) Inductive Power Charging System, to: Typical System blocks shows bq5105xB used as a Wireless Power Li-Ion/Li-Pol Battery Charger	1
• Added note: Visit ti.com/wirelesspower for product details and design resources	1
Changes from Revision B (September 2012) to Revision C	Page
• First release of the full data sheet	1

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
BQ51050BRHLR	ACTIVE	QFN	RHL	20	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR		BQ51050B	Samples
BQ51050BRHLT	ACTIVE	QFN	RHL	20	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR		BQ51050B	Samples
BQ51050BYFPR	ACTIVE	DSBGA	YFP	28	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM		BQ51050B	Samples
BQ51050BYFPT	ACTIVE	DSBGA	YFP	28	250	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM		BQ51050B	Samples
BQ51051BRHLR	ACTIVE	QFN	RHL	20	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR		BQ51051B	Samples
BQ51051BRHLT	ACTIVE	QFN	RHL	20	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR		BQ51051B	Samples
BQ51051BYFPR	ACTIVE	DSBGA	YFP	28	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM		BQ51051B	Samples
BQ51051BYFPT	ACTIVE	DSBGA	YFP	28	250	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM		BQ51051B	Samples

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

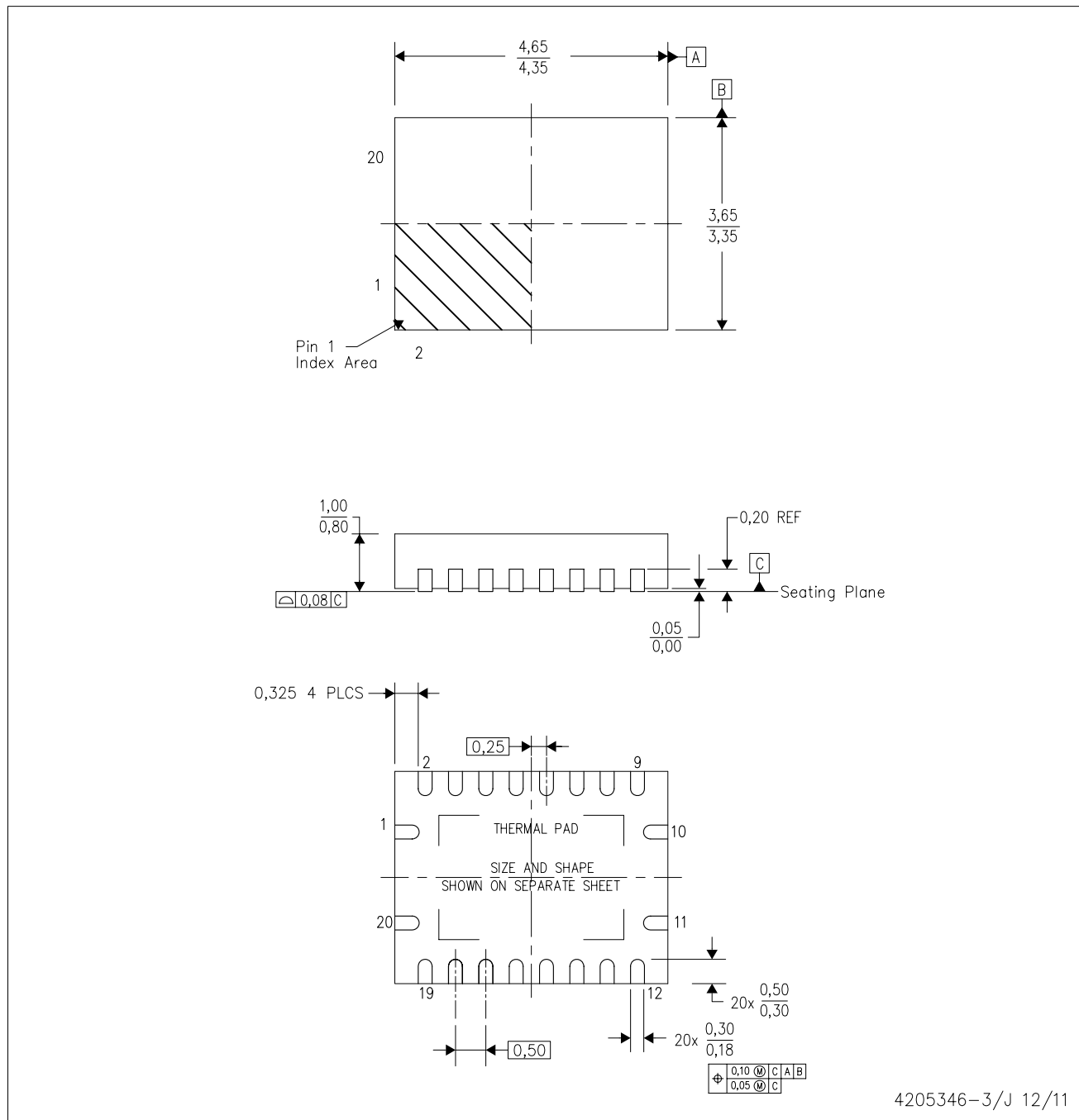
⁽⁴⁾ Only one of markings shown within the brackets will appear on the physical device.

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RHL (R-PVQFN-N20)

PLASTIC QUAD FLATPACK NO-LEAD



4205346-3/J 12/11

- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - This drawing is subject to change without notice.
 - QFN (Quad Flatpack No-Lead) Package configuration.
 - The package thermal pad must be soldered to the board for thermal and mechanical performance.
 - See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.

RHL (S-PVQFN-N20)

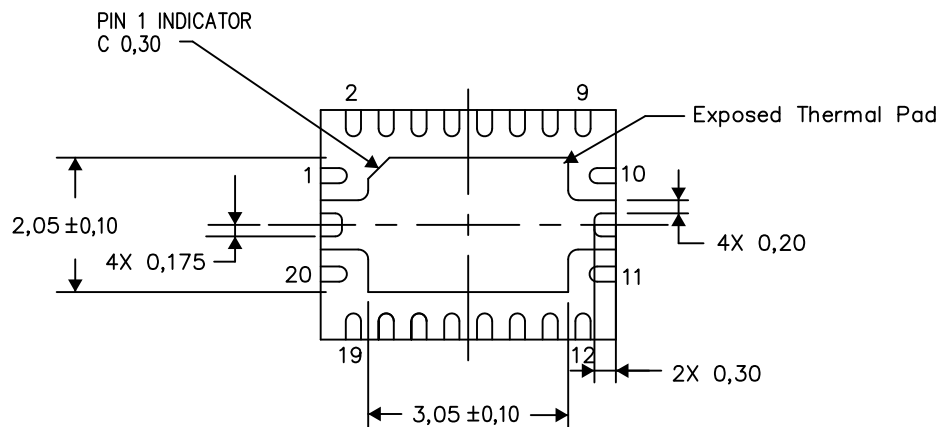
PLASTIC QUAD FLATPACK NO-LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



Bottom View

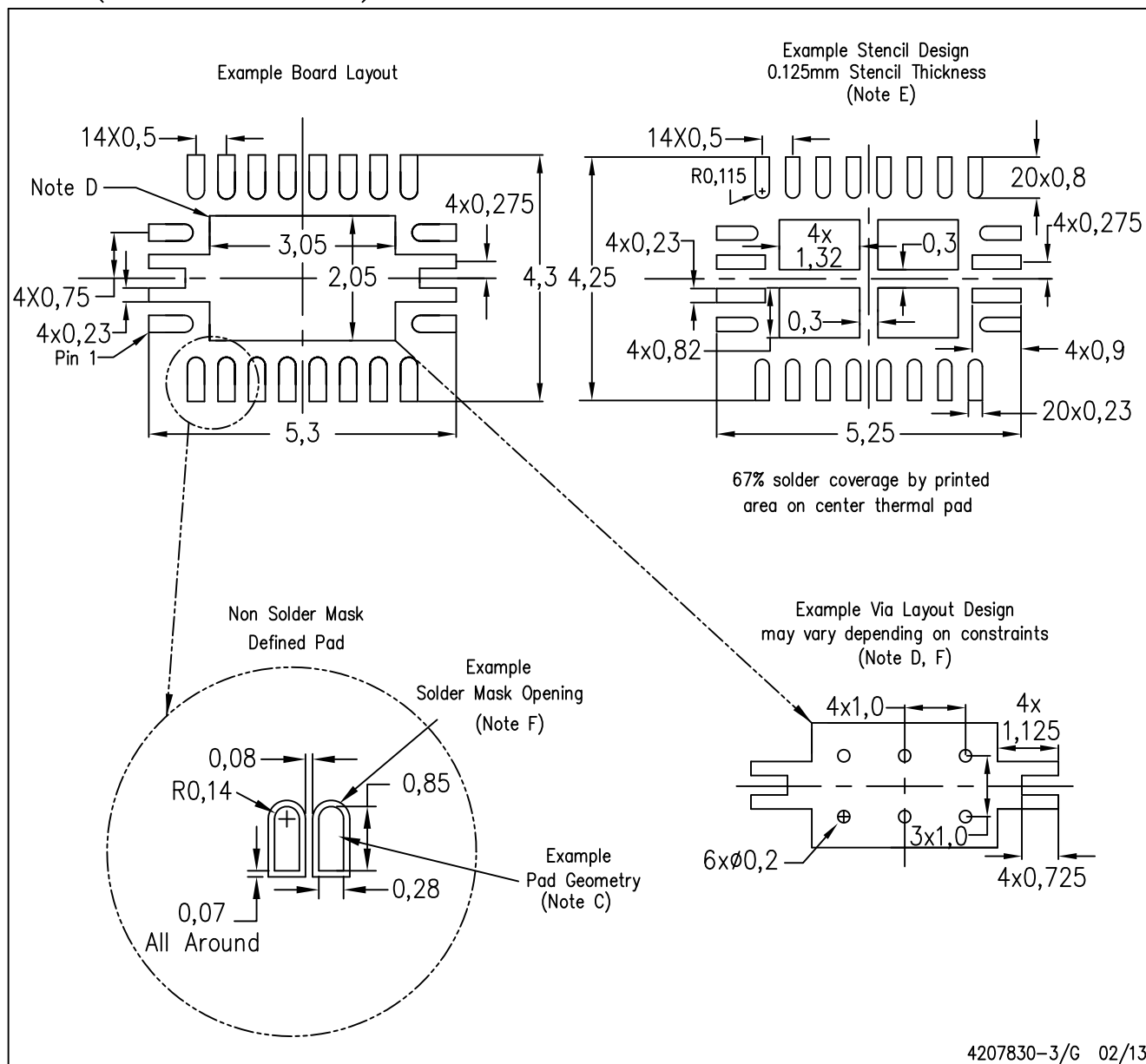
Exposed Thermal Pad Dimensions

4206363-3/M 08/12

NOTE: All linear dimensions are in millimeters

RHL (R-PVQFN-N20)

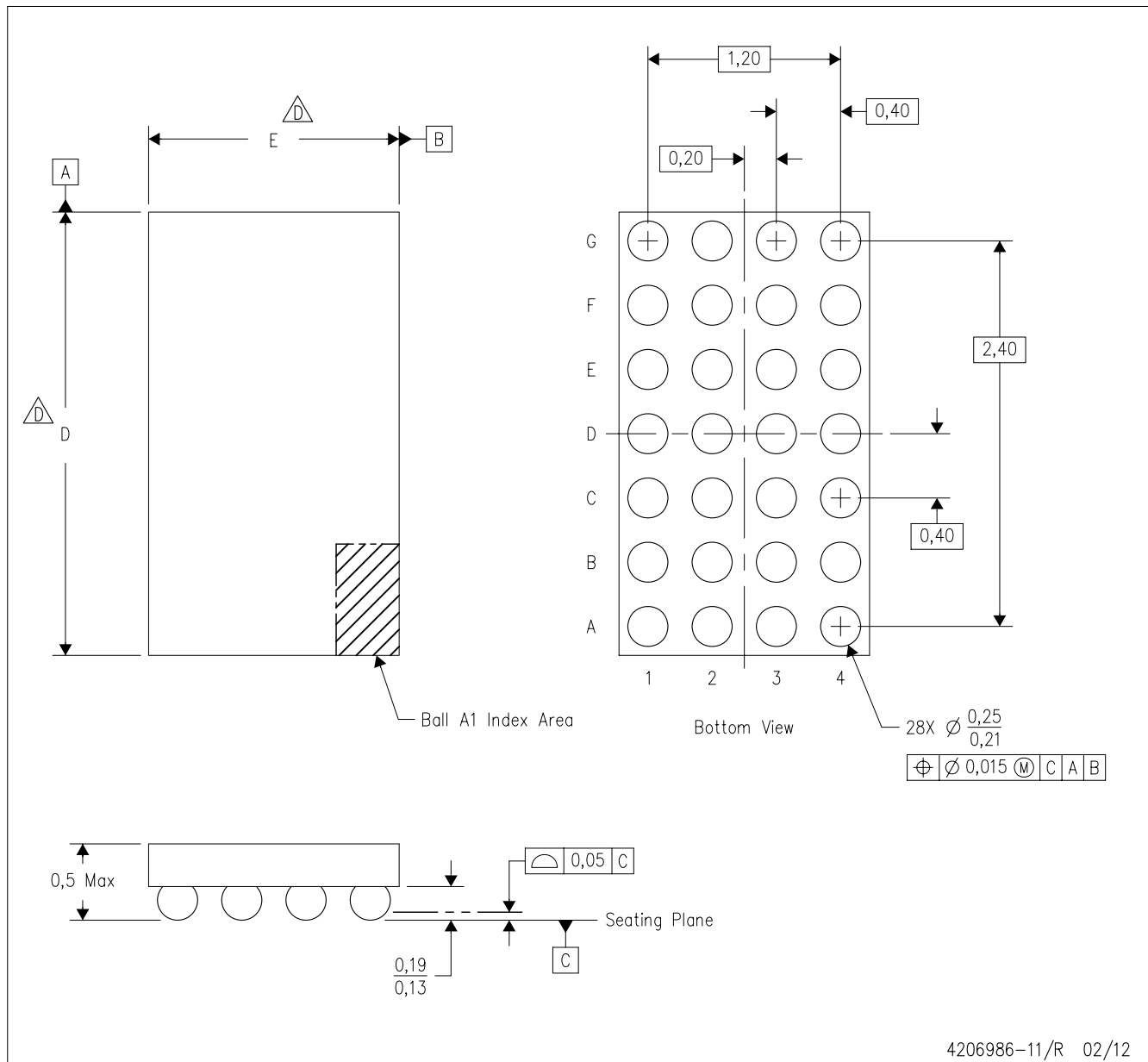
PLASTIC QUAD FLATPACK NO-LEAD



- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Publication IPC-7351 is recommended for alternate designs.
 - This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat-Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <<http://www.ti.com>>.
 - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
 - Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.

YFP (R-XBGA-N28)

DIE-SIZE BALL GRID ARRAY



- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - This drawing is subject to change without notice.
 - NanoFree™ package configuration.
 - To determine the exact package size of a particular device, refer to the device datasheet or contact a local TI representative.
 - This package contains Pb-free balls.

NanoFree is a trademark of Texas Instruments

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