无线功率接收器的实现及其原理

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2015年5月

RICHTEK
your power partner.

关于无线充电

- 这个概念有问题吗？

Wireless Power Standards

	WPC	PMA	A4WP
标准	Qi V1.1	PMA	Rezence
创立时间	2008	2012	2012
技术	磁感应	磁感应	磁共振
工作频率	100~205kHz	201~304kHz	6.78MHz
通讯方式	ASK/FSK	ASK	Bluetooth 2.4GHz
耦合方式	紧耦合	紧耦合	松耦合
充电距离	<5mm	<5mm	<50mm
充电设备数量	1	1	n
系统效率 (%)	60~80%	60~80%	40~70%
主要成员	ConvenientPower, Samsung, LG, Nokia, Panasonic, Philip, TI, RICHTEK立锜科技	Duracell Powermat, Google, AT&T, Starbucks	Qualcomm, INTEL, DELL, Broadcom, Samsung, RICHTEK立锜科技

62 Qi-Enabled Phones: Where is yours?

Qi INTEGRATED, Qi READY:

NOKIA

TECHDY

Qi INTEGRATED, Qi READY:

motorola

Google

PHILIPS

htc

SAMSUNG

PANTECH

LG

SHARP

CASIO
the unexpected extra

NEC

Panasonic

FUJITSU

BlackBerry

KYOCERA

Qi-Enabled Lifestyle

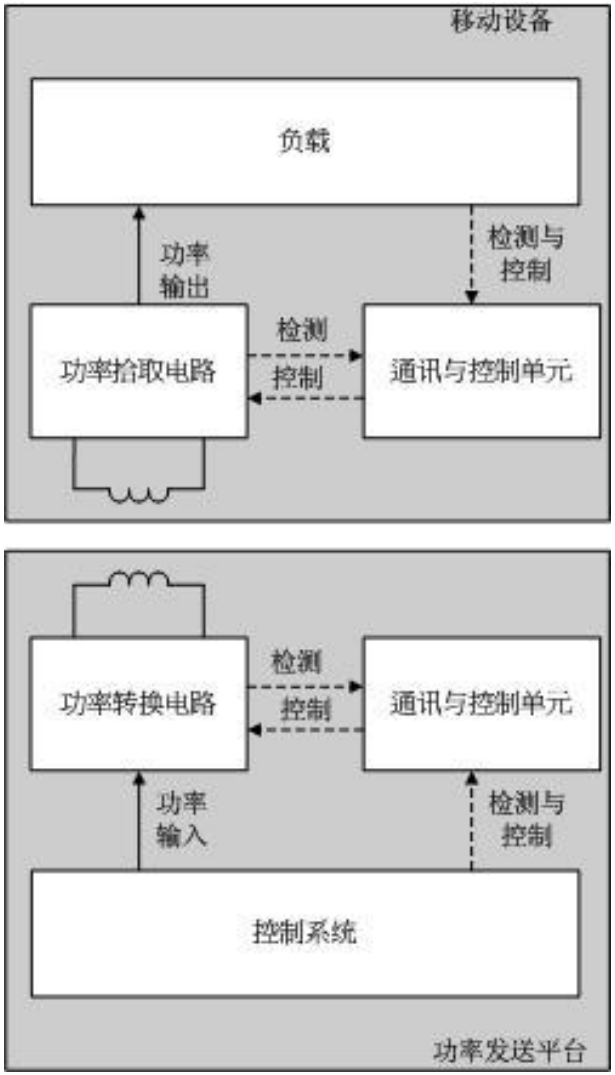
RAPID PENETRATION IN THE CONSUMER ECOSYSTEM

Qi receivers integrated in mobile devices

Accessories Qi chargers and Qi docking stations

Embedded Qi chargers in furniture and cars

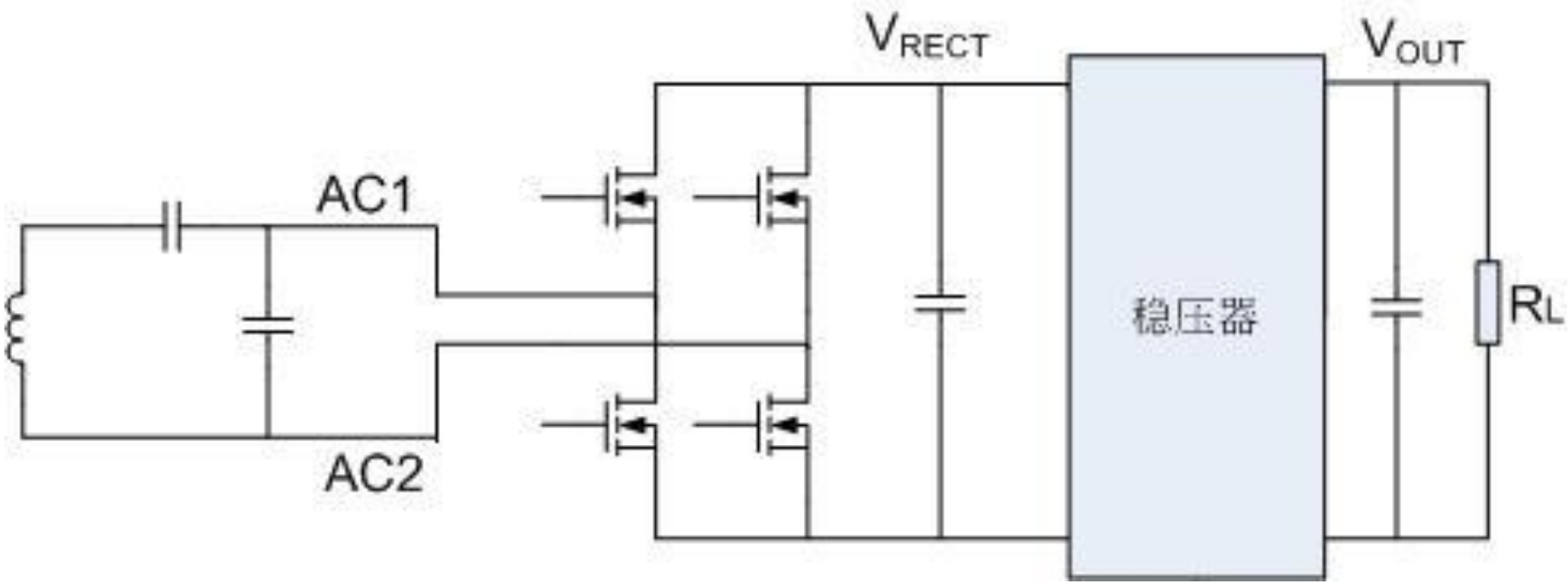
无线功率传输系统


移动设备
负载
功率
输出
检测与
控制
功率拾取电路
检测
控制
通讯与控制单元
功率转换电路
检测
控制
通讯与控制单元
功率
输入
检测与
控制
控制系统
功率发送平台

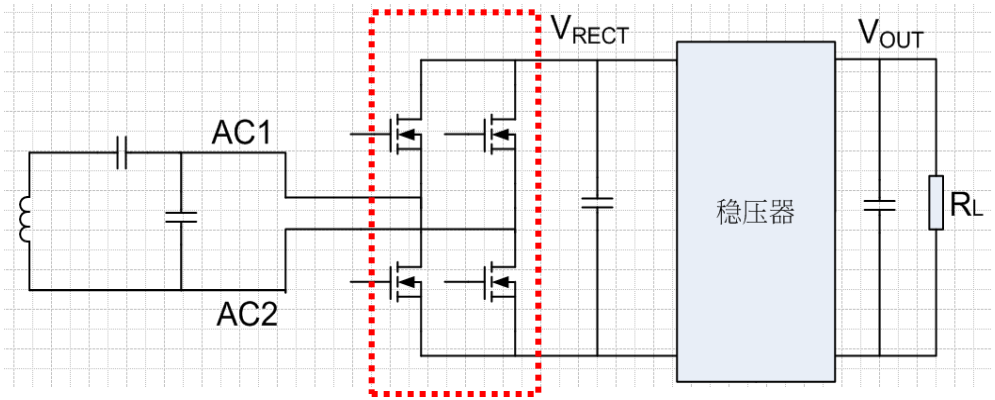
无线功率接收器的基本构造

- 功率拾取
- 嵌入式 MCU
- 应用电路
- 工作模式
- 材料清单
- 基本的性能
- 个性化的配置

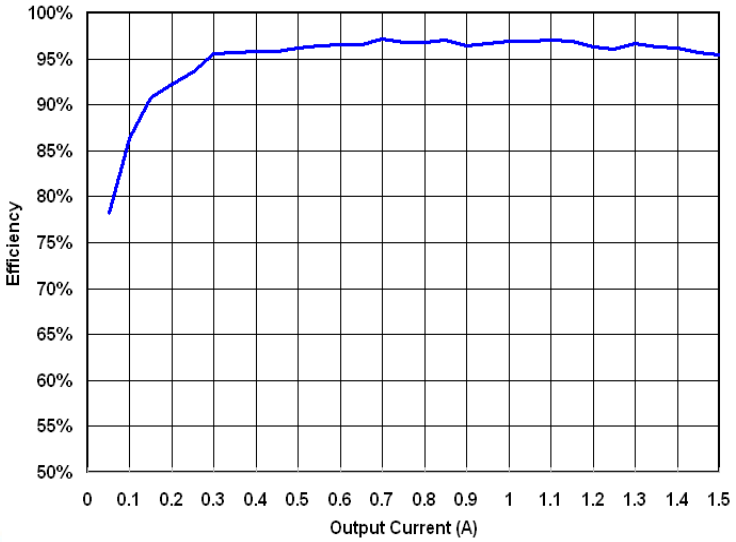
功率拾取电路——核心部分



可编程的同步整流器



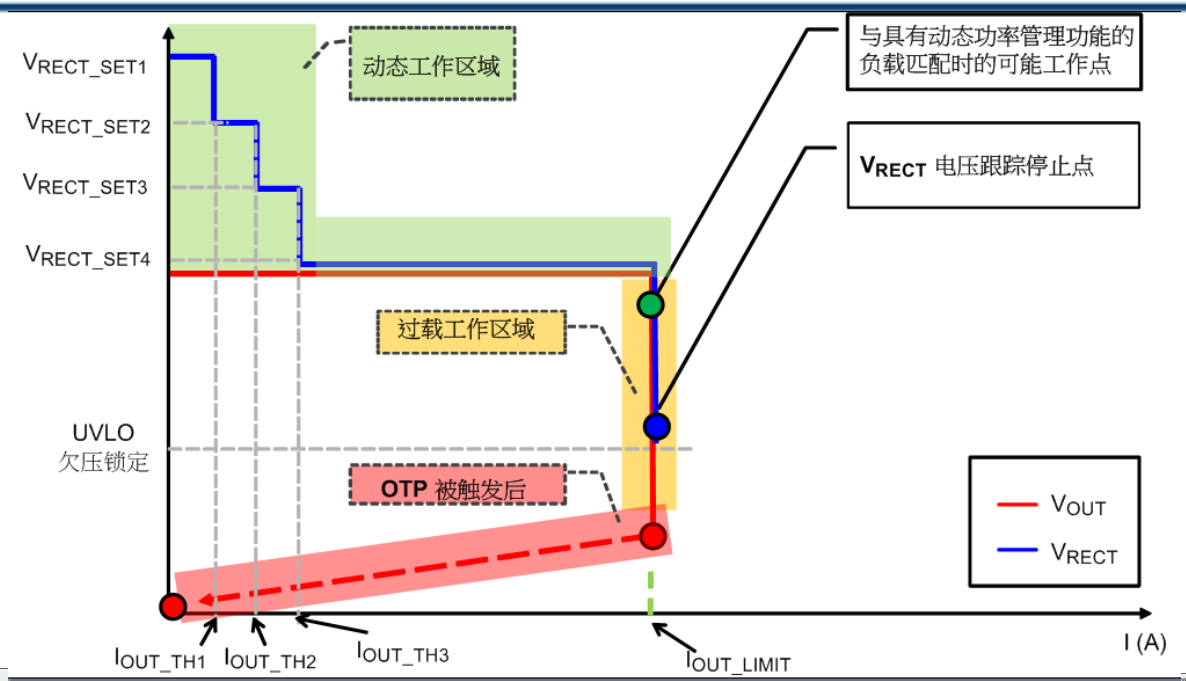
- 非同步
- 半同步
- 全同步

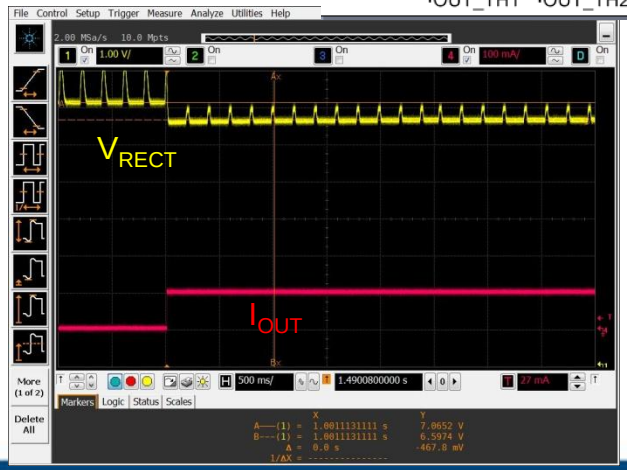


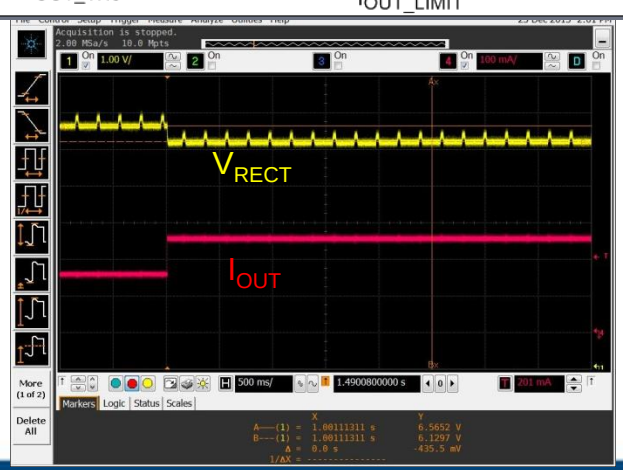
V_{AC1}-V_{AC2} (2V/div)

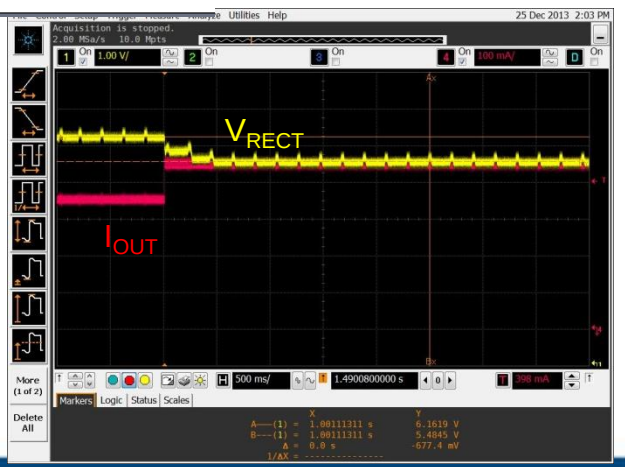
V_{RECT} (2V/div) I_{AC1} (1A/div)

通过适当的配置提升性能





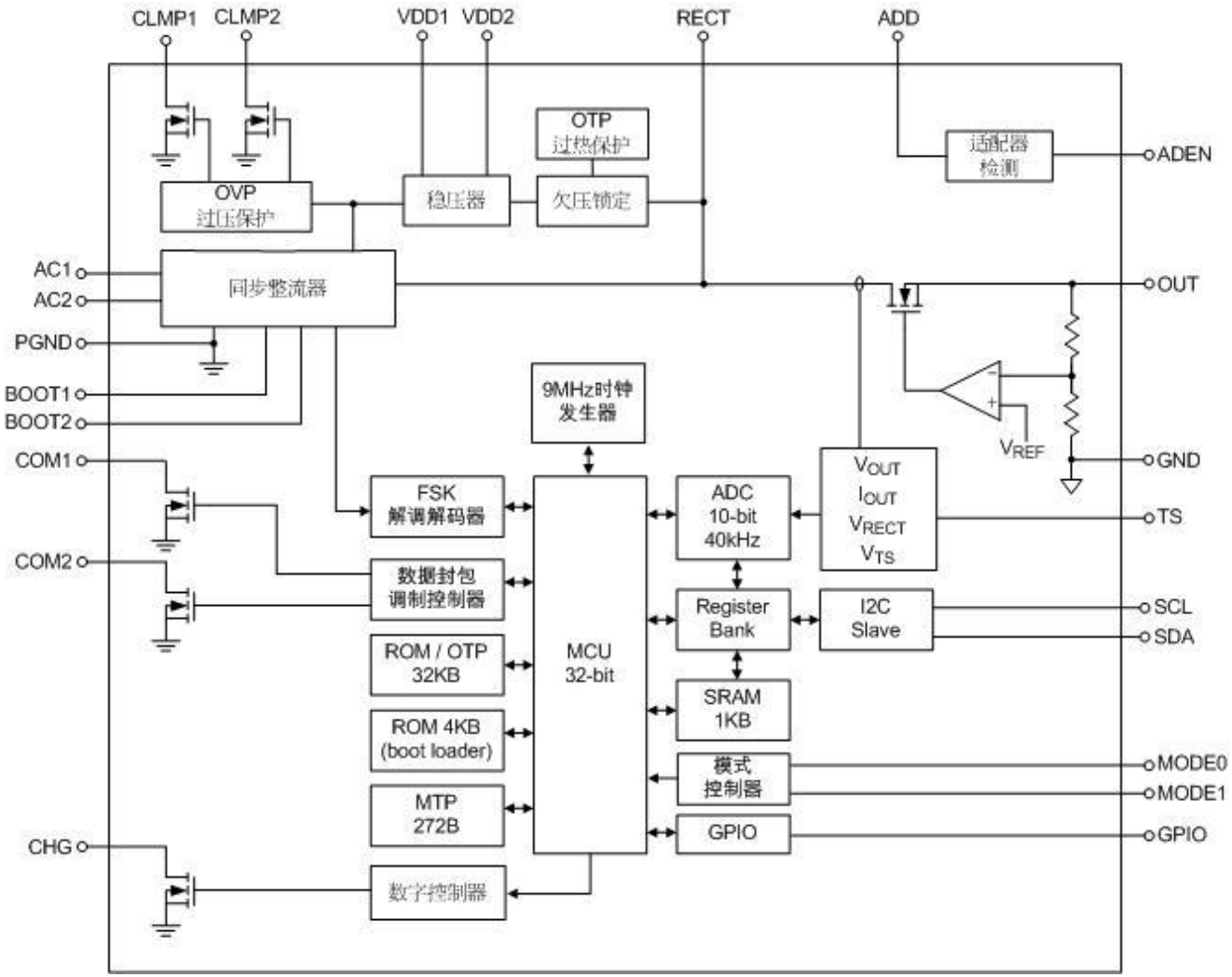




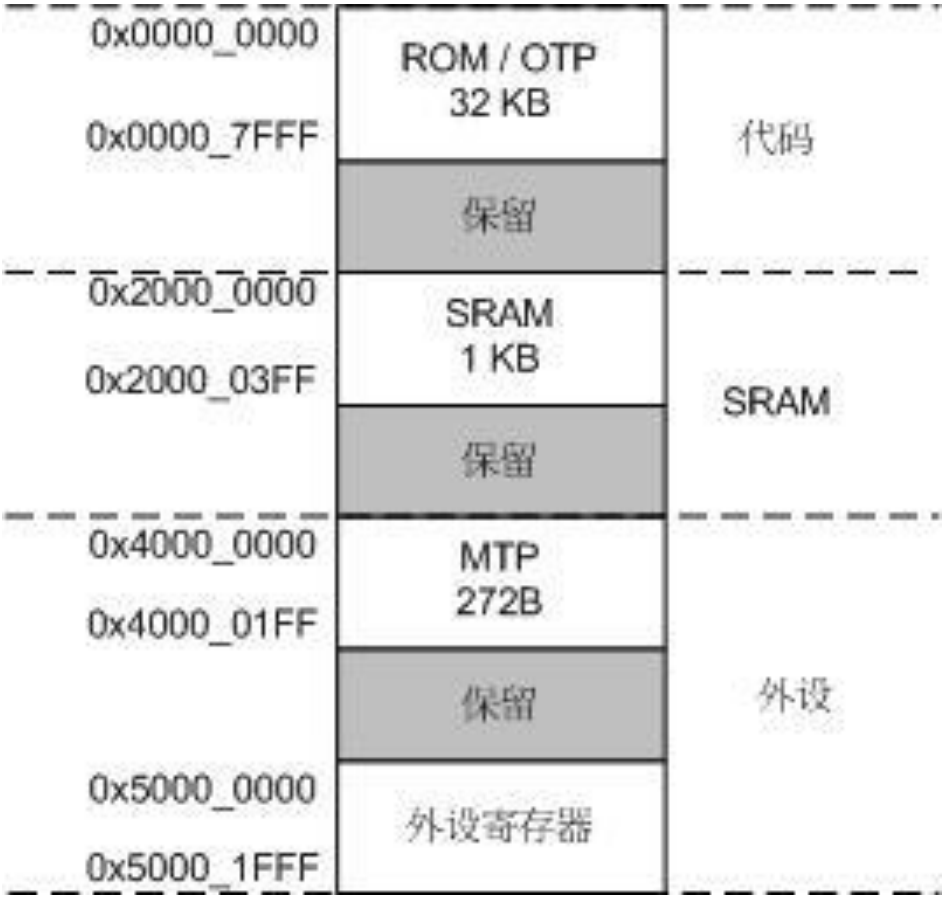
整流器电压设定表

输出电流 I_{OUT}	整流器目标电压
< I_{OUT_TH1}	V_{RECT_SET1}
I_{OUT_TH1} 至 I_{OUT_TH2}	V_{RECT_SET2}
I_{OUT_TH2} 至 I_{OUT_TH3}	V_{RECT_SET3}
> I_{OUT_TH3}	V_{RECT_SET4}

嵌入式 MCU


CLMP1
CLMP2
VDD1
VDD2
RECT
ADD
OTP
过热保护
适配器
检测
ADEN
OVP
过压保护
稳压器
欠压锁定
AC1
AC2
同步整流器
OUT
PGND
BOOT1
BOOT2
9MHz时钟
发生器
VREF
GND
COM1
FSK
解调解码器
ADC
10-bit
40kHz
VOUT
IOUT
VRECT
VTS
TS
COM2
数据封包
调制控制器
Register
Bank
I2C
Slave
SCL
SDA
ROM / OTP
32KB
MCU
32-bit
SRAM
1KB
ROM 4KB
(boot loader)
模式
控制器
MODE0
MODE1
MTP
272B
GPIO
CHG
数字控制器

MCU 的存储空间配置


0x0000_0000
ROM / OTP
32 KB
0x0000_7FFF
保留
代码
0x2000_0000
SRAM
1 KB
0x2000_03FF
保留
SRAM
0x4000_0000
MTP
272B
0x4000_01FF
保留
外设
0x5000_0000
外设寄存器
0x5000_1FFF

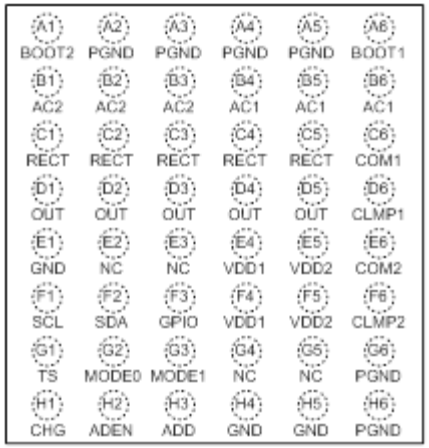
RT1650x 无线功率接收器

主要特性

- 全集成 7.5W 无线功率接收器
- 符合 WPC LP v1.1 和 PMA 规范
- 效率高达96%的同步整流器
- 动态整流器电压控制
- 集成 ARM® 32-bit Cortex-M0
- I^2C 接口
- ASK/FSK 通讯
- 低热量 @ 7.5W
- 5W 时系统效率达80%
- 超级稳定的输出
- 多输入切换控制
- 支持位置检测、定位功能
- OCP/OVP/OTP
- WL-CSP 和 QFN 封装

封装和引脚定义

(顶视图)

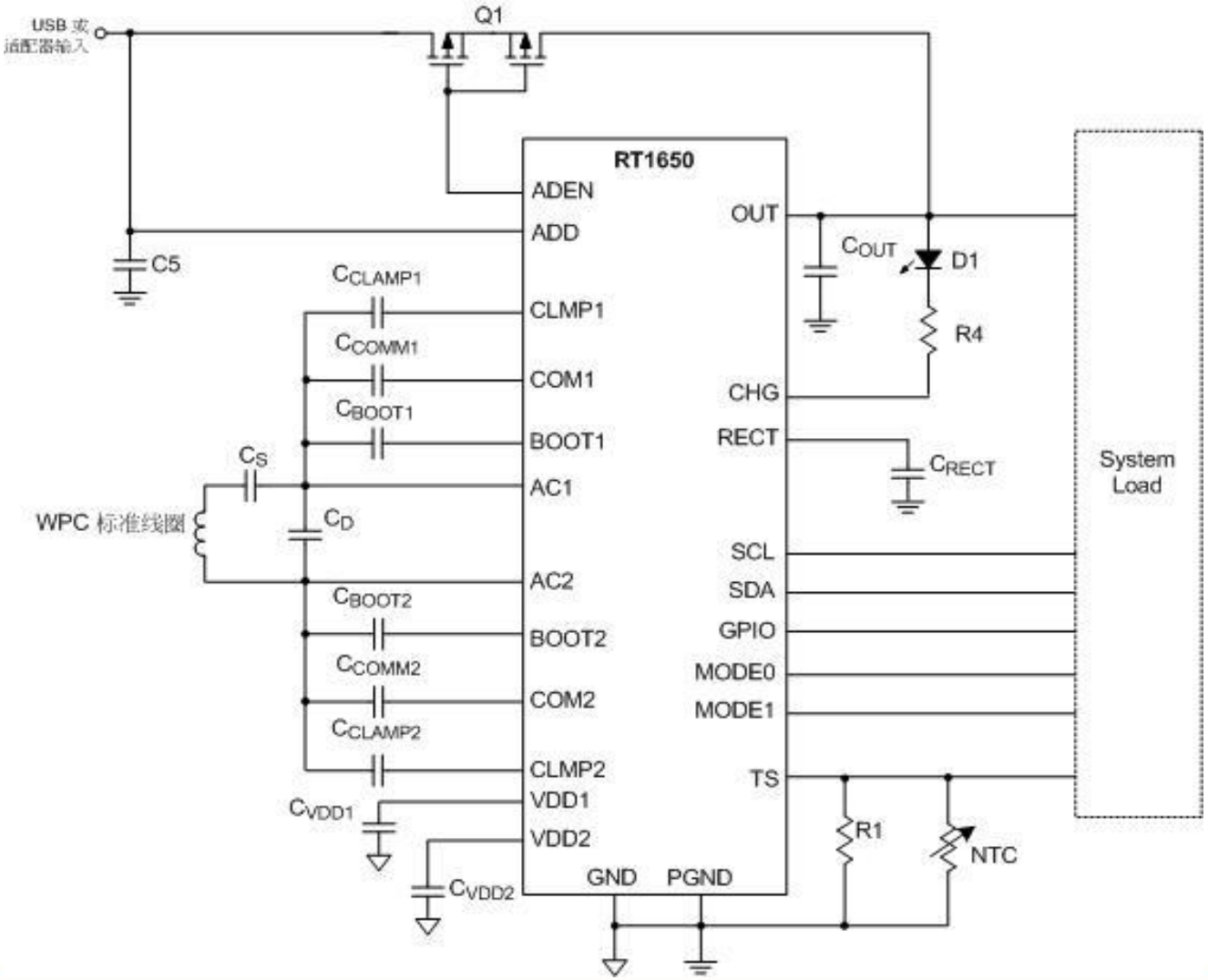


WL-CSP-48B 3x3.4 (BSC)

符合的标准

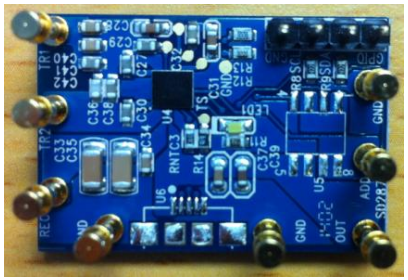
型号	行业标准		
	WPC LP v1.1	WPC MP v0.9	PMA
RT1650A	Yes	Yes	Yes

完整的接收端


USB 或
适配器输入
Q1
RT1650
ADEN
ADD
CLMP1
COM1
BOOT1
AC1
AC2
BOOT2
COM2
CLMP2
VDD1
VDD2
GND
PGND
OUT
CHG
RECT
SCL
SDA
GPIO
MODE0
MODE1
TS
C5
CCLAMP1
CCOMM1
CBOOT1
CS
CD
WPC 标准线圈
CBOOT2
CCOMM2
CCLAMP2
CVDD1
CVDD2
COUT
D1
R4
CRECT
R1
NTC
System
Load

BOM

Reference	Value	Description	Package	Manufacture
U1	RT1650A	Wireless Power Receiver	WLCSP	Richtek
C1	68 nFx2 + 47 nF	Capacitor, 50V, X7R, 10%	0603	
C2	1800 pF + 100 pF	Capacitor, 50V, X7R, 10%	0603	
C3	10 uF	Capacitor, 25V, X5R, 10%	0805	
C4	1 uF + 0.1uF	Capacitor, 50V, X5R, 10%	0603	
C5, C6, C7*	1 uF	Capacitor, 50V, X5R, 10%	0603	
Cboot1, Cboot2	10 nF	Capacitor, 50V, X7R, 10%	0603	
Ccomm1, Ccomm2	22 nF	Capacitor, 50V, X7R, 10%	0603	
Cclamp1, Cclamp2	0.47 uF	Capacitor, 50V, X7R, 10%	0603	
Coil	10-13 uH	Receiver coil		WE, GT, TDK
Q1*	P-MOSFET	MOSFET Dual P-channel		
R1*	33 kohm	Resistor	0603	
R4*	1.5 kohm	Resistor	0603	
NTC*	NCP15WF104F03RC	100 kohm, ±1%, β=4250K	0603	
D1*	LTST-C190GKT	LED	0603	



EVM: 20 mm x 30 mm

* Note: these components are optional

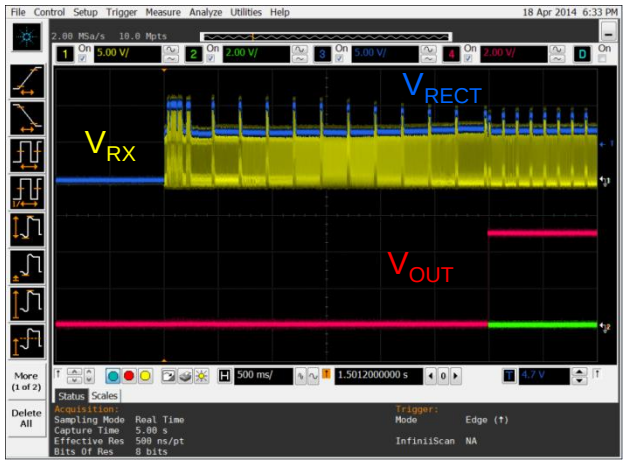
优异的性能

	RT1650x	XX	XXX
$I_{OUT, MAX}$	1.5A	1A	1A
$P_{OUT, MAX}$	7.5W	5W	5W
内嵌 MCU	Yes	No	Yes
输出级	LDO	LDO	Buck
封装	CSP 3x3.4mm QFN 5x5mm	DSBGA 1.9x3mm QFN 4.5x3.5mm	CSP 4.86x4.65mm QFN 7x7mm
整流器效率 (5W)	96%	94%	90%
系统效率 (5W)	80%	72%	65%
符合 WPC 规范的 ASK / FSK 通讯	Yes	No	No
电池充满检测	Yes	No	No
对准定位优化	Yes	No	No
快充支持	Yes	No	No

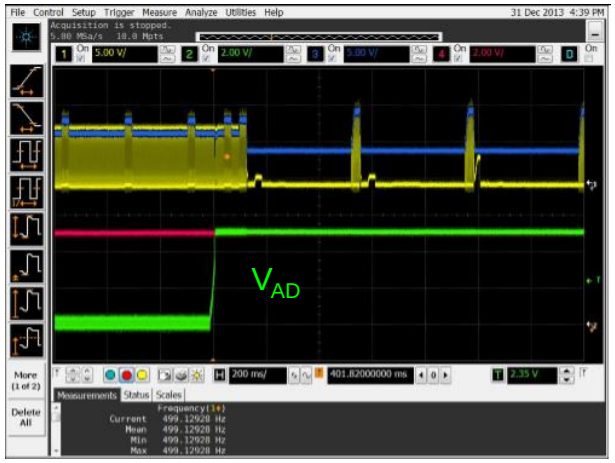
供电模式

Mode	MODE0	MODE1	Wireless Power	Adapter Power	OTG
Default	0	0	ON	ON(*)	OFF
Wireless	0	1	ON	OFF	OFF
Adapter	1	0	OFF	ON	Allowed
Disable	1	1	OFF	OFF	OFF

(*)Note: If both adapter power and wireless power are present, adapter power is given higher priority.



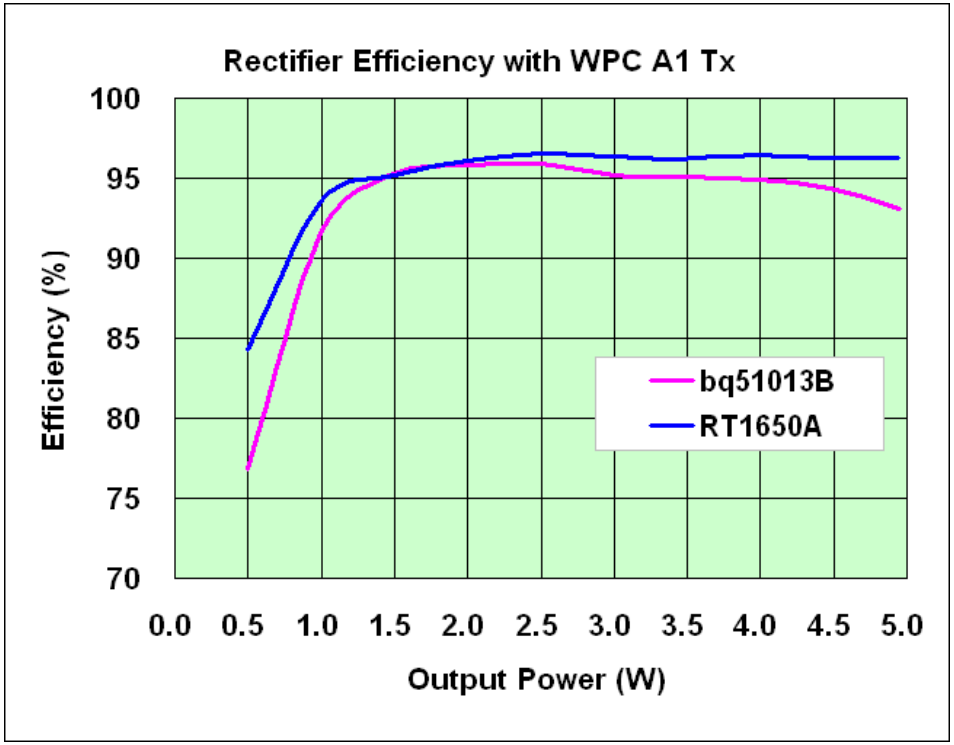
无线供电中



适配器供电开始

适配器供电结束

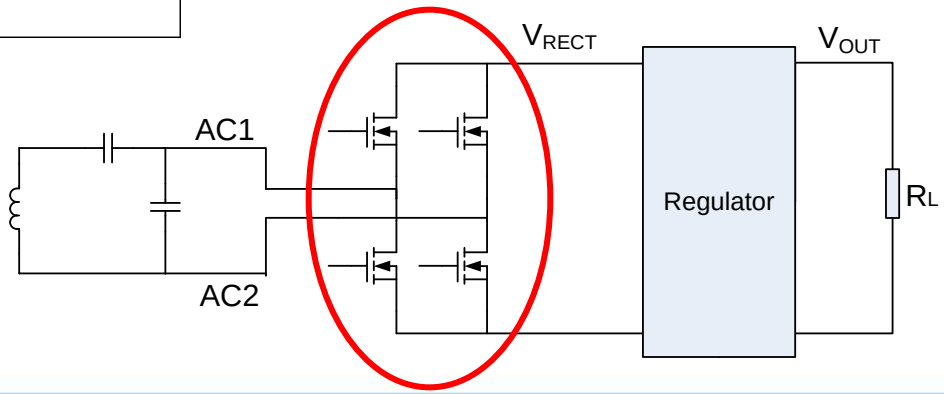
整流器效率的测量方法



整流器效率 =

$(V_{RECT} \times I_{OUT}) / (P_{AC})$

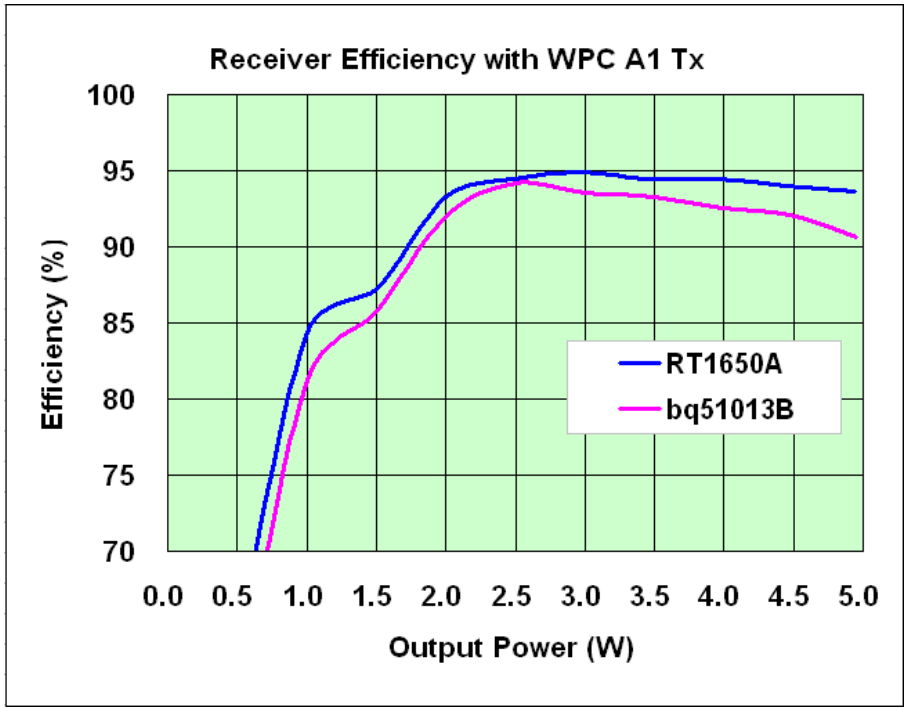
测试环境：
RT1650A EVB + WPC A1 Tx
bq51013B EVB + WPC A1 Tx
V_{IN}= 19V
V_{OUT}= 5V

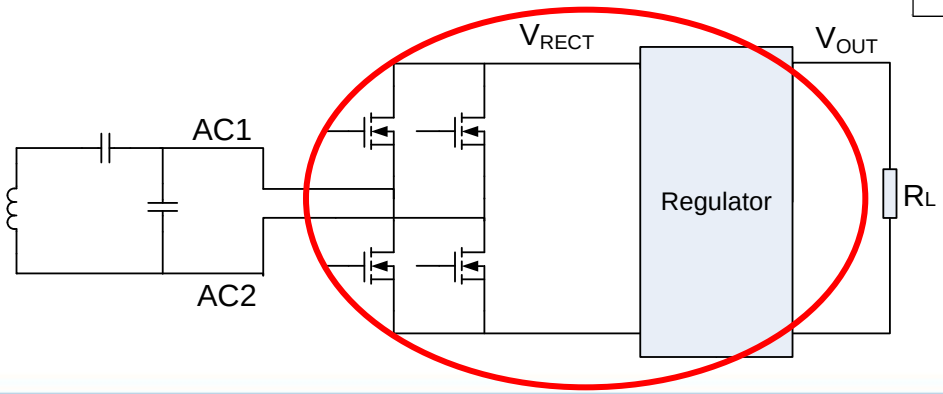


接收器效率的測量方法

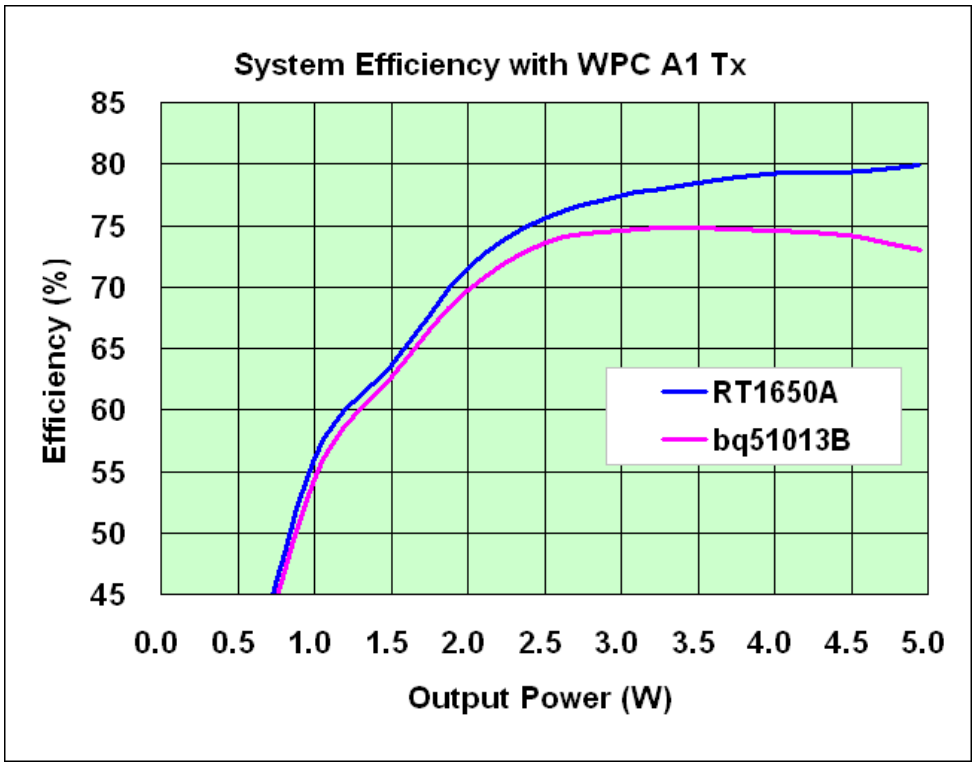
接收器效率=

$(V_{OUT} \times I_{OUT}) / (P_{AC})$





系统效率的测量方法

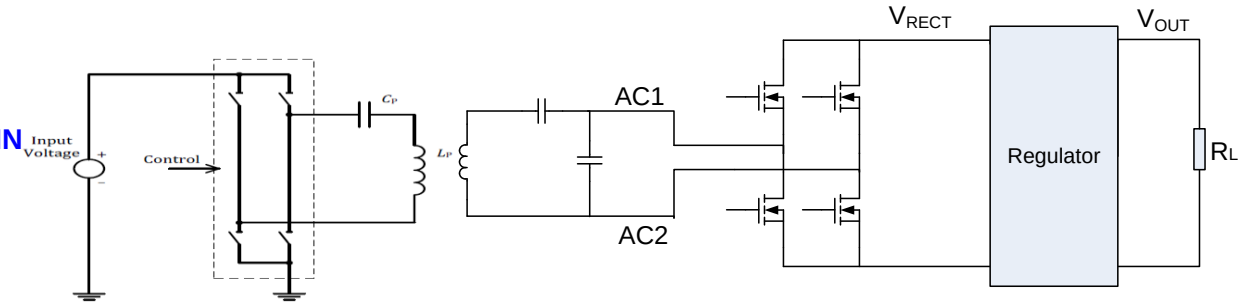


系统效率 =

$(V_{OUT} \times I_{OUT}) / (V_{IN} \times I_{IN})$

DC

V_{IN}, I_{IN}

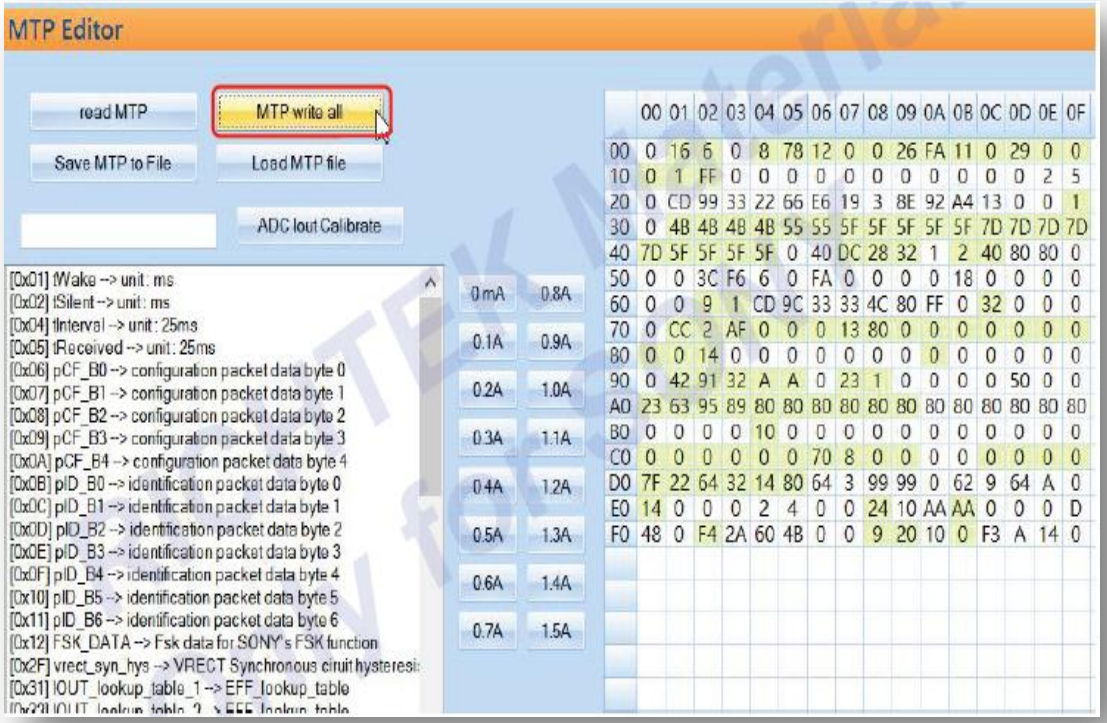


DC

V_{OUT}, I_{OUT}

用MTP支持灵活的设计

- 同步整流器
- V_{RECT} 电压控制
- ASK/FSK 通讯
- 充满检测标准
- 温度控制
- 发热量调节
- 电流限制
- 定义高/低功率传输
- I^2C 接口
- 对准定位



通讯

- 目的
- ASK
- FSK

对通讯的需要

- 调节输入的功率，使V_{RECT}稳定……
- 发送EPT命令
- 协调工作状态

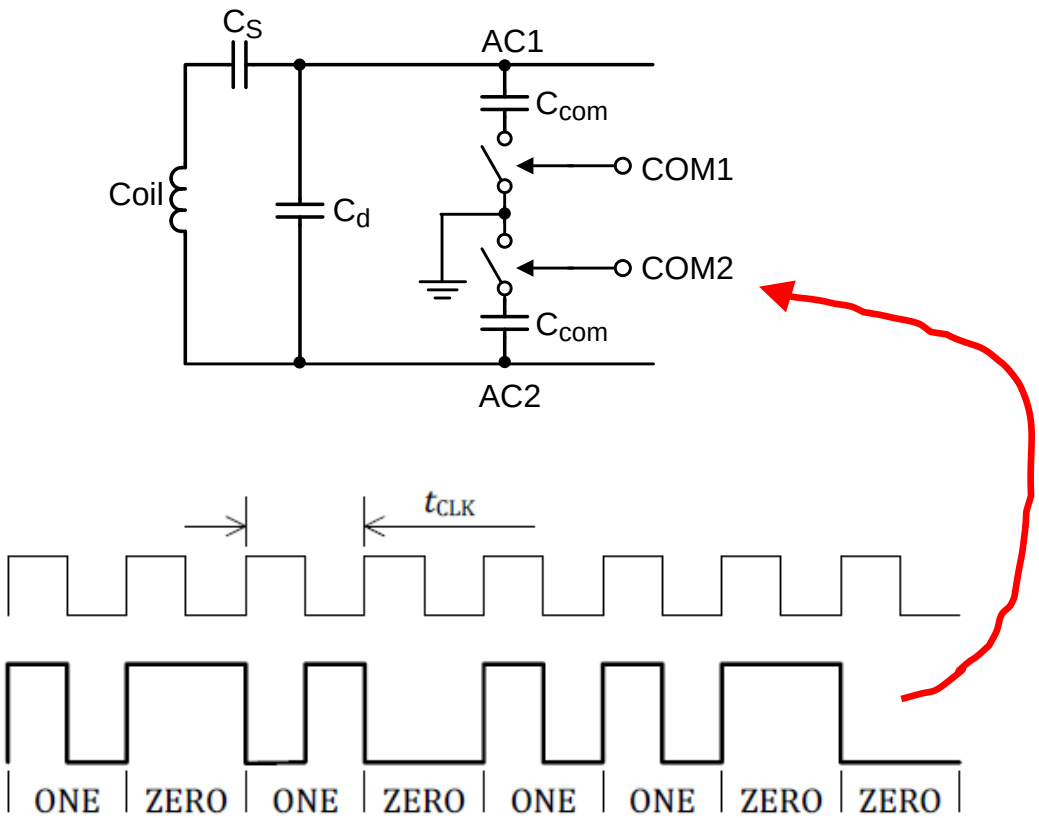
各种各样的数据包

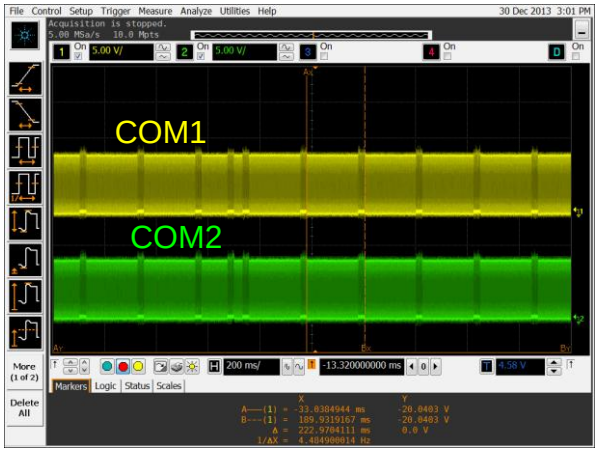
Table 6-3: Packet types

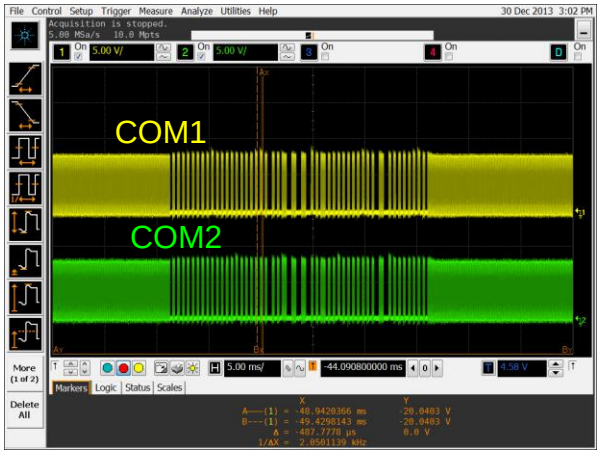
Header*	Packet Types	Message Size
ping phase		
0x01	Signal Strength	1
0x02	End Power Transfer	1
identification & configuration phase		
0x06	Power Control Hold-off	1
0x51	Configuration	5
0x71	Identification	7
0x81	Extended Identification	8
power transfer phase		
0x02	End Power Transfer	1
0x03	Control Error	1
0x04	Received Power	1
0x05	Charge Status	1
identification & configuration / power transfer phase		
0x18	Proprietary	1
0x19	Proprietary	1
0x28	Proprietary	2
0x29	Proprietary	2
0x38	Proprietary	3
0x48	Proprietary	4
0x58	Proprietary	5
0x68	Proprietary	6
0x78	Proprietary	7
0x84	Proprietary	8
0xA4	Proprietary	12
0xC4	Proprietary	16
0xE2	Proprietary	20

*Header values not listed in this table correspond to reserved Packet types

ASK 调制







- 2kbits/s
- 差分双向编码

数据字节及数据包的构成

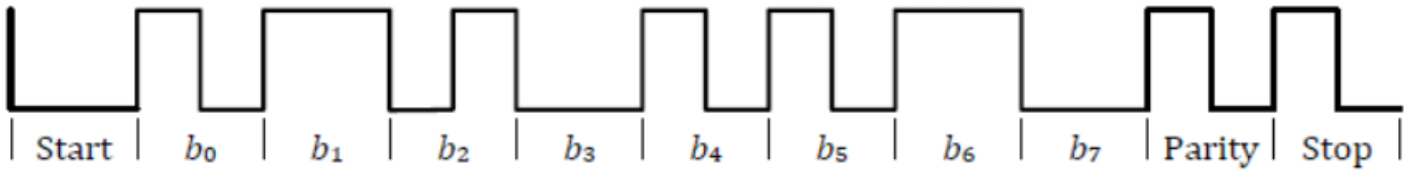


Figure 6-3: Example of the asynchronous serial format

Figure 6-4: Packet format

EPT命令的构成

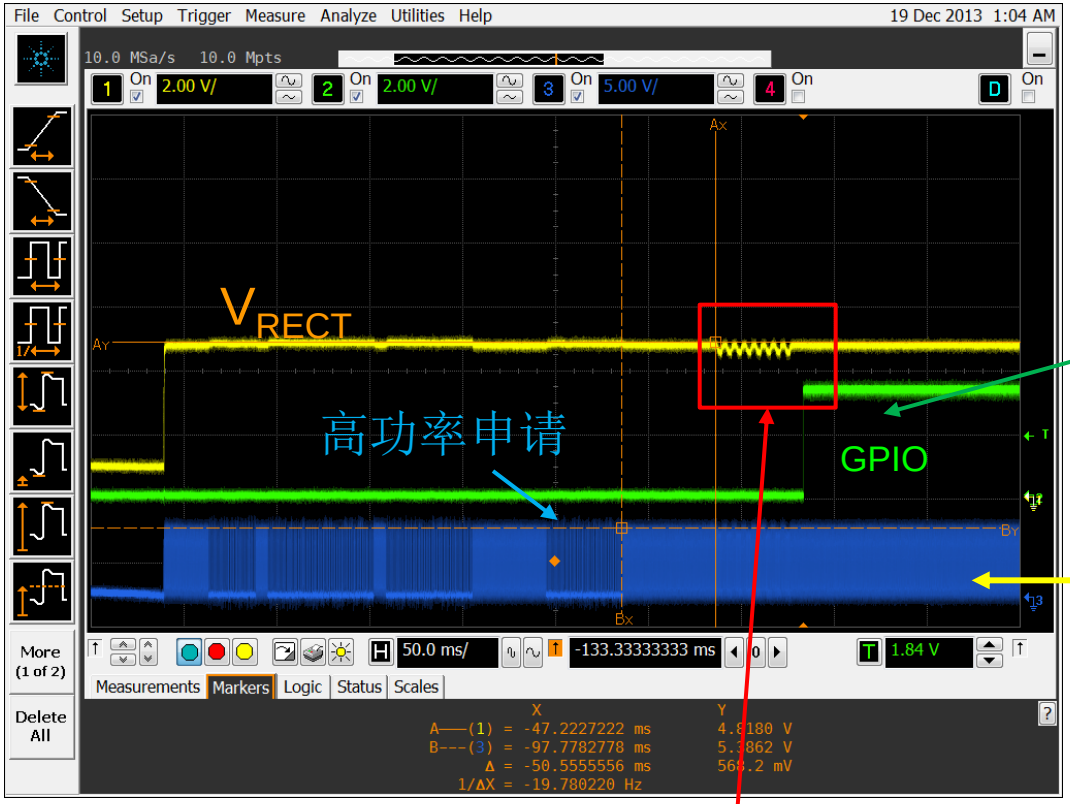
- **Header**
  - 0x02

- **Message**

附加信息类型	数值	发生条件
未知	0x00	V_{ADD} > 3.6V
充电完成	0x01	收到来自I²C的命令、MODE0变成高电平或V_{TS}变成高电平
内部故障	0x02	T_J > 150°C
过热	0x03	V_{TS} < V_{TS_HOT}， V_{TS} > V_{TS_COLD}， V_{TS} 变成低电平
过压	0x04	RT1650A未使用
过流	0x05	RT1650A未使用
电池失效	0x06	收到来自I²C的命令
重配置	0x07	RT1650A未使用
无响应	0x08	V_{RECT}目标电压无法达成

FSK 调制

功率发送端向接收端传递信息的方法

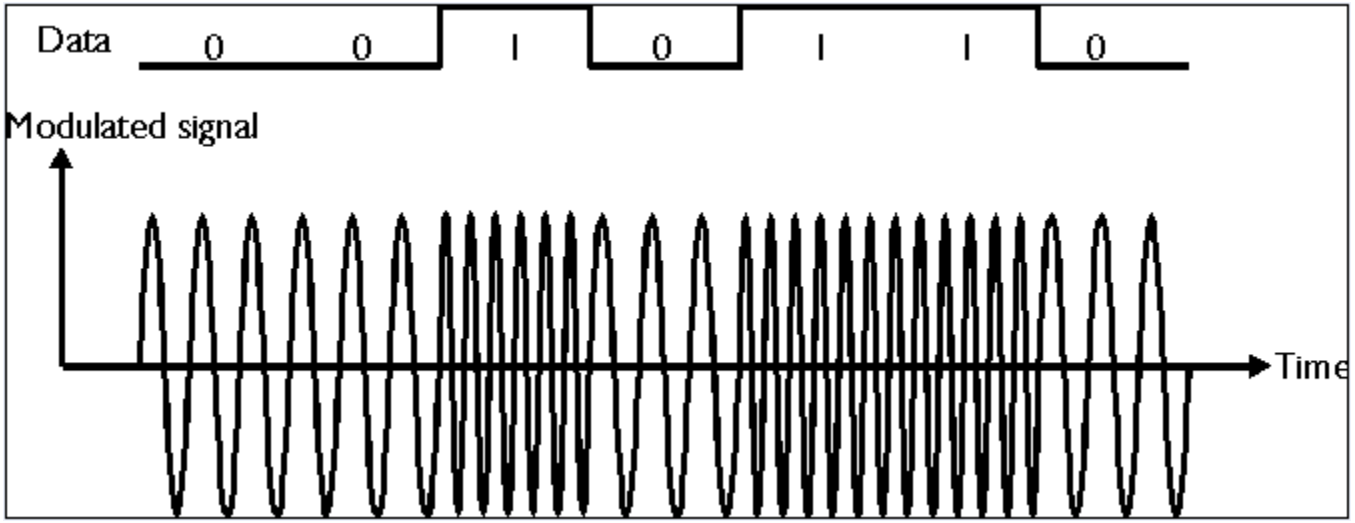


GPIO 指示

COM1 信号

Tx 回应

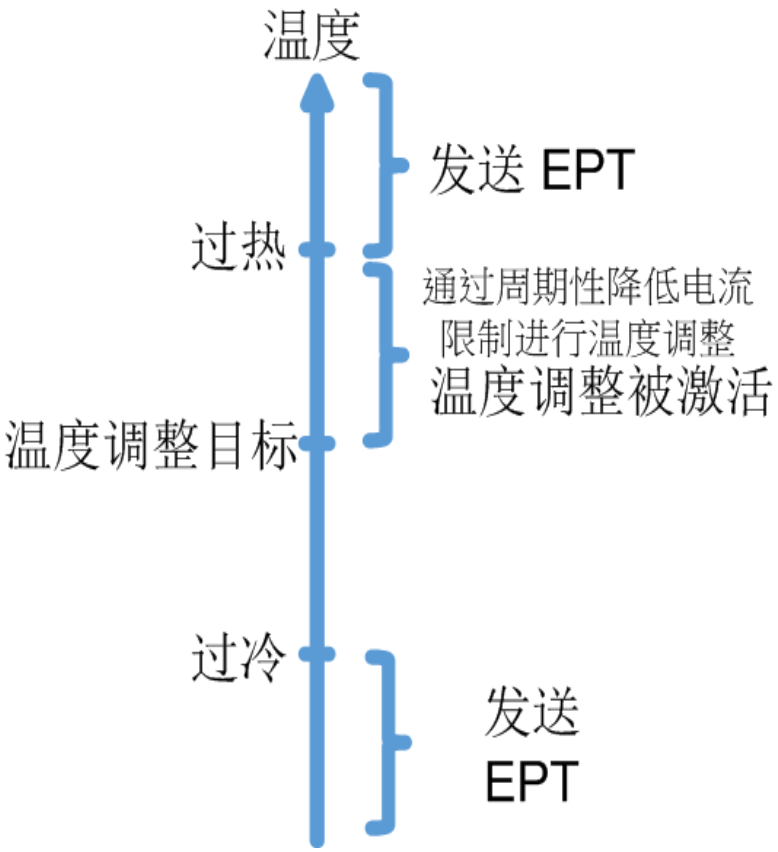
FSK 调制

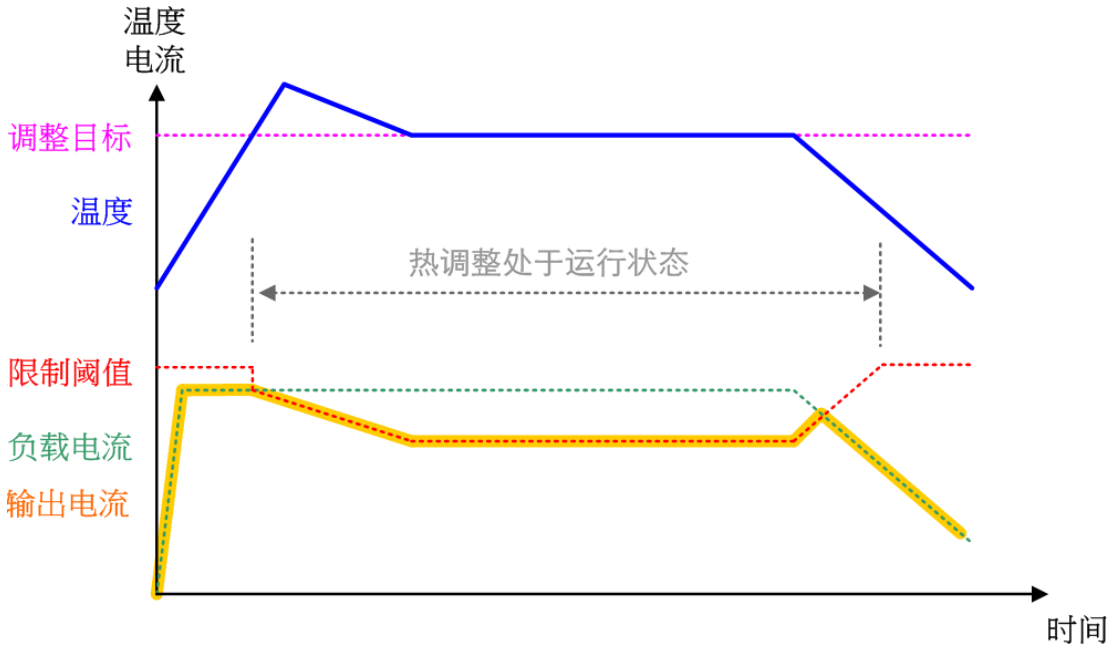


安全

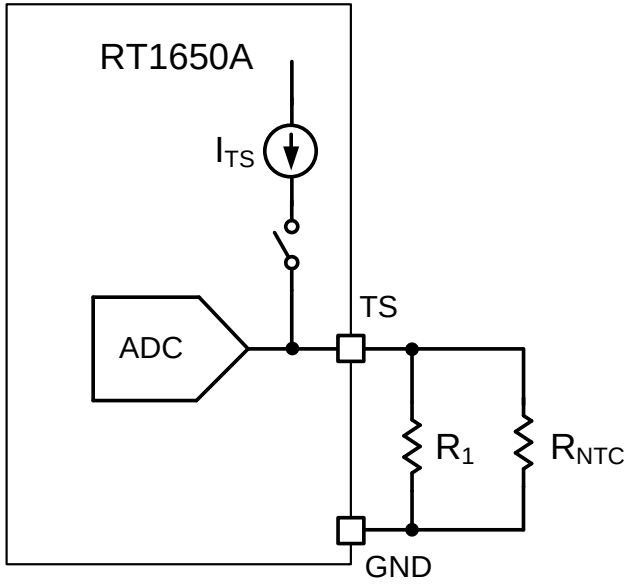
- 热管理
- 过压保护
- 充满检测

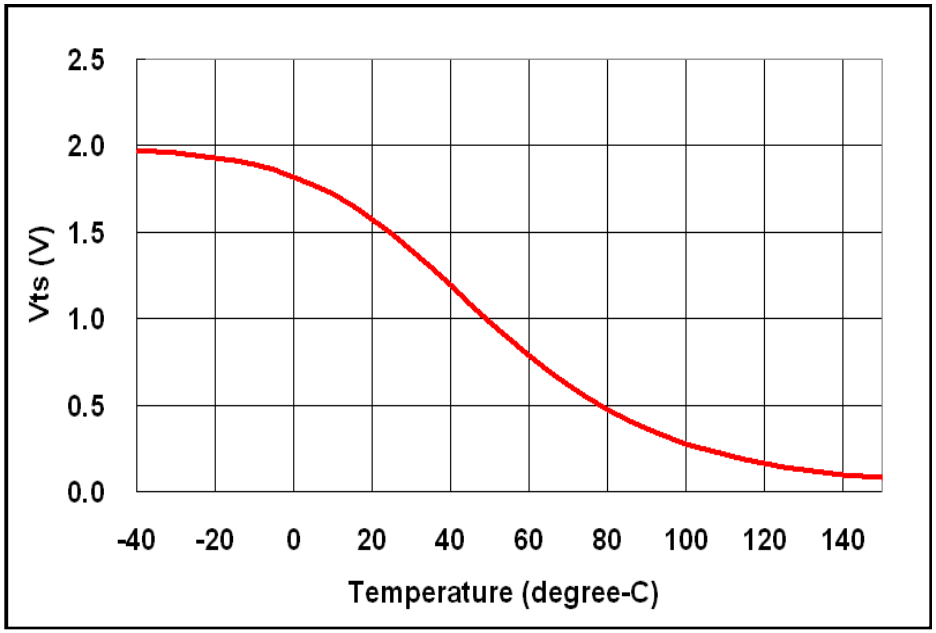
设备温度控制方法


温度
发送 EPT
过热
通过周期性降低电流
限制进行温度调整
温度调整被激活
温度调整目标
过冷
发送
EPT


温度
电流
调整目标
温度
热调整处于运行状态
限制阈值
负载电流
输出电流
时间

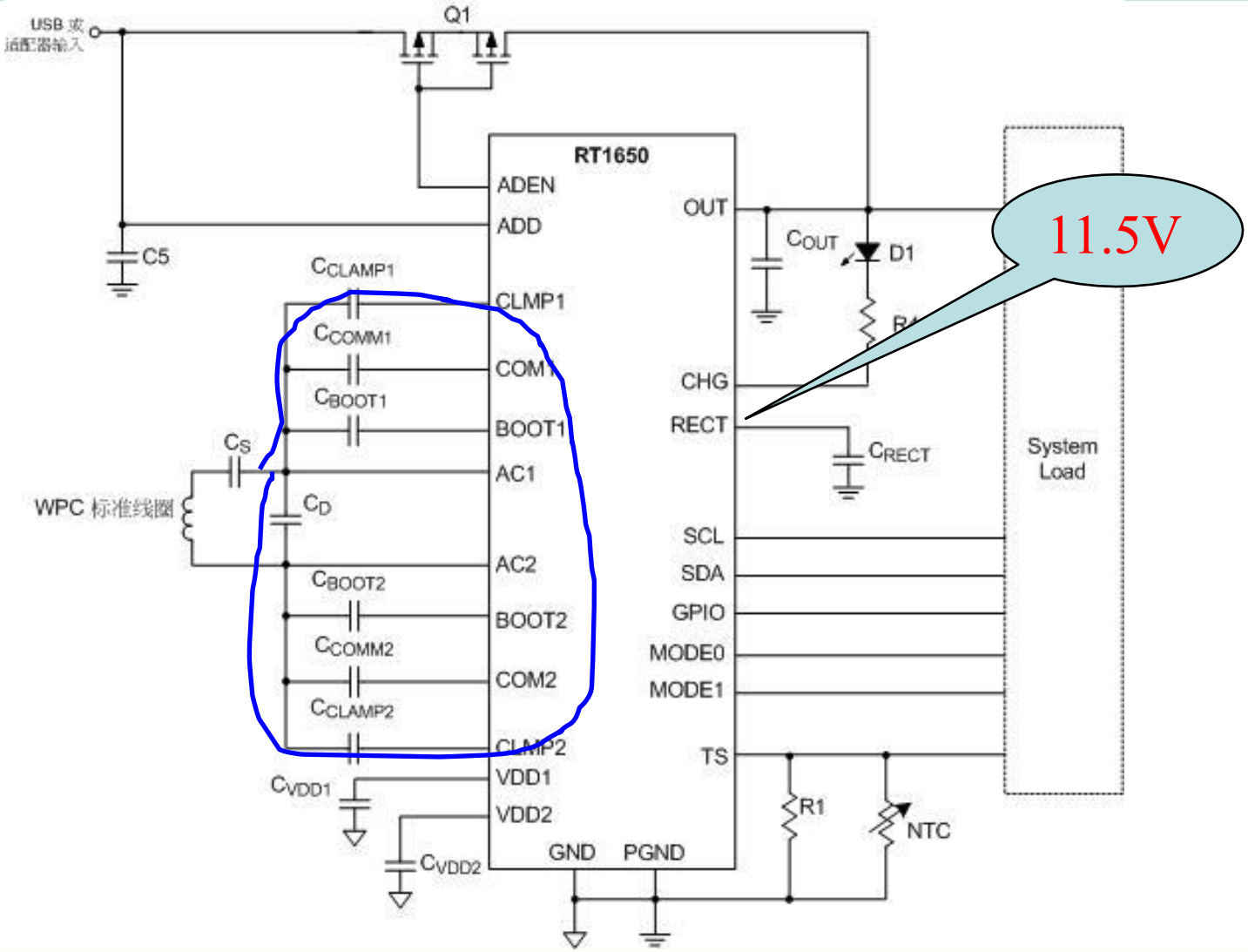
设备温度的检测与阈值控制



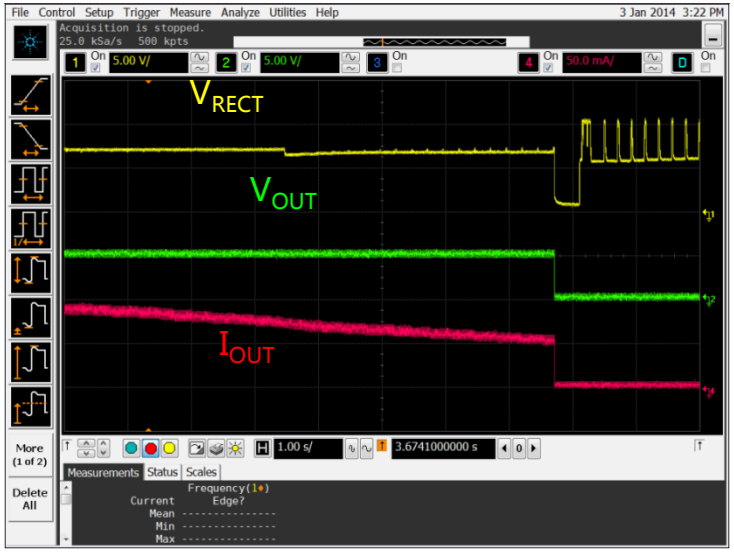


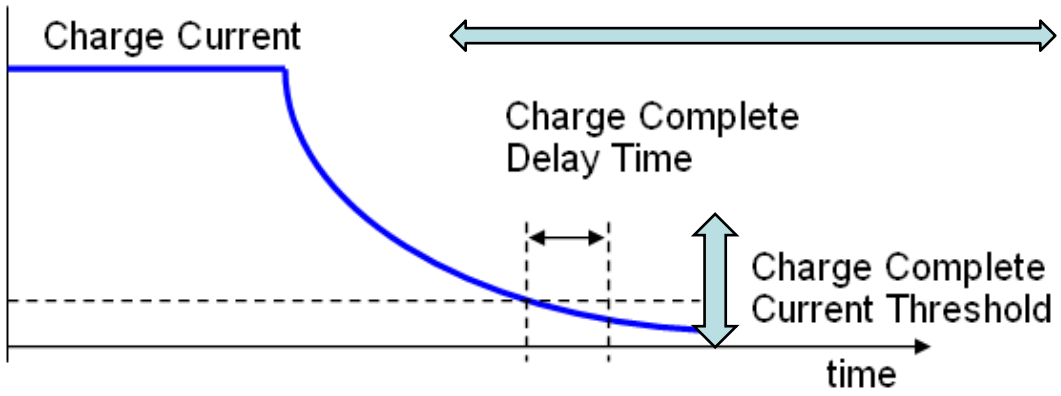
TS Sense/Control Input						
V_{TS_REG}	TS Thermoregulation Threshold	V_{TS} Falling (TS_th=8'h192)		786		mV
V_{TS_HOT}	Too-Hot Protection Threshold	V_{TS} Falling (TS_hot=8'h8E)		278		mV
V_{TS_COLD}	Too-Cold Protection Threshold	V_{TS} Rising (TS_hot=8'h3A4)		1.82		V
I_{TS}	TS Output Current			60		µA

过压保护


USB 或
适配器输入
Q1
RT1650
ADEN
ADD
OUT
CHG
RECT
SCL
SDA
GPIO
MODE0
MODE1
TS
CLMP1
COM1
BOOT1
AC1
AC2
BOOT2
COM2
CLMP2
VDD1
VDD2
GND
PGND
C5
CCLAMP1
CCOMM1
CBOOT1
CS
CD
WPC 标准线圈
CBOOT2
CCOMM2
CCLAMP2
CVDD1
CVDD2
COUT
D1
CRECT
R1
NTC
System
Load
11.5V

电池充满检测





充电完成，停止供电

阅读链接

RICHTEK

your power partner.

thank you.