Dual Mode (WPC) 5W Wireless Power Receiver and Battery Charger

General Description

The RT1652 is a wireless power receiver compliant with WPC Low Power v1.2 standard. The RT1652 integrates a synchronous full-bridge rectifier, a low dropout regulator, and a logic controller for control and communication. The device receives AC power from a WPC compatible wireless transmitter and provides output power up to 5W, which could be used as a power supply for a charger of mobile or consumer devices. The RT1652 output can also connect to Li+ battery directly, the direct charge mode features on running battery charger profile (PreCharge/CC/CV), to simplify the charging function design and improve the overall charging efficiency.

The logic controller can support bi-direction channel communication including amplitude shift keying (ASK) modulation for power signal to the transmitter. The RT1652 provides Foreign Object Detection (FOD) function to meet the requirement after WPC V1.2. It communicates with the transmitter for the received power to determine if a foreign object is present within the magnetic interface. This provides a higher level of safety.

The RT1652 provides a programmable dynamic rectifier voltage control function to improve power efficiency, a programmable power management control for maximum power delivery, a programmable current limit for suitable load setting, a programmable temperature setting with external NTC for thermoregulation, and proper protection functions such as UVLO, OVP, and OTP.

Applications

- Cell Phones, Smart Phones, and Headsets
- Wireless Power Embedded Battery Packs
- Portable Media Players
- Hand-held Devices
- Wearable Devices

Features

- **Wireless Power Receiver Compliant**
  - **WPC qi V1.3**
- **Battery Charger**
  - **Programmable 3V to 12V Out Regulation Voltage**
- **Integrated Synchronous Rectifier Switch**
  - **Support Output Power Up to 5W**
  - **High Rectifier Efficiency Up to 96%**
  - **High System Efficiency Up to 80%**
  - **Programmable Loading for Synchronous Rectifier Operation**
- **Programmable Dynamic Rectifier Voltage Control for Optimized Transient Response and Power Efficiency**
- **Highly Accurate Received Power Calculation for FOD Function**
  - **12-bit ADC for Voltage/Current Measurement**
  - **Coil Power Loss Modeling for Optimized Compensation**
  - **Adaptive Power Offset Compensation**
- **Embedded Logic Controller**
  - **272B MTP for Programmable**
- **Support Bi-direction Channel Communication**
  - **ASK Modulation for Power Signal to Wireless Power Transmitter**
- **Programmable Temperature Control**
- **Programmable Charge Status Packet (0x05)**
- **Support Alignment with Transmitter**
- **Support Enable, Charge Complete and Fault Control Inputs**
- **Receiver Controlled EPT Packet**
- **Over-Current Limit**
- **Over-Voltage Protection**
- **Thermal Shutdown**
- **CSP 2.8mm x 2.6mm 36B (Pitch = 0.4mm)**
- **Low Profile (0.5mm Max.)**

Ordering Information

RT1652□

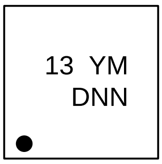
Package Type
WSC : WL-CSP-36B 2.8x2.6 (BSC)

Note :

Richtek products are :

- RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- Suitable for use in SnPb or Pb-free soldering processes.

Marking Information



13 : Product Code
YMDNN : Date Code

Pin Configuration

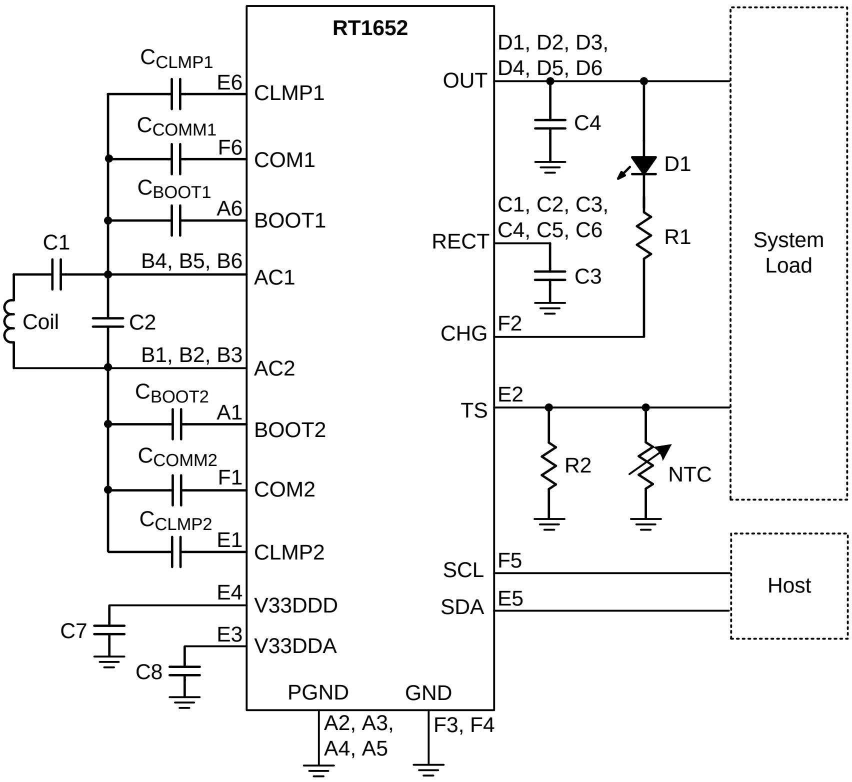
(TOP VIEW)

A1 BOOT2	A2 PGND	A3 PGND	A4 PGND	A5 PGND	A6 BOOT1
B1 AC2	B2 AC2	B3 AC2	B4 AC1	B5 AC1	B6 AC1
C1 RECT	C2 RECT	C3 RECT	C4 RECT	C5 RECT	C6 RECT
D1 OUT	D2 OUT	D3 OUT	D4 OUT	D5 OUT	D6 OUT
E1 CLMP2	E2 TS	E3 V33DDA	E4 V33DDD	E5 SDA	E6 CLMP1
F1 COM2	F2 CHG	F3 VSSA	F4 VSSD	F5 SCL	F6 COM1

WL-CSP-36B 2.8x2.6 (BSC)

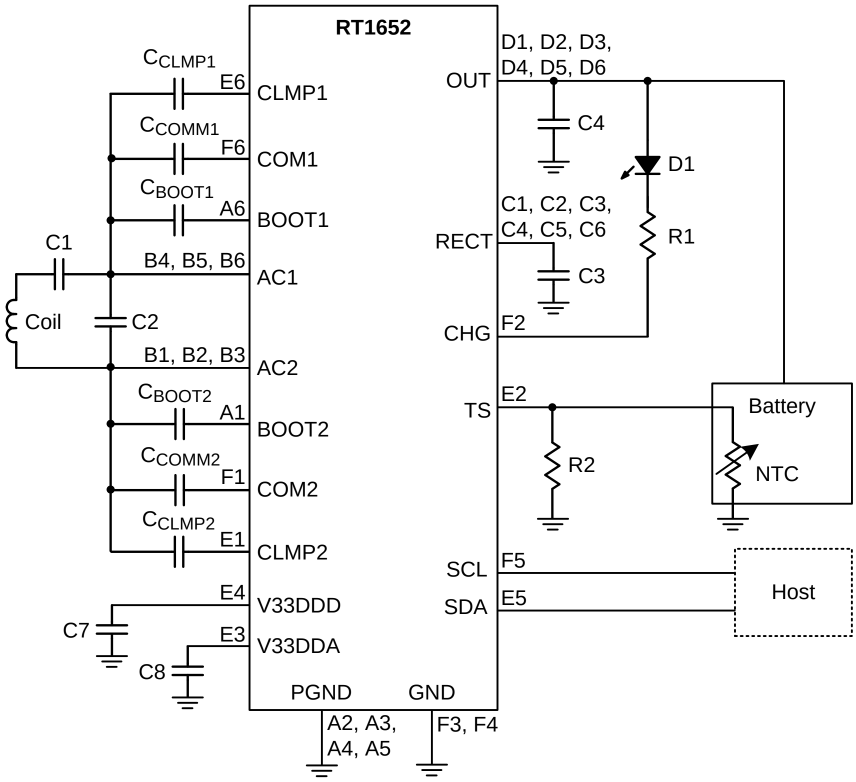
Typical Application Circuit I

(Used as a Wireless Power Receiver for System Loads)



Typical Application Circuit II

(Used as a Wireless Power Receiver for Battery Charger)

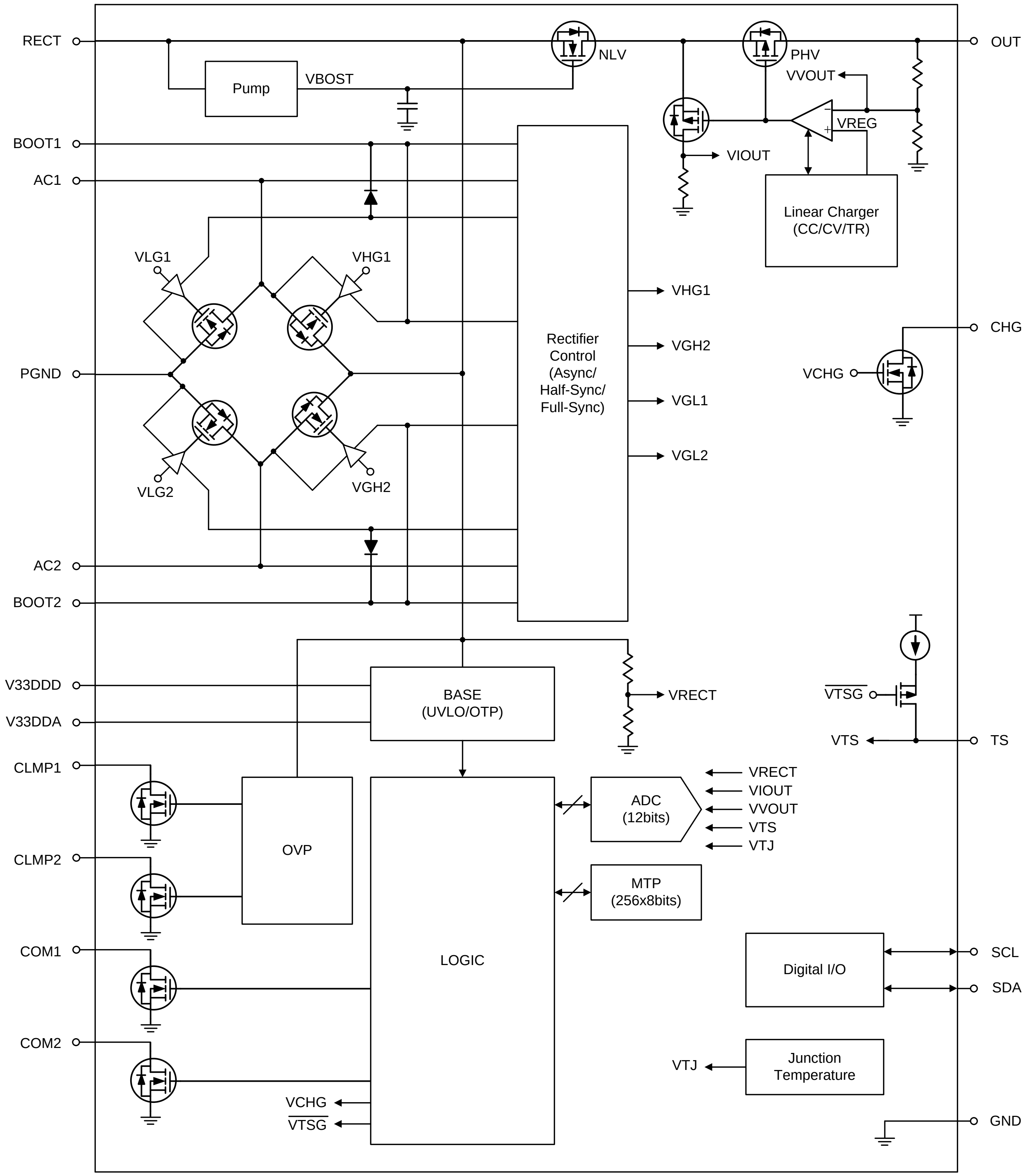


Functional Pin Description

Pin No.	Pin Name	I/O	Pin Function
B4 to B6	AC1	I	AC power input from receiver coil.
B1 to B3	AC2	I	
A6	BOOT1	O	Bootstrap supply for driving the high-side FETs of synchronous rectifier. Connect a 10nF ceramic capacitor from BOOT1 to AC1 and from BOOT2 to AC2.
A1	BOOT2	O	
C1 to C6	RECT	O	Output of synchronous rectifier. Connect a ceramic capacitor (10μF to 22μF) between this pin to PGND.
D1 to D6	OUT	O	Power output of regulator.
F6	COM1	O	Open-drain output for communication with transmitter. Connect through a capacitor to AC1/AC2 for capacitive load modulation.
F1	COM2	O	
E6	CLMP1	O	Open-drain output for over-voltage clamp protection. Connect a 0.47μF ceramic capacitor between this pin to AC1/AC2. When the RECT voltage exceeds 11.5V, both switches will be turned on and the capacitors will act as a low impedance to protect the IC from damage.
E1	CLMP2	O	
A2 to A5	PGND		Power ground.

Pin No.	Pin Name	I/O	Pin Function
E2	TS	I	Temperature sense input. Connect a NTC between this pin and GND for temperature sensing. If the temperature sensing function is desired, connect a 10kΩ resistor to GND. Host side can control this pin to send end power transfer (EPT) to the transmitter: pull-low for EPT fault; pull-up for EPT termination.
F2	CHG	O	Open-drain indicator output. When the output regulator is enabled, this pin is pulled to low.
F5	SCL	I	I^2C compatible series-clock input for internal register/MTP access.
E5	SDA	I/O	I^2C compatible series-data input/output for internal register/MTP access.
E4	V33DDD	O	Voltage supply for internal circuit. Connect a 1μF ceramic capacitor between this pin and GND.
E3	V33DDA	O	Voltage supply for internal circuit. Connect a 1μF ceramic capacitor between this pin and GND.
F3	VSSA	GND	Analog ground.
F4	VSSD	GND	Digital ground.

Functional Block Diagram



Operation

Digital Controller Circuit

To flexibly control whole functions, this chip embedded a MTP (Multiple Time Programmable) memory to save various setting and parameters. The external host can real-time read some power information via I^2C interface.

OVP (Over-Voltage Protection)

The OVP function using to protect the abnormal power signal to let the RT1652 damaged. Once the VRECT exceeds 14.5V, this block will drive the CLAMP MOS to avoid the over voltage damage.

OTP (Over-Temperature Protection)

The OTP function shuts down the linear regulator operation when the junction temperature exceeds 150°C. Once the junction temperature cools down by around 20°C, the receiver will automatically resume operating.

Synchronous Rectifier Control

This block detect the zero-cross of the AC1 and AC2 voltage then control the high-side and low-side MOS of the rectifier. The RT1652 provide the Asynchronous, Half-synchronous and Full-synchronous control to optimize the rectifier efficiency.

Packet Control

This block build up the WPC standard 2kHz bi-phase encoding scheme with the asynchronous serial format and the packet structure. This block control the open-drain MOS to achieve the ASK (Amplitude Shift Key) communication.

Absolute Maximum Ratings (Note 1)

- Supply Input Voltage, OUT, CHG ---------- –0.3V to 20V
- Supply Input Voltage, AC1, AC2, RECT, COM1, COM2, CLMP1, CLMP2 (Note 6) ---------- –0.3V to 23V
- Supply Input Voltage, BOOT1, BOOT2 ---------- –0.3V to 26V
- Other Pins ---------- –0.3V to 6V
- Input Current, AC1, AC2 ---------- 2A (rms)
- Output Current, OUT ---------- 2A
- Output Sink Current, CHG ---------- 15mA
- Output Sink Current, COM1, COM2 ---------- 1A
- Power Dissipation, P_D @ T_A = 25°C
  WL-CSP-36B 2.8x2.6 (BSC) ---------- 3.33W
- Package Thermal Resistance (Note 2)
  WL-CSP-36B 2.8x2.6 (BSC), θ_{JA} ---------- 30°C/W
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Junction Temperature ---------- 150°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Model) ---------- 2kV

Recommended Operating Conditions (Note 4)

- Supply Input Voltage Range, RECT ---------- 2.7V to 14.5V
- Input Current, RECT ---------- 1.5A
- Output Current, OUT ---------- 1.5A
- Sink Current, COM ---------- 500mA
- Ambient Temperature Range ---------- –40°C to 85°C
- Junction Temperature Range ---------- –40°C to 125°C

Electrical Characteristics

(T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input						
RECT Under-Voltage Lockout Threshold	V_{RECT_UVLO}	V_{RECT} rising : 0V → 3V	2.6	2.7	2.8	V
RECT UVLO Hysteresis		V_{RECT} falling : 3V → 0V	190	250	310	mV
RECT Over-Voltage Threshold	V_{RECT_OVP}	V_{RECT} rising : 13.5V → 15.5V	14	14.5	15	V
RECT Over-Voltage Hysteresis		V_{RECT} falling : 15.5V → 13.5V	100	150	200	mV
Dynamic V_{RECT} Setting-1	V_{RECT_SET1}	(VRECT_SET1 = 8'hC8) (Note 5)	--	2	--	V

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Dynamic V_{RECT} Setting-2	V_{RECT_SET2}	(VRECT_SET2 = 8'h96) (Note 5)	--	1.5	--	V
Dynamic V_{RECT} Setting-3	V_{RECT_SET3}	(VRECT_SET3 = 8'h32) (Note 5)	--	0.5	--	V
Dynamic V_{RECT} Setting-4	V_{RECT_SET4}	(VRECT_SET4 = 8'h1E) (Note 5)	--	0.3	--	V
I_{OUT} Hysteresis for Dynamic V_{RECT} Settings	$I_{OUT\_TH\_HYS}$	Output current < 400mA	--	20	--	mA
		Output current > 400mA	--	5	--	%
RECT Quiescent Current	I_Q		2	3	4	mA
Regulator Output						
OUT Regulation Voltage	V_{OUT_REG}	I_{OUT} = 1mA	4.95	5	5.05	V
		I_{OUT} = 1A	4.94	4.99	5.04	
		I_{OUT} = 1.5A	4.90	4.96	5.02	
Regulator Drop-out Voltage	V_{DROP}	V_{RECT} – V_{OUT}, I_{OUT} = 1A	50	100	150	mV
Output Current Limit	I_{OUT_LIMIT}	Programmable (Note 5)	0.1	--	2	A
Output Current Limit Tolerance		I_{OUT} =1.5A (Note 5)	–10	--	10	%
OUT Leakage Current	I_{OUT_LKG}	V_{OUT} disabled	--	--	1	μA
Synchronous Rectifier						
Programmable I_{OUT} Threshold Range to Enable Half-Synchronous Rectifier	I_{SR_TH}	I_{OUT} rising (Note 5)	50	--	500	mA
Programmable I_{OUT} Threshold Range to Enable Full-Synchronous Rectifier		I_{OUT} rising (Note 5)	150	--	750	
Programmable I_{OUT} Hysteresis Range		I_{OUT} falling (Note 5)	25	--	100	
Rectifier Diode Voltage in Asynchronous Mode	V_{DIODE}	$I_{AC\text{-}VRECT}$ = 250mA	0.5	0.65	0.8	V
TS Sense/Control Input						
TS Thermoregulation Threshold	V_{TS_REG}	V_{TS} falling (TS_th = 8'h192) (Note 5)	--	474	--	mV
Too-Hot Protection Threshold	V_{TS_HOT}	V_{TS} falling (TS_hot = 8'h8E) (Note 5)	--	277	--	mV
Too-Cold Protection Threshold	V_{TS_COLD}	V_{TS} rising (TS_hot = 12'h3A4) (Note 5)	--	1.98	--	V
TS Output Current	I_{TS}		--	60	--	μA
Over-Temperature Protection						
Over-Temperature Protection Threshold	T_J	(Note 5)	--	150	--	°C
Over-Temperature Protection Hysteresis		(Note 5)	--	20	--	

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
CHG Indicator Output						
CHG Low-Level Output Voltage	V_{CHG_L}	I_{SINK} = 5mA	--	--	100	mV
CHG Leakage Current When Disabled	I_{CHG_LKG}	V_{CHG} = 20V	--	--	1	μA
COM Outputs						
COM1, COM2 N-FET On-Resistance	R_{ON_COM}	V_{RECT} = 2.6V	0.6	0.9	1.2	Ω
COM1, COM2 Signaling Frequency	f_{COM}	(Note 5)	1.92	2	2.08	kHz
COM1, COM2 Leakage Current	I_{COM_LKG}	V_{COM1} = V_{COM2} = 20V	--	--	1	μA
CLAMP Outputs						
CLMP1, CLMP2 N-FET On-Resistance	R_{ON_CLM}		0.5	0.75	1	Ω
Received Power (WPC Related Measurements)						
Received Power Accuracy	P_{RX_AC}	I_{OUT} = 0A to 1A (Note 5)	--	--	0.25	W
I^2C Compatible Interface (Note5)						
Logic Input (SDA, SCL) Low Level	V_{SCL_L}		--	--	0.6	V
Logic Input (SDA, SCL) High Level	V_{SCL_H}		1.2	--	--	V
SCL Clock Frequency	f_{CLK}		10	--	400	kHz
Output Fall Time	$t_{FL2COUT}$		--	--	250	ns
Bus Free Time Between Stop/Start	t_{BUF}		1.3	--	--	μs
Hold Time Start Condition	t_{HD_STA}		0.6	--	--	μs
Setup Time for Start Condition	t_{SU_STA}		0.6	--	--	μs
SCL Low Time	t_{LOW}		1.3	--	--	μs
SCL High Time	t_{HIGH}		0.6	--	--	μs
Data Setup Time	t_{SU_DAT}		100	--	--	ns
Data Hold Time	t_{HD_DAT}		0	--	900	ns
Setup Time for Stop Condition	t_{SU_STO}		0.6	--	--	μs

Note 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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Note 2. θ_{JA} is measured under natural convection (still air) at T_A = 25°C with the component mounted on a high effective-thermal-conductivity four-layer test board on a JEDEC 51-7 thermal measurement standard.

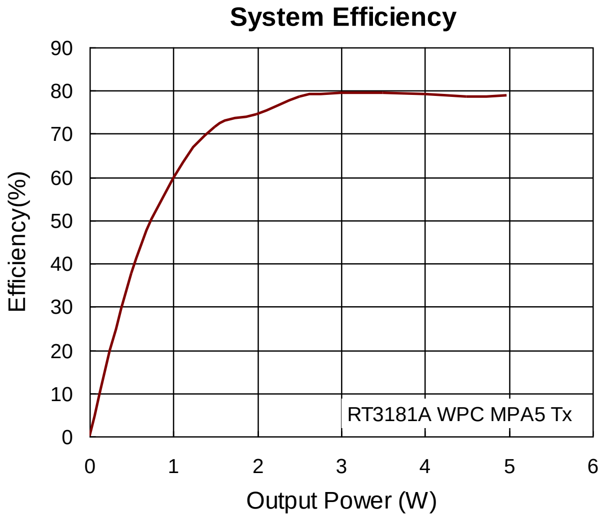
Note 3. Devices are ESD sensitive. Handling precautions are recommended.

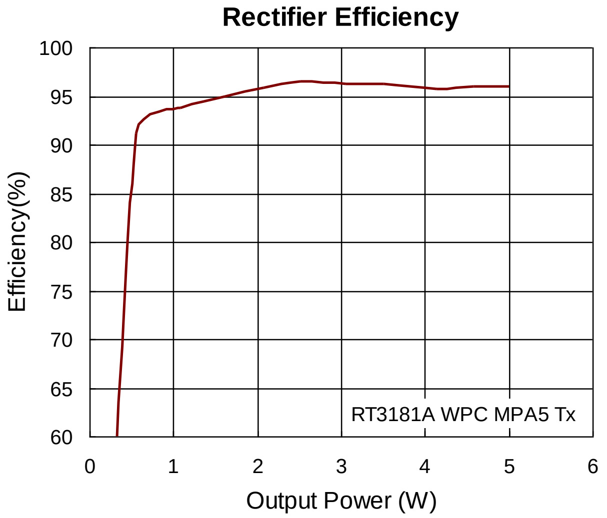
Note 4. The device is not guaranteed to function outside its operating conditions.

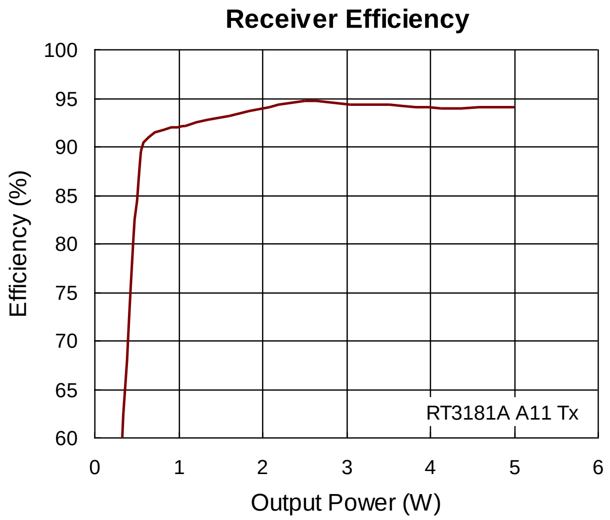
Note 5. Specification is guaranteed by design and/or correlation with statistical process control.

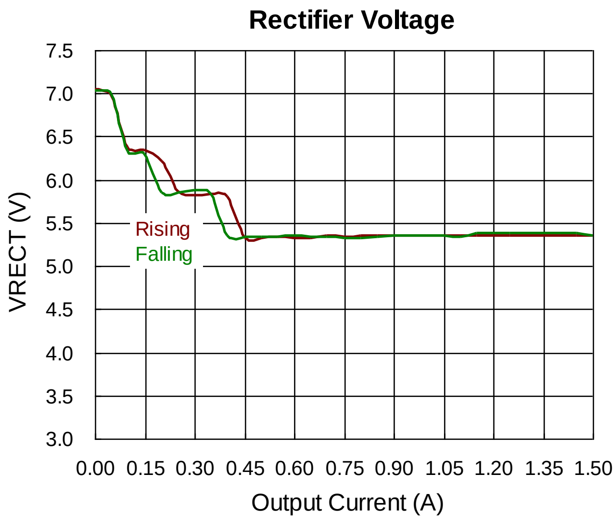
Note 6. These test items are tested by pulse condition. The pulse patent which is 10% of duty cycle and 10ms width

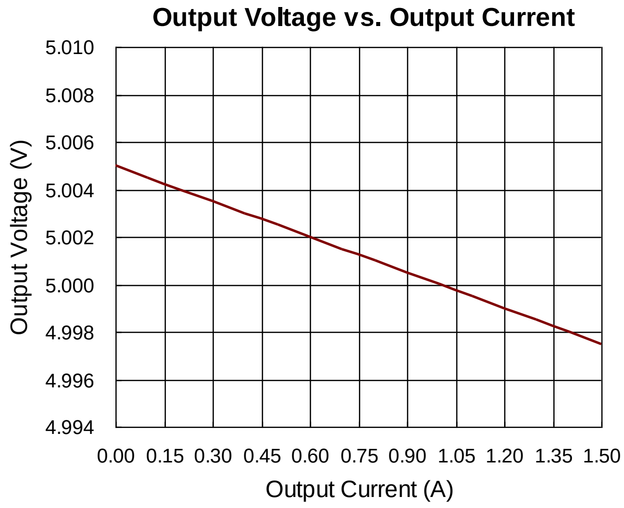
Typical Operating Characteristics

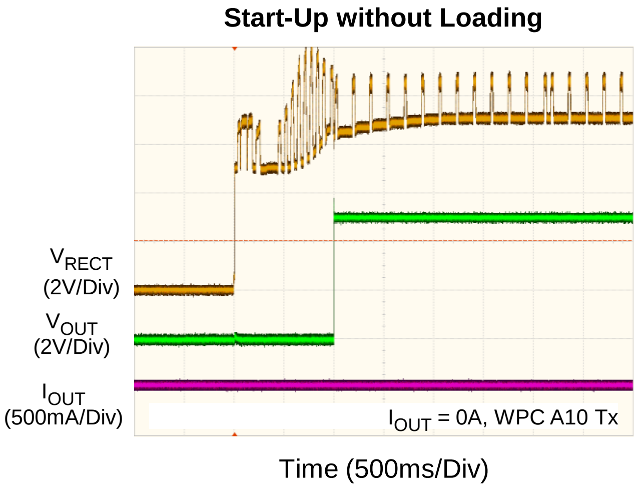




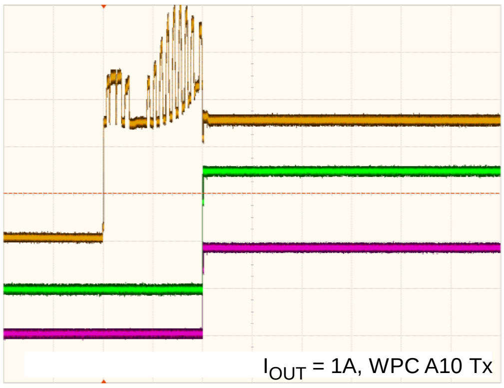






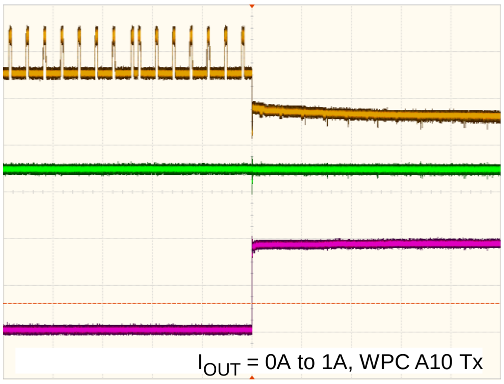


Start-Up with Loading



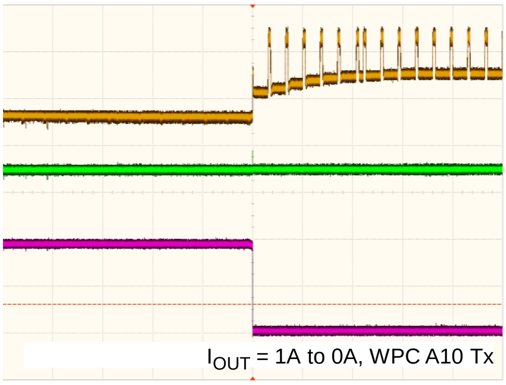
Time (500ms/Div)

Load Transient Response



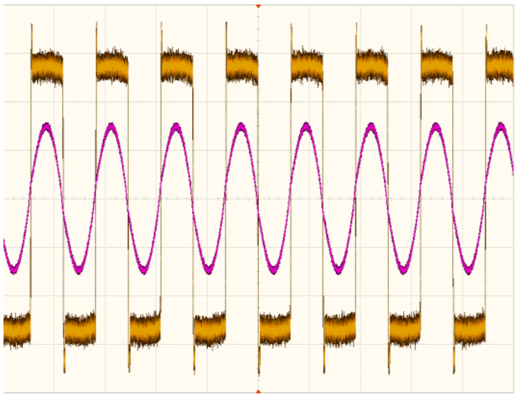
Time (500ms/Div)

Load Transient Response



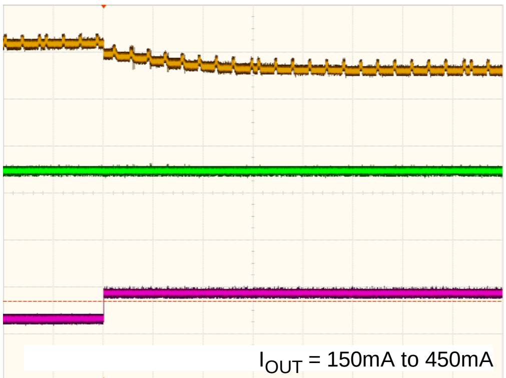
Time (500ms/Div)

Synchronous Rectifier



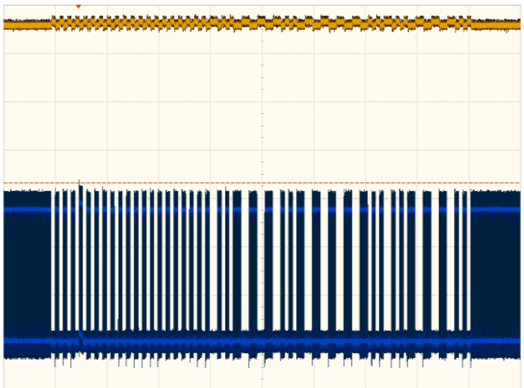
Time (5μs/Div)

Dynamic Rectifier Voltage



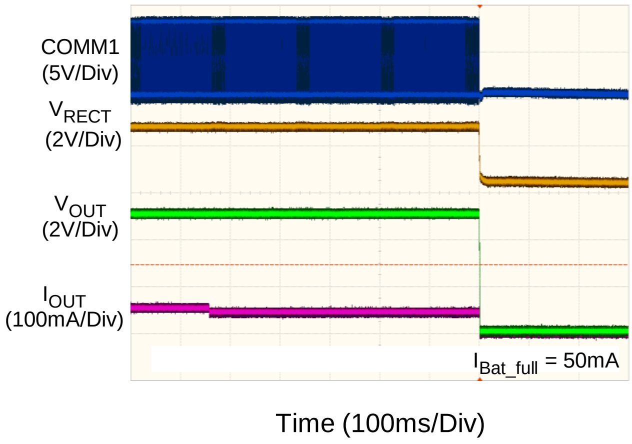
Time (500ms/Div)

Communication



Time (3.29ms/Div)

Battery Full Detection



Functional Description

Richtek's component specification does not include the following information in the Application Information section. Thereby no warranty is given regarding its validity and accuracy. Customers should take responsibility to verify their own designs and to ensure the functional suitability of their components and systems.

Description of the Wireless Power System

A wireless power system is composed by a power transmitter with one or more primary coils and a power receiver in a mobile system. Power transmitter will transfer power via a DC-to-AC inverter to drive a strong-coupled inductor to power receiver in a mobile device.

The power transferred to power receiver is controlled by itself. The power receiver sends communication packets with control error voltage information to the power transmitter for power tracking. The bit rate of the communication link from receiver to transmitter is 2kbps.

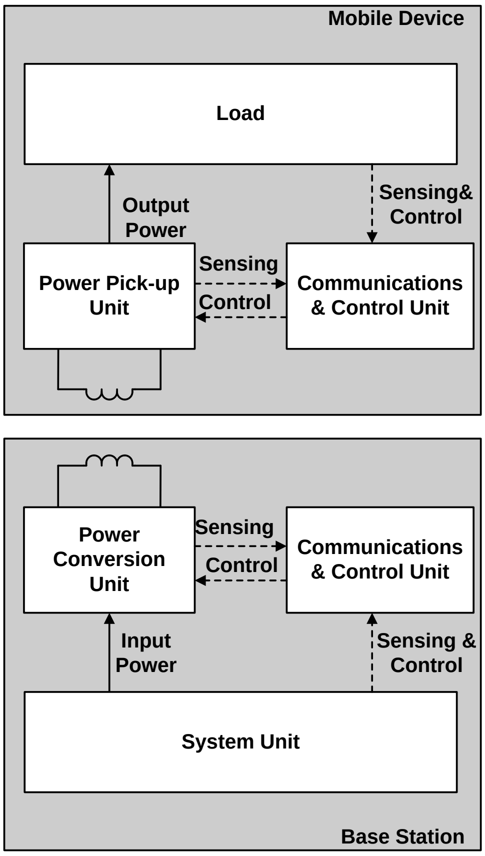


Figure 1. Wireless Power System

Start-Up

When the receiver is placed on the power pad, the receiver coil is inductively coupled to the magnetic flux generated by the coil in the power 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. The RT1652 communicates to the transmitter by switching on and off the COM FETs.

Power Transfer Phases

There are 4 power transfer phases for the WPC V1.2.

- Selection : As soon as the Power Transmitter applies a Power Signal, the Power Receiver shall enter the selection phase.
- Ping : The power Receiver should send the Digital Ping Packet to power Transmitter then into next phase. If not, the system shall revert to the Selection phase. The power Receiver also can send the End Power transfer Packet to stop the power Transmitter.
- Identification & Configuration : In this phase, the Power Receiver identifies the revision of the System Description Wireless Power Transfer the Power Receiver complies and configuration information such as the maximum power that the Power Receiver intends to provide at its output. The Power Transmitter uses this information to create a Power Transfer Contract.
- Power Transfer : In this phase, the Power Transmitter continues to provide power to the Power Receiver. The power Receiver sends the Control Error Packet for adjusting the Primary Cell current. The Power Transmitter stops to provide power when the Received Power Packet is too low to trigger the FOD function or End Power Transfer Packet is sent from power Receiver.

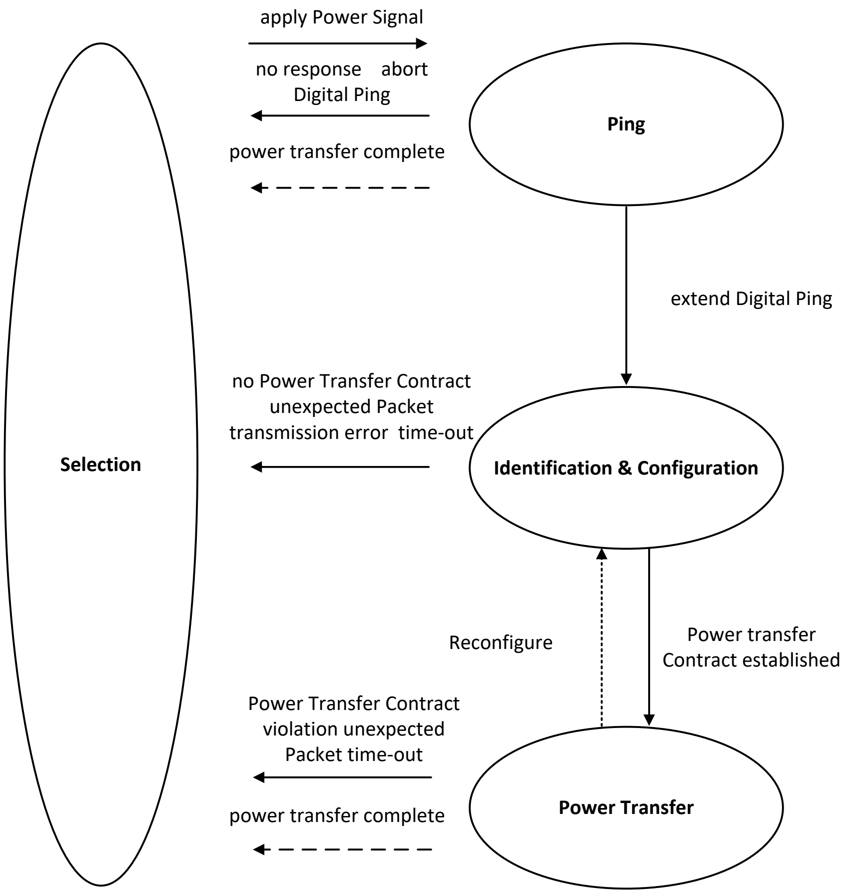


Figure 2. WPC V1.2 Low Power Transfer Phases

Micro Controller Unit

Peripheral

There are 2 peripheral blocks in RT1652, MTP and peripheral registers. MTP (Multiple Time Programmable Memory) is primarily used to save non-volatile user setting data and part of MTP store internal factory setting. User firmware can control some of chip hardware behavior via peripheral registers. It also could be an interface to communicate with external I^2C via the registers.

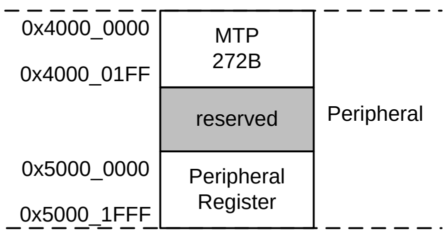


Figure 3. Memory Map

Programmable Dynamic Rectifier Voltage Control

The RT1652 provides a programmable Dynamic Rectifier Voltage Control function to optimize the transient response and power efficiency for applications. Table 1 and Figure 4 show an example to summarize how the rectifier behavior is dynamically adjusted based the registers V_{RECT_SETx} [7:0] (x = 1 to 4), which are available to be programmed by users.

Table 1. Dynamic Rectifier Voltage Setting

Output Current, I_{OUT}	Rectifier Voltage Target
< I_{OUT_TH1}	V_{RECT_SET1}
I_{OUT_TH1} to I_{OUT_TH2}	V_{RECT_SET2}
I_{OUT_TH2} to I_{OUT_TH3}	V_{RECT_SET3}
> I_{OUT_TH3}	V_{RECT_SET4}

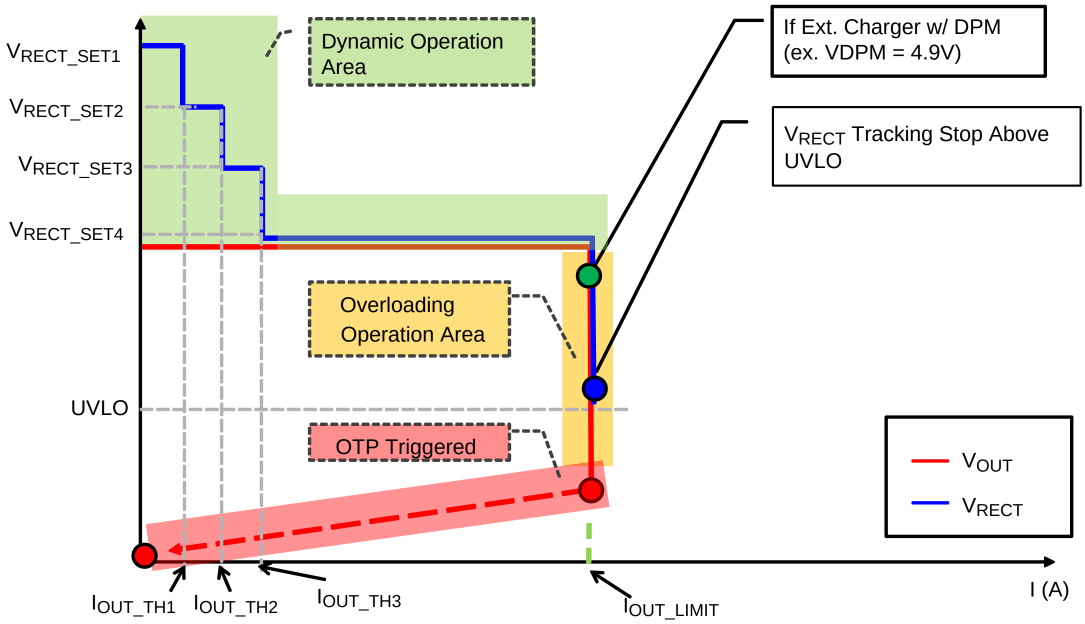


Figure 4. Dynamic Rectifier Voltage vs. Output Current

Thermal Management

The RT1652 provides an external device thermal management function with an external NTC thermistor and a resistor connected between TS pin and GND pin shown as Figure 5. User can use this function to control the temperature of the coil, battery or other device. An internal current source (60μA) is provided to the external NTC thermistor and generates a voltage at the TS pin. The TS voltage is detected and sent to the ADC converter for external device thermal manage control.

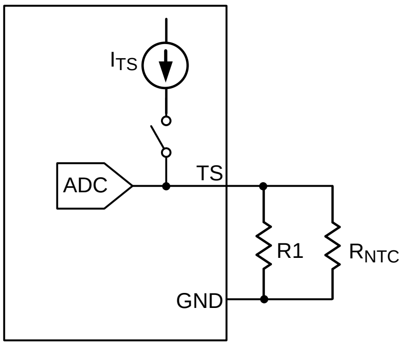


Figure 5. NTC Circuit for Device Temperature Detection and Thermoregulation

The thermal management function is shown as Figure 6. If the temperature is higher than Hot_temp or lower than Cold_temp threshold, the RT1652 will send the EPT to disable the power transfer. When the detected temperature increases and reaches the desired Regulation_temp, RT1652 will decrease the current limit to reduce the output current to regulate the temperature. When the detected temperature is lower than the Regulation_temp, the current limit will increase to the default value. This function is shown as Figure 7.

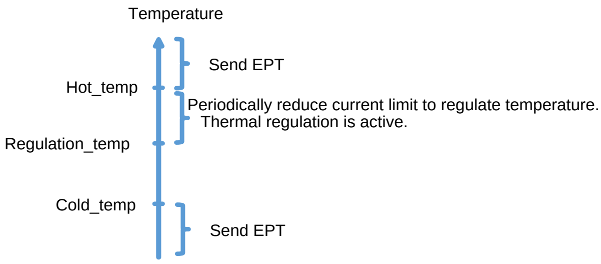


Figure 6. Thermal Management Function

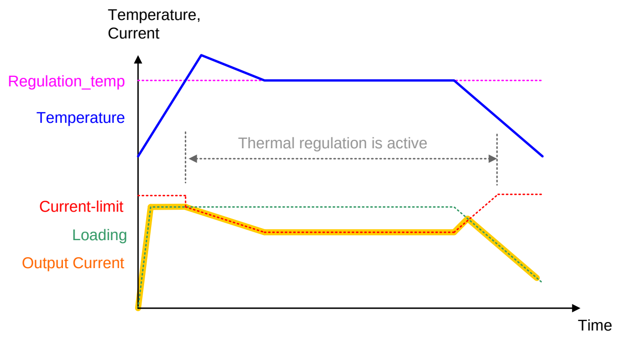


Figure 7. Thermoregulation Control

The NTC thermistor should be placed as close as possible to the device such as battery or mobile device. The recommended NTC thermistor is NCP15WF104F03RC (tolerance ±1%, β = 4250k). The typical resistance of the NTC is 100kΩ at 25°C. The recommended resistance for R_1 is 33kΩ (±1%).The value of the NTC thermistor at the desired temperature can be estimated by the following equation.

$$R_{NTC\_Reg} = R_O e^{\beta\left(\frac{1}{T_{Reg}} - \frac{1}{T_0}\right)}$$

$$R_{eg} = \frac{R_1 \times R_{NTC\_Reg}}{R_1 + R_{NTC\_Reg}}$$

where T_{Reg} is the desired regulation temperature in degree Kelvin. R_O is the nominal resistance at temperature T_0 and β is the temperature coefficient of the NTC thermistor. Req is the equivalent resistor of NTC thermistor in parallel with R_1.

Figure 8 shows the equivalent resistance of the thermistor in parallel with R_1 resistor varies with operating temperature. Figure 9 shows the VTS voltage with operating temperature. Customer can select the desire temperature and calculate the mapping data by the following equation.

Data = (VST/2 x 1024)

If the thermal management function is not used (R_{NTC} = open), the resistor R1 = 24kΩ must be connected between the TS and GND pins. (or disable TS function in MTP)

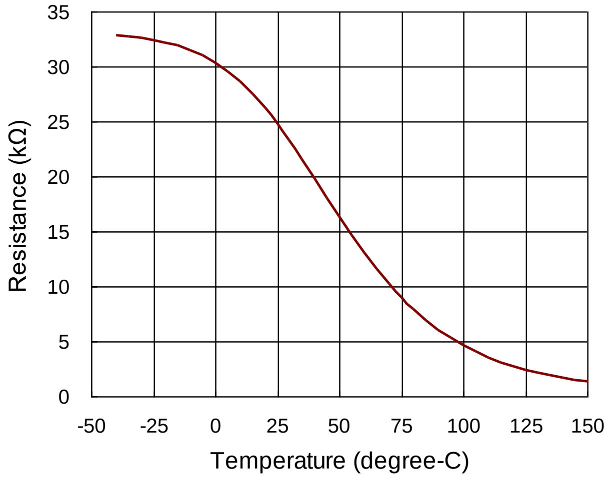


Figure 8. Equivalent Resistance for Temperature Sensing

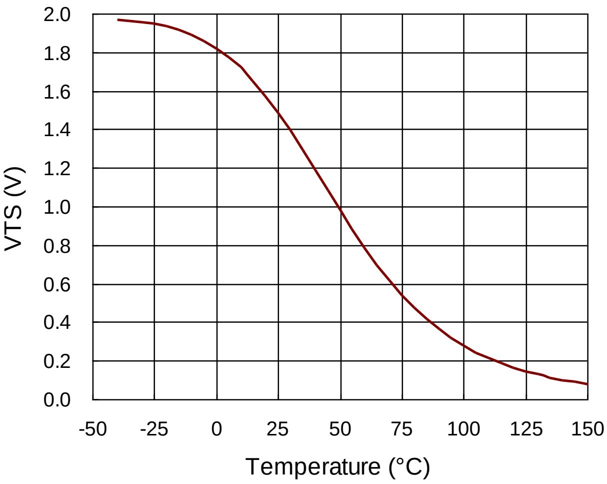


Figure 9. Thermal Sensing Voltage

Communication

The RT1652 supports two communication modulations, Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), to communicate with the power transmitter. For ASK modulation, the RT1652 provides two integrated communication N-FETs which are connected to the COM1 and COM2 pins. These N-FETs are used for modulating the secondary load current which allows the RT1652 to communicate Control Error and configuration information to the transmitter. Figure 10 shows the RT1652 operating with capacitive load modulation. When the N-FETs are turned-on, there is effectively a capacitor connected between AC1 and AC2. The impedance seen by the coil will be reflected in the primary as a change in current.

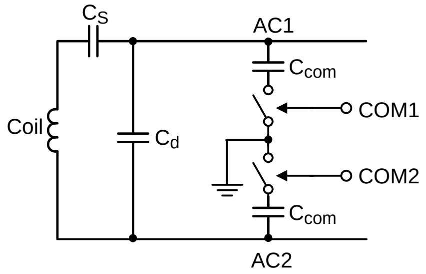


Figure 10. Capacitive Load Modulation

Bit Encoding Scheme

According to WPC protocol, the RT1652 uses a differential bi-phase encoding scheme to modulate data bits onto the Power Signal. The internal clock signal has a frequency 2kHz. The Receiver shall encode a ONE bit using two transitions in the Power Signal, such that the first transition coincides with the rising edge of the clock signal, and the second transition coincides with the falling edge of the clock signal. The Receiver shall encode a ZERO bit using a single transition in the Power Signal, which coincides with the rising edge of the clock signal. Figure 11 shows an example of the differential bi-phase encoding.

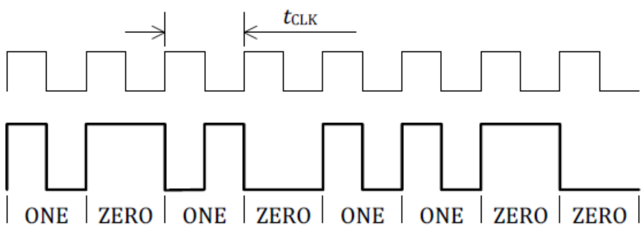


Figure 11. Example of the Differential Bi-phase Encoding

End Power Transfer Packet (WPC Header 0x02)

The End Power Transfer (EPT) packet is a special command for the RT1652 to request the transmitter to terminate power transfer. Table 2 specifies the reasons coulomb and their responding data field value. The condition column corresponds to the values sent by the RT1652 for a given reason.

Table 2. End Power Transfer (EPT) packet

Reason	Value	Condition
Under-Temperature	0x00	V_{TS} > V_{TS_COLD} or from I²C
Charge Complete	0x01	Charge done in battery mode
Over-Temperature	0x03	V_{TS} < V_{TS_HOT} or T_J > 150°C

I²C Interface

The RT1652 provides I²C interface to communicate with external host device. Besides OTP firmware programming and MTP setting programming can be approached through the I²C interface, the external host can also communicate with the RT1652 to achieve more flexible applications. For example, the host can read the ADC information via the I²C Interface. In addition, the I²C is used to read the internal status and the power source is from the VRECT. If the wireless function disable or in the adapter mode, the I²C can't be accessed. Table 3 shows the register definition. It's not fixed, the registers definition can be costumed by firmware. If user need to read other information via I²C, please discuss with RICHTEK firmware engineer.

I²C Slave

0100100X (in binary format)

0x49 / 0x48 (hex format, include R/W bit)

MSB							LSB
0	1	0	0	1	0	0	R/W

Table 3. RT1652 Register Definition

Address	MSB	LSB	Name	Description
0xD3 and 0xD7[1:0]	9	0	V_{RECT}	V_{RECT} (4V to 12V), unit = 19.0735mV
0xD4 and 0xD7[3:2]	9	0	I_{OUT}	I_{OUT} (0A to 1A), unit = 2mA
0xD5 and 0xD7[5:4]	9	0	V_{OUT}	V_{OUT} (4V to 12V), unit = 19.0735mV
0xD6 and 0xD7[7:6]	9	0	V_{TS}	V_{TS} (0V to 2V), unit = 2mV
0xD8	7	0	Control error packet	Depend on configuration setting
0xD9	7	0	Received power	Unit : 39.0625mW
0xDA and 0xDB[1:0]	9	0	V_{TJ}	Unit : 0.42deg.
Battery Charger Setting				
0x0A	7	0	V_{RECT} setting for short and pre-charge status	Unit : 38.15mV
0x10	7	0	Short circuit protection threshold voltage	Unit : 38.15mV
0x19	7	0	Current limit for pre-charge status	Unit : 8mA
0x11	7	0	Pre-charge threshold voltage	Unit : 38.15mV
0x1A	7	0	Current limit for short circuit status	Unit : 8mA
0x0B	7	0	V_{RECT} setting for constant current mode	Unit : 38.15mV
0x17	7	0	Current limit for constant current mode status	Unit : 8mA
0x16	7	0	Full battery voltage setting	Unit : 48mV
0x0C	7	0	V_{RECT} setting for full battery mode	Unit : 38.15mV
0x12	7	0	Termination current setting	Unit : 8mA

Indicator Output

An open-drain output pin, CHG, is provided to indicate the status of wireless power receiver. The CHG pin can be connected to a LED for charge status indicator. When the output of the RT1652 is enabled, the open-drain N-FET at CHG pin will be pulled to low level.

Input Over-Voltage Protection

When the input voltage increases suddenly, the RT1652 adjusts voltage-control loop to maintain regulator output voltage and sends control error packets to the transmitter every 30ms until the input voltage comes back to the V_{RECT} target level (refer to Dynamic Rectifier Voltage Control Section). Once the V_{RECT} voltage exceeds its over-voltage threshold (11.5V typ.), the RT1652 turns on the N-FETs at CLMP1 and CLMP2 pins to shunt the input current through external capacitors. By the way the CLAMP function may affect the communication signal to let the Tx re-start up.

Over-Temperature Protection

The RT1652 provides an Over-Temperature Protection (OTP) feature to prevent excessive power dissipation from overheating the device. The OTP function shuts down the linear regulator operation when the junction temperature exceeds 150°C. Once the junction temperature cools down by around 20°C, the receiver will automatically resume operating.

Foreign Object Detection

The RT1652 is a WPC 1.1.1 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 RT1652 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 (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). In WPC1.1.1 specification, Foreign Object Detection (FOD) is enforced. This means the RT1652 will received power information with known accuracy to the transmitter. The received power is sensed as the Figure 12.

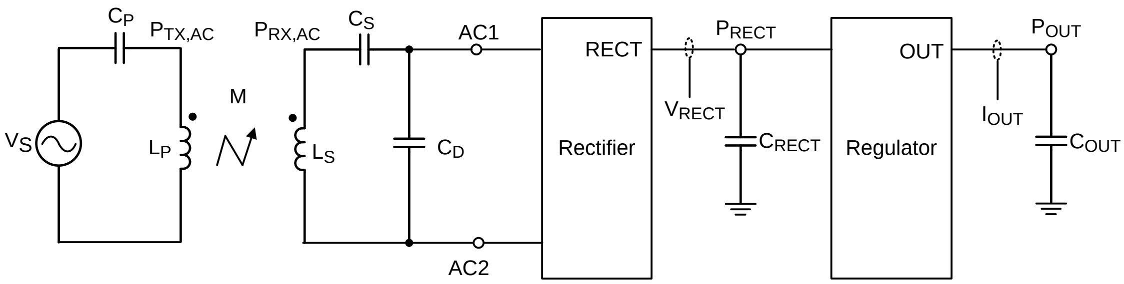


Figure 12. Received Power Sensed

Battery Charger Setting and Description

The RT1652 is linear-mode battery charger for portable application. It integrates current regulation and voltage regulation for every charging status. The charging status include short, pre-charging, constant current, constant voltage and end of charging mode.

Section I (Short protection, Short) : If battery voltage is lower than threshold of short voltage (depend on user setting. 0x10), then the current limit (depend on user setting. 0x1A) is set to short protection level automatically.

Section II (Pre-charge function, Pre-charge) : If battery voltage is lower than threshold of pre-charge (depend on user setting. 0x11), then the current limit (depend on user setting. 0x19) is set to pre-charging current level automatically.

Section III (Constant current mode, CC) : If battery voltage is higher than threshold of pre-charge (depend on user setting. 0x11), then the current limit (depend on user setting. 0x17) is set to constant current mode level automatically.

Section IV (Constant voltage mode, CV) : Full battery voltage setting (depend on user setting. 0x16)

Section V (End of charge mode, EOC) : RT1652 will sent end of power if battery current is lower than termination current.

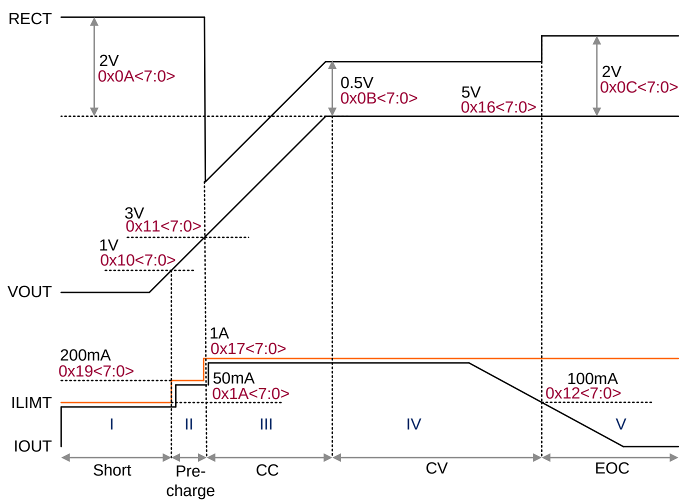


Figure 13. Battery Charge Behavior

Battery Charge Complete Detection

The RT1652 supports battery charge complete detection function. A programmable charge complete current threshold and a programmable charge complete delay time are provided. This function can be used to send the Charge Status packet (0x05) to the transmitter for indicating a full charged status 100%. Note that this packet does not turn off the transmitter. The charge complete current threshold is adjustable from 0mA to 255mA and the default value is 50mA. The charge complete time is also adjustable from 0 seconds to 2550 seconds and the default value is 180 seconds.

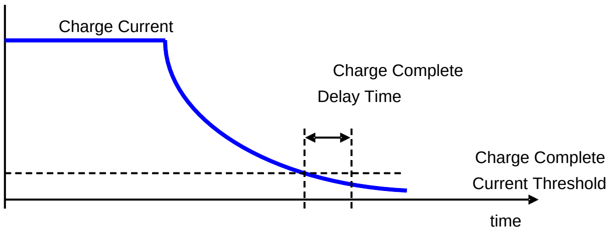


Figure 14. Battery Charge Complete Detection

There are 3 operation modes when the charge complete status is detected. The first mode is to send a CS packet (0x05) to transmitter only. The CS packet does not turn off the transmitter. In the second mode, the RT1652 will send a CS packet (0x05) and an EPT packet to transmitter. In the third mode, the RT1652 will send a CS packet (0x05) and stop communication with the transmitter.

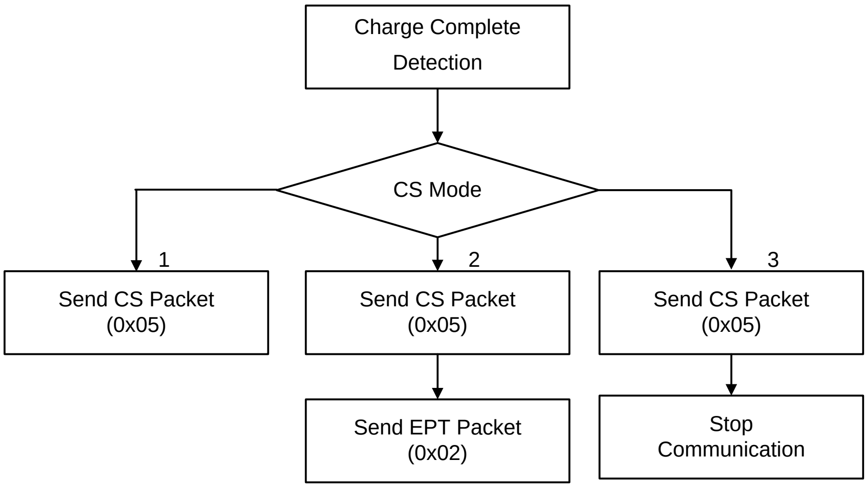


Figure 15. Operation Modes of Charge Complete Detection

Receiver Coil and Resonant Capacitors

According to WPC specification, the dual resonant circuit of the power receiver comprises the receiver coil and capacitors C1 and C2. The receiver coil design is related to system design. Coil shape, material, inductance and shielding need to be considered. Shielding provides protection from interference between wireless power system and mobile electronic device. The recommended coil self-inductance is between 8μH to 13μH. The capacitance of the resonant capacitors can be calculated by the following equations.

$$C1 = \frac{1}{L'_S \times (2\pi f_S)^2}$$

$$C2 = \frac{1}{L_S \times (2\pi f_d)^2 - \frac{1}{C1}}$$

In these equations, fs is resonant frequency with typical value 100kHz; and fd is another resonant frequency with typical value 1000kHz. L's is coil self-inductance when placed on the interface surface of a transmitter; and L_S is the self-inductance when placed away from the transmitter.

Firmware Setting

Please refer to another document for detailed description of firmware setting.

Thermal Considerations

The junction temperature should never exceed the absolute maximum junction temperature $T_{J(MAX)}$, listed under Absolute Maximum Ratings, to avoid permanent damage to the device. The maximum allowable power dissipation depends on the thermal resistance of the IC package, the PCB layout, the rate of surrounding airflow, and the difference between the junction and ambient temperatures. The maximum power dissipation can be calculated using the following formula :

$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$

where $T_{J(MAX)}$ is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction-to-ambient thermal resistance.

For continuous operation, the maximum operating junction temperature indicated under Recommended Operating Conditions is 125°C. The junction-to-ambient thermal resistance, θ_{JA}, is highly package dependent. For a WL-CSP-36B 2.8x2.6 (BSC) package, the thermal resistance, θ_{JA}, is 30°C/W on a standard JEDEC 51-7 high effective-thermal-conductivity four-layer test board. The maximum power dissipation at T_A = 25°C can be calculated as below :

$P_{D(MAX)}$ = (125°C − 25°C) / (30°C/W) = 3.33W for a WL-CSP-36B 2.8x2.6 (BSC) package.

The maximum power dissipation depends on the operating ambient temperature for the fixed $T_{J(MAX)}$ and the thermal resistance, θ_{JA}. The derating curves in Figure 16 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

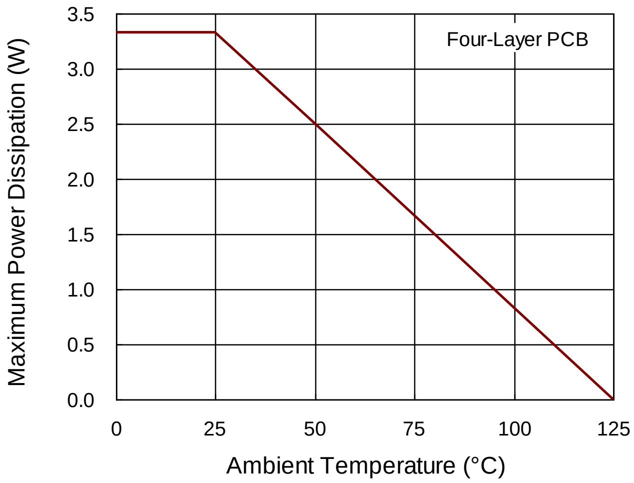


Figure 16. Derating Curve of Maximum Power Dissipation

Layout Considerations

Follow the PCB layout guidelines for optimal performance of the IC.

- Keep the traces of main current paths as short and wide as possible.
- Place the capacitors as close as possible to the IC.
- Power ground should be as large as possible and connected to a power plane for thermal dissipation.

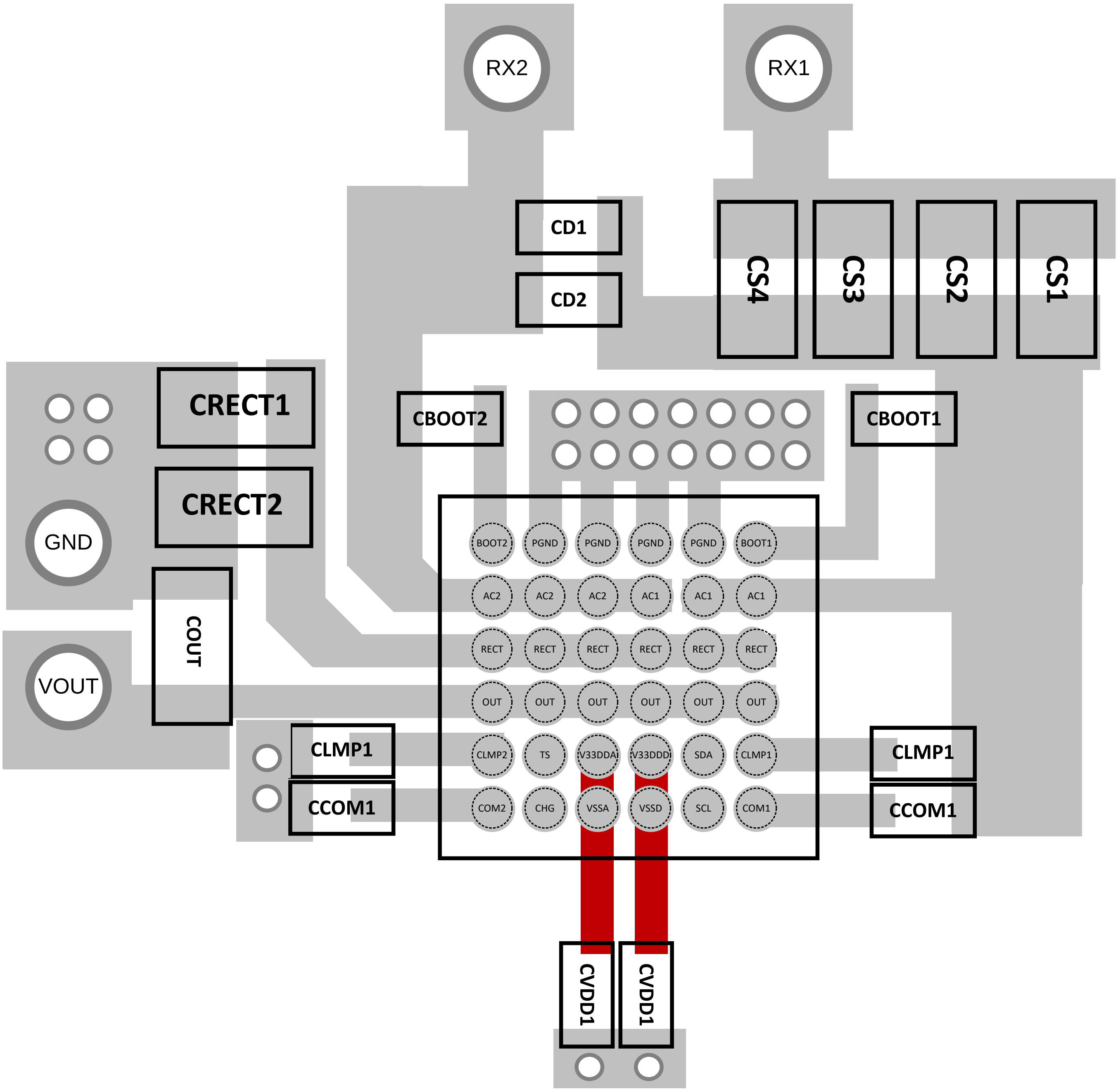
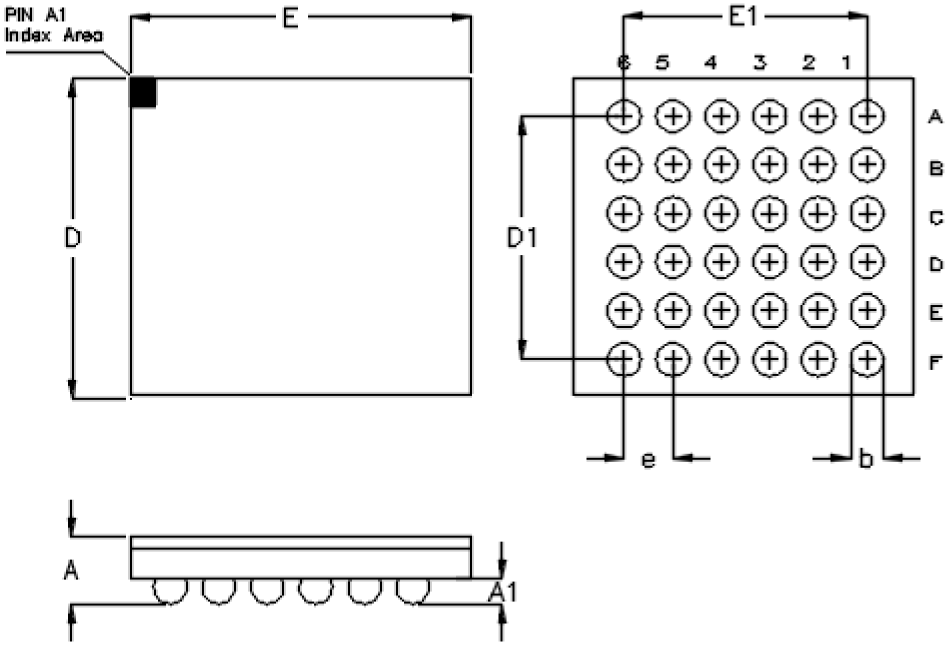


Figure 17. PCB Layout Guide

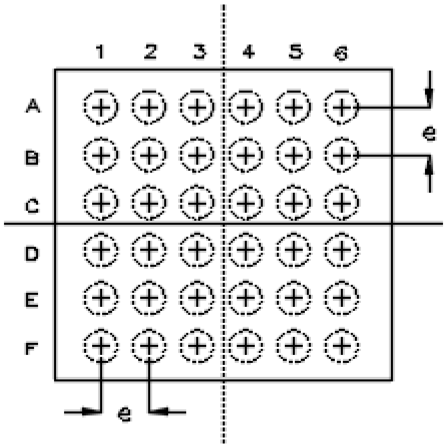
Outline Dimension

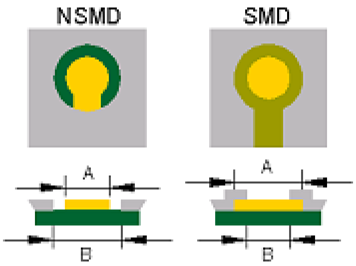


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.500	0.600	0.020	0.024
A1	0.170	0.230	0.007	0.009
b	0.240	0.300	0.009	0.012
D	2.750	2.850	0.108	0.112
D1	2.000		0.079	
E	2.550	2.650	0.100	0.104
E1	2.000		0.079	
e	0.400		0.016	

36B WL-CSP 2.8x2.6 Package (BSC)

Footprint Information





Package	Number of Pin	Type	Footprint Dimension (mm)			Tolerance
			e	A	B	
WL-CSP2.8*2.6-36(BSC)	36	NSMD	0.400	0.240	0.340	±0.025
		SMD		0.270	0.240	

Richtek Technology Corporation
14F, No. 8, Tai Yuen 1st Street, Chupei City
Hsinchu, Taiwan, R.O.C.
Tel: (8863)5526789

Datasheet Revision History

Version	Date	Description	Item
03	2022/12/5	Modify	Features on P1 Functional Description on P13