实时音频信号跟踪的18V, 15A全集成同步升压转换器

18V,15A Fully-Integrated Synchronous Boost Converter with Adaptive Audio-Tracking Function

■ FEATURES

- Adaptive Audio-Tracking Power Supply
SN grounded, V_{IN} = 2.7~4.5V, V_{OUT} = 5V~12V
$R_{SN(to\ GND)}$ = 100k, V_{IN} = 2.7~8.5V, V_{OUT} = 9V~15V
SN float, V_{IN} = 2.7~8.5V, V_{OUT} = 9V~18V
- Programmable switch peak current limit: up to 15A
- High Efficiency
93% (V_{IN} = 7.4V, V_{OUT}=15.5V, I_{OUT} =1.5A)
- 1.0μA current consumption during shutdown
- Adjustable switching frequency: 200k to 1.0MHz
- Programmable soft start
- Output overvoltage protection (at 22V), cycle-by-cycle overcurrent protection, thermal shutdown protection
- Pb-free Packages,QFN3.5×4.5-20L

- 实时音频信号跟踪的电源供电
SN 短接地, V_{IN} = 2.7~4.5V, V_{OUT} = 5V~12V
$R_{SN(to\ GND)}$ = 100k, V_{IN} = 2.7~8.5V, V_{OUT} = 9V~15V
SN 悬空, V_{IN} = 2.7~8.5V, V_{OUT} = 9V~18V
- 可编程峰值电流：15A
- 高转换效率：
93% (V_{IN} = 7.4V, V_{OUT}=15.5V, I_{OUT} =1.5A)
- 低关断功耗，关断电流1uA
- 可调节的开关频率：200k-1.0M
- 可编程软启动
- 输出过压 (22V)、逐周期过流、热关断等保护
- QFN3.5×4.5-20L 无铅超薄封装

■ APPLICATIONS

- Wireless/ Speakers
- Portable Speakers
- 无线音箱
- 便携式音箱

■ DESCRIPTION

The HT71778 is a high-power density, fully integrated synchronous boost converter with a 16mΩ power switch and a 18mΩ rectifier switch to provide a high efficiency and small size solution in portable systems.

The HT71778 has wide input voltage range to support applications with single cell or two cell in series Lithium batteries. The device can provide an adaptive audio-tracking power supply for audio power amplifier so that the system can always keep high efficiency in the whole output power range. The battery endurance can be improved by more than 50%, compared to power supply that is directly boosted.

The HT71778 uses adaptive constant off-time peak current control topology to regulate the output voltage. In moderate to heavy load condition, it works in the PWM mode. In light load condition, the device works in PFM mode to improve the efficiency. The switching frequency in the PWM mode is adjustable ranging from 200kHz to 1.0MHz by an external resistor.

The HT71778 also implements a programmable soft-start function and an adjustable switching peak current limit function. In addition, the device provides 22V output overvoltage protection, cycle-by-cycle overcurrent protection, and thermal shutdown protection.

HT71778是一款高功率、全集成升压转换器，集成16mΩ功率开关管和18mΩ同步整流管，为便携式系统提供高效的小尺寸解决方案。

HT71778具有宽输入电压范围，可为采用单节或两节锂电池的应用提供支持。该器件可为音频功率放大器提供实时跟随音源信号的电源供电，从而在整个功率段内使整个系统保持在高效率。该方式供电相比直接升压供电方式，电池续航时间预计可提升50%以上[1]。

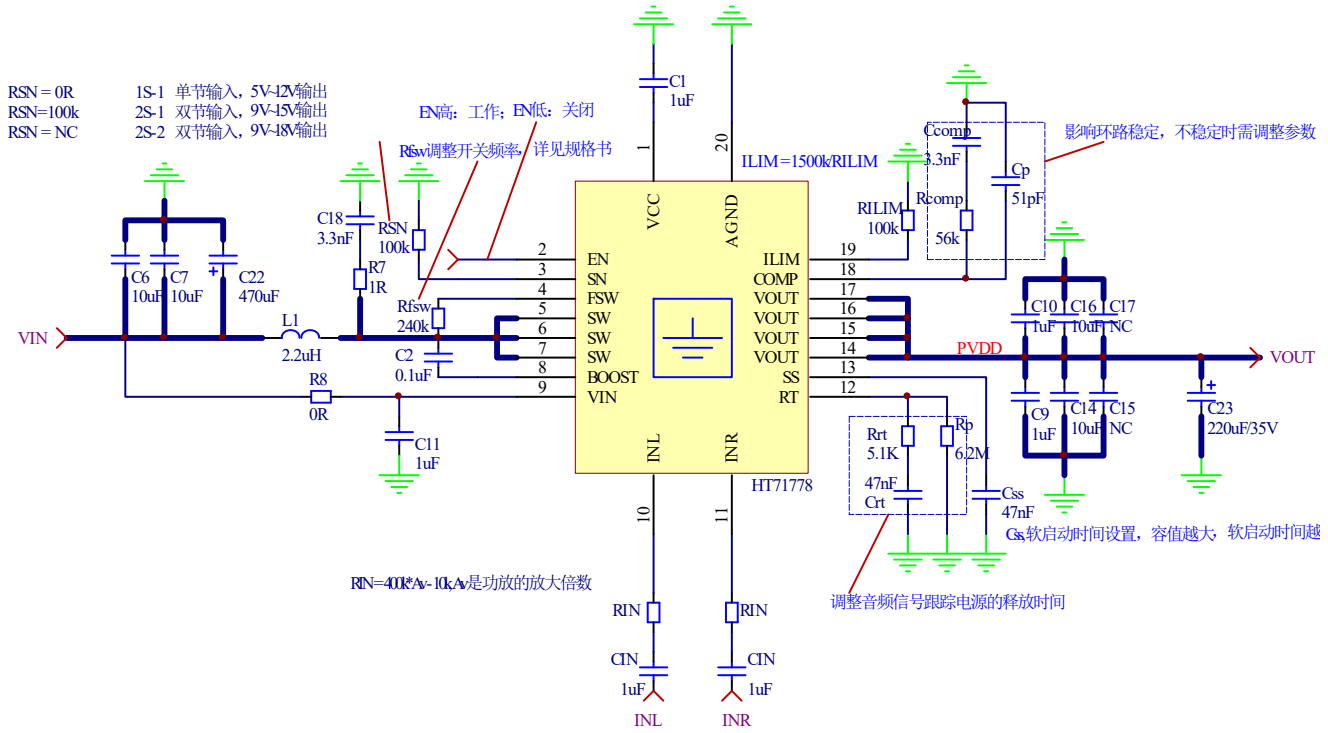
HT71778采用自适应恒定关断时间峰值电流控制拓扑结构来调节输出电压。在中等到重负载条件下，HT71778工作在PWM 模式。在轻负载条件下，该器件工作在可提高效率的PFM模式。PWM模式下，HT71778的开关频率可通过外部电阻调节，支持200kHz至1.0MHz的范围。

HT71778还支持可编程的软启动，以及可调节的开关峰值电流限制。

此外，该器件还提供有22V输出过压保护、逐周期过流保护和热关断保护。

[1] 视不同音乐、功率、电压等条件影响，实际续航提升会有较大不同

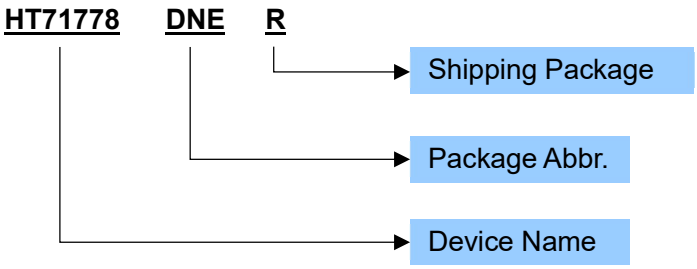
■ TYPICAL APPLICATION



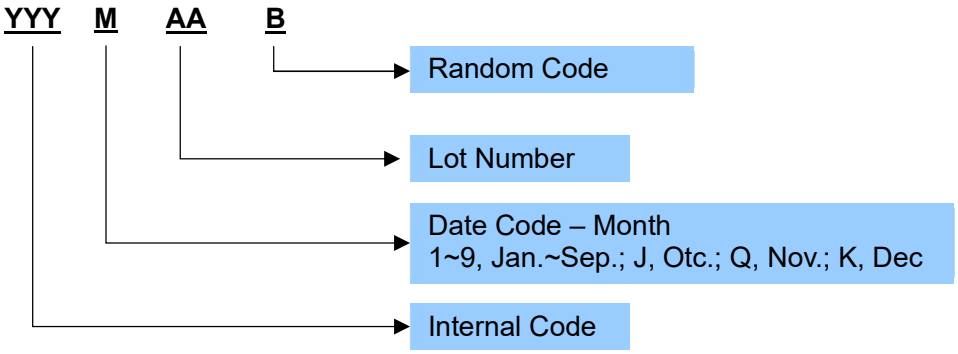
■ ORDERING INFORMATION

Part Number	Package Type	Package Abbr.	Marking	Shipping Package / MOQ
HT71778DNER	QFN3.5×4.5-20L	DNE	HT71778 YYYMAAB[1]	TBD

Part Number

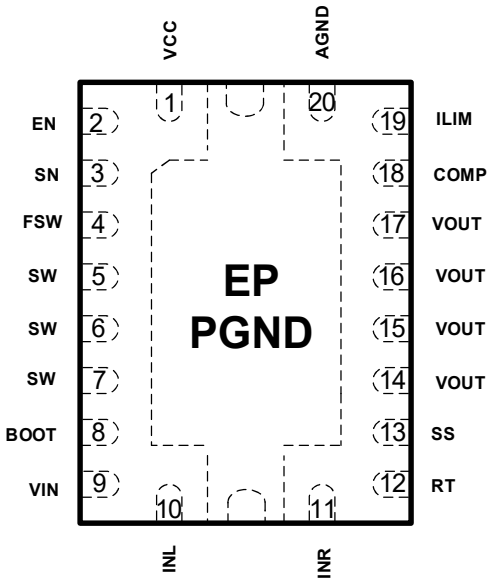


Production Tracking Code



[1] YYYMAAB is production tracking code

■ TERMINAL CONFIGURATION



Top View

■ TERMINAL FUNCTION

Terminal No.	Name	I/O[1]	Description
1	VCC	O	Output of the internal regulator. A ceramic capacitor of 2.2uF is required between this pin and ground. 接2.2uF到地。
2	EN	I	Enable logic input. Logic high level enables the device. Logic low level disables the device and turns it into shutdown mode. 使能输入，接高电平使能，低电平关断
3	SN	O	Output voltage selection, see detail in application information. 输出电压选择，详见应用说明
4	FSW	I	The switching frequency is programmed by a resister between this pin and the SW pin. 接电阻到SW脚，调节PWM开关频率
5,6,7	SW	P	The switching node pin of the converter. 升压开关节点
8	BOOT	O	Power supply for high-side MOSTFET gate driver. A ceramic capacitor of 0.1μF must be connected between this pin and the SW pin. 接0.1uF电容到SW
9	VIN	P	IC power supply input. 电源输入脚
10	INL	I	Audio input left channel. 左声道音频输入端
11	INR	I	Audio input right channel. 右声道音频输入端
12	RT	O	Release time network setting for audio tracking. 音频跟踪释放时间设置
13	SS	O	Soft-start programming pin. An external capacitor connected to ground sets the ramp rate of the internal error amplifier's reference voltage during soft-start. 接电容到地，设置软起动时间。
14,15,16	VOUT	P	Boost converter output. 升压输出
17	FB	I	Voltage feedback. 电压反馈
18	COMP	O	Output of the internal error amplifier, the loop compensation network should be connected between this pin and the AGND pin. 接阻容补偿网络到地。
19	ILIM	O	Adjustable switch peak current limit. An external resister should be connected between this pin and the AGND pin. 接电阻到地，调节开关峰值限制电流
20	AGND	G	Signal ground of the IC. 器件信号地
EP	PGND	G	Provides both electrical and thermal connection from the device to the board. A matching ground pad must be provided on the PCB and the device connected to it via solder. For proper electrical operation, this ground pad must be connected to the system ground. 既是地，又是散热PAD

[1] I: Input; O: Output; G: Ground; P: Power; BST: BOOT Strap; OD: Open drain

■ SPECIFICATIONS[1]

● Absolute Maximum Ratings[*2]

PARAMETER		Symbol	MIN	MAX	UNIT
Voltage range	BOOT	/	-0.3	SW+7	V
	EN, SW, FSW, V_{OUT}, V_{IN}		-0.3	22	
	VCC, SS, COMP, INL, INR		-0.3	7	
	ILIM, SN, RT		-0.3	3.6	
Operating temperature range		T_A	-40	85	℃
Operating junction temperature range		T_J	-40	150	℃
Storage temperature range		T_{STG}	-50	150	℃

● Recommended Operating Conditions

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
VIN pin	V_{IN}		2.7		20	V
Input voltage range	V_{IN}	SN grounded	2.7		4.5	V
		RSN(to GND) = 100k or SN float	2.7		8.5	V
Output voltage range	V_{OUT}		Decided by SN pin			
Inductance, effective value	L		0.47	2.2	10	μH
Input capacitance, effective value	C_I		10			μF
Output capacitance, effective value	C_O		6.8	47	1000	μF
Operating temperature	T_a		-40	25	85	℃
Operating junction temperature	T_J		-40		125	℃

● Electrical Characteristics[*3]

Condition: Ta = 25ºC, V_{IN} = 2.7V-20V, V_{OUT}=4.5-20V, unless otherwise specified.

Power Supply

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
Under-voltage lockout (UVLO) threshold	V_{IN_UVLO}	VIN rising		2.5		V
		VIN falling		2.3		V
VIN UVLO hysteresis	V_{IN_HYS}			200		mV
VCC UVLO threshold	V_{CC_UVLO}			2.1		V
Operating quiescent current from V_{IN}	I_Q	IC enabled, no load, V_{FB} = 1.3V, V_{OUT} = 12V		1		uA
Operating quiescent current from V_{OUT}				150		
Shutdown current into V_{IN}	I_{SD}	IC disabled, no load, no feedback resistor divider		1		uA
VCC regulation	V_{CC}	V_{IN} = 4.0V, V_{OUT} = 12V, light load		5.249		V
		V_{IN} = 4.0V, V_{OUT} = 12V, I_{LOAD} = 1A		5.008		V

[1] Depending on parts and PCB layout, characteristics may be changed.
[2] 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.
[3] Depending on parts and pattern layout, characteristics may be changed

Input and Output

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
EN high threshold voltage	V_{ENH}				1.5	V
EN low threshold voltage	V_{ENL}		0.3			V
EN internal pull-down resistance	R_{EN}			1300		kΩ
Soft-start charging current	I_{SS}			5		uA
Output voltage at SN pin	V_{SN}			1.6		V
Output overvoltage protection	V_{OVP}			22		V

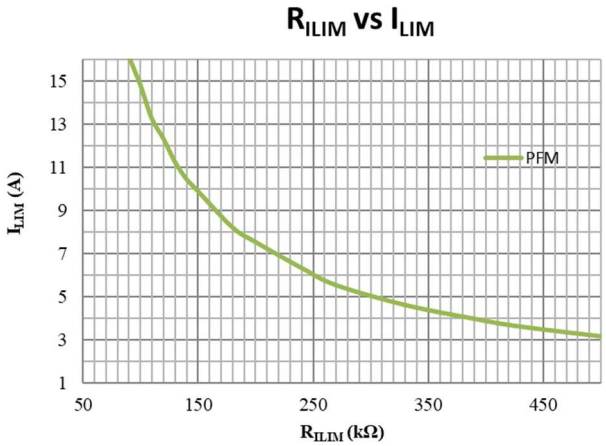
ERROR AMPLIFIER

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
COMP pin sink current	I_{SINK}	V_{FB} = V_{REF} +200 mV, V_{COMP} = 1.5 V		20		uA
COMP pin source current	I_{SOURCE}	V_{FB} = V_{REF} –200 mV, V_{COMP} = 1.5 V		20		uA
High clamp voltage at the COMP pin	V_{CC_LPH}	V_{FB} = 1 V, R_{ILIM} = 100 kΩ		2.1		V
Low clamp voltage at the COMP pin	V_{CC_LPL}	V_{FB} = 1.4 V, R_{ILIM} = 100 kΩ,		0.95		V
Error amplifier transconductance	G_{EA}	V_{COMP} = 1.5 V		204		uA/V

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
POWER SWITCH						
MOSFET on-resistance	$R_{DS(on)}$	High-side MOSFET		18		mΩ
		Low-side MOSFET		16		mΩ
CURRENT LIMIT						
Peak switch current limit	I_{LIM}	R_{ILIM} = 120 kΩ		12.3		A
		R_{ILIM} = 100 kΩ		14.8		
Reference voltage at the ILIM pin	V_{ILIM}			1.204		V
SWITCHING FREQUENCY						
Switching frequency	f_{SW}	R_{FREQ} = 200 kΩ, V_{IN} = 3.7V, V_{OUT} = 12V		520		kHz
Minimum on-time	t_{ON_min}	R_{FREQ} = 200 kΩ, V_{IN} = 3.7V, V_{OUT} = 12V		230		ns
THERMAL SHUTDOWN						
Thermal shutdown threshold	T_{SD}			160		℃
Thermal shutdown hysteresis	T_{SD_HYS}			20		℃

■ TYPICAL OPERATING CHARACTERISTICS

Condition: L = 2.2uH, R_{ILIM} = 100k， R_{FREQ} = 240k, RC (1Ω+3.3nF) from SW to GND, otherwise specified.



■ APPLICATION INFORMATION

1 Operation

The synchronous boost converter HT71778 operates at a quasi-constant frequency pulse width modulation (PWM) in moderate to heavy load condition. In light load condition, the HT71778 implements in PFM mode.

同步升压芯片 HT71778 在重载时，工作在类似固定频率的 PWM 调制。在轻载时，其工作在 PFM 模式。

2 Adaptive Audio-Tracking Power Supply (SN, INL, INR and RT pin)

The output voltage can adaptively change in accordance with the audio signal that is input through INL and INR terminal. Therefore, the device can provide an adaptive audio-tracking power supply for audio power amplifier so that the system can always keep high efficiency in the whole output power range, see as the following picture.

The minimum and maximum output voltage can be set by SN terminal for different applications, see as the following table.

HT71778 的输出电压能根据音频信号大小（由 INL 和 INR 端输入）而动态变化，即其能提供一个动态跟随音频的供电给音频功放，如下图，从而使系统在整个功率范围内保持高效率。

HT71778 的最小输出电压和最高输出电压由 SN 端口设置决定，如下表。

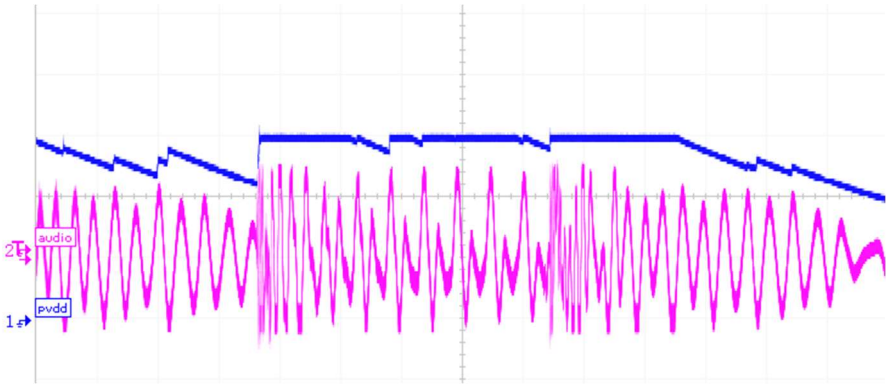


Figure 1 Adaptive Audio-Tracking Power Supply

Table 1 SN Terminal Setting

Mode	R_{SN} (Connect between SN pin and GND)	Output Voltage		Applications
		Min voltage (Typ.)	Max voltage (Typ.)	
1S-1	0R	5.0V	12.0V	One-cell battery (单节锂电电压输入)
2S-1	100k	9.0V	15.0V	Two-cell battery in series with low output voltage requirement (双节锂电串联电压输入，低输出电压需求)
2S-2	NC	9.0V	18.0V	Two-cell battery in series with high output voltage requirement (双节锂电串联电压输入，高输出电压需求)

The audio signal source (also the input audio signal of the audio power amplifier) should be input into INL and INR terminal via DC-cut capacitors (C_{IN}) and external input resistors (R_{IN}). If differential audio signal is input into audio power amplifier, only one terminal of the differential audio input pair is input into INL and INR via C_{IN} and R_{IN}.

The C_{IN} is recommended to be 1uF, and the R_{IN} can be determined by:

音频信号源（也即音频功放的音频输入信号）需要通过隔直电容 C_{IN} 和外置输入电阻 R_{IN} 接入 INL 和 INR。如果音频功放输入信号采用差分信号，则只需将差分对中的一端信号通过 C_{IN} 和 R_{IN} 接入 INL 和 INR。

C_{IN} 推荐使用 1uF，R_{IN} 则由以下公式得到：

$$R_{IN} = \frac{600k}{C \times Av} + 10k \quad \text{, PA is single-ended input} \qquad \text{Equation 1}$$

$$R_{IN} = \frac{1200k}{C \times Av} + 10k \quad \text{, PA is differential input} \qquad \text{Equation 2}$$

Where Av is the amplification factor of the audio power amplifier (PA), C is a constant. Normally C = 1.5, Bigger C or smaller R_{IN} will get a higher output voltage to track the audio signal, so that the power amplifier is more unlikely to be clipping with an instant peak music, somehow the system efficiency is decreased. The following table shows some RIN values in different typical applications.

其中 Av 是音频功放的放大倍数，C 是一个常数。更大的 C、更小的 R_{IN} 能够得到相对于音频信号所需更高的电压， 在瞬时大音乐信号时功放更不易削顶失真，但系统效率会下降。下表是典型应用中的 R_{IN} 推荐值。

Table 2 Maximum Output Voltage Settings

Av (Gain) of PA	R_{IN}	
	Single-ended input PA	Differential input PA
10 (20dB)	50k	90k
20 (26dB)	30k	50k
40 (32dB)	20k	30k

If the audio signal source has only one channel, then the only one channel of the signal inputs both INL and INR via C_{IN} and R_{IN}.

The RT terminal is used for setting the release time of the audio tracking, see as the following picture. The recommended network for RT terminal can be seen in TYPICAL APPLICATION.

如果音频信号源只有一个通道，则该通道信号同时通过 C_{IN} 和 C_{IN} 输入到 INL 和 INR。

RT 引脚可用来设置音频跟踪的释放时间，如下图所示。推荐的 RT 网络值，可以参见典型应用。

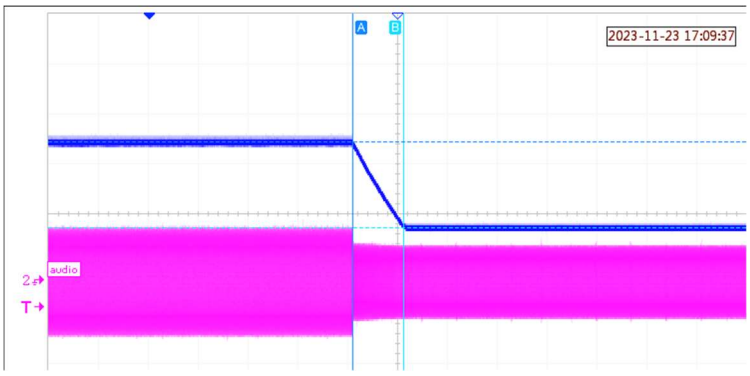


Figure 2 IIS Audio Data Format Timing

3 Enable and Startup (EN and SS pin)

The HT71778 has an adjustable soft start function to prevent high inrush current during start-up. To minimize the inrush current during start-up, an external capacitor, connected to the SS pin and charged with a constant current, is used to slowly ramp up the internal positive input of the error amplifier. The larger the capacitance at the SS pin, the slower the ramp of the output voltage and the longer the soft-start time. A 47-nF capacitor is usually sufficient for most applications.

When the EN pin is pulled into logic low, the HT71778 goes into the shutdown mode and stops switching. Only when EN pin is pulled into logic high, the HT71778 works.

HT71778 具有软起动功能，防止启动时的高浪涌电流。SS 脚需外界电容到地，一般 47nF，SS 使用恒定电流对该电容充电，电容越大，充电时间越长，即软起动时间越长。

EN 为芯片使能脚，EN 拉低，芯片进入关断模式，停止开关；EN 拉高，芯片进入工作状态。

4 Adjustable Switching Frequency (FSW pin)

This device features a wide adjustable switching frequency ranging from 200 kHz to 1.0MHz. The switching frequency is set by a resistor (R_{FREQ}) connected between the FSW pin and the SW pin of the HT71778. The switching frequency can be calculated by:

HT71778 的开关频率可通过 FSW 与 SW 之间的电阻 R_{FREQ} 调节，范围 200 kHz 到 1.0MHz。

$$R_{FREQ} = \frac{4\times(\frac{1}{f_{SW}} - t_{DELAY}\times\frac{V_{OUT}}{V_{IN}})}{C_{FREQ}}$$ Equation 3

where

- R_{FREQ} is the resistance connected between the FSW pin and the SW pin.
- C_{FREQ} = 25.1pF.
- f_{SW} is the desired switching frequency.
- t_{DELAY} = 201.8ns.
- V_{IN} is the input voltage.
- V_{OUT} is the output voltage.

其中：

- R_{FREQ}即SW和FSW间电阻；
- C_{FREQ} = 25.1pF.
- f_{SW}即开关频率.
- t_{DELAY} = 201.8ns.
- V_{IN} 是输入电压.
- V_{OUT} 是输出电压。

5 Adjustable Peak Current Limit (ILIM pin)

To avoid an accidental large peak current, an internal cycle-by-cycle current limit is adopted. The low-side switch is turned off immediately as soon as the switch current touches the limit. The peak switch current limit can be set by a resistor (RILIM) at the ILIM pin to ground. The relationship between the current limit and the resistance is as follows:

芯片采用逐周期电流限制，避免意外的大峰值电流。当开关电流达到设置的限流值，低侧开关管立即断开。峰值开关电流限制（限流值 ILIM）可以通过 ILIM 引脚对地接 R_{ILIM} 进行设置。限制值 ILIM 和电阻 R_{ILIM} 之间的关系如下：

$$I_{LIM} = \frac{1500000}{R_{ILIM}}$$ Equation 4

6 Inductor Selection (SW pin)

The inductor is the most important component in switching power regulator design. Three most important specifications to the performance of the inductor are the inductor value, DC resistance, and saturation current.

To be simplified, the inductor value can be set as 2.2uH which can be used in most cases.

The rated current, especially the saturation current should be larger than the peak current during the whole operation. The peak current can be calculated as follows.

电感是该芯片的关键器件，影响性能的主要是其电感值，直流阻抗，饱和电流。

对于电感值，使用 2.2uH 的电感可以满足大部分应用。

对于额定电流，特别是饱和电流，必须大于所有工作条件下的最大峰值电流，最大峰值电流计算如下：

$$I_{Lpeak} = I_{DC} + \frac{I_{PP}}{2} \quad \text{Equation 5}$$

$$I_{DC} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times \eta} \quad \text{Equation 6}$$

$$I_{PP} = \frac{1}{L \times (\frac{1}{V_{OUT} - V_{IN}} + \frac{1}{V_{IN}}) \times f_{SW}} \quad \text{Equation 7}$$

Boost converter efficiency is affected significantly by the inductor's DC resistance (DCR), equivalent series resistance (ESR) at the switching frequency, and the core loss. An inductor with lower DCR and ESR would increase the efficiency significantly.

The inductor should be placed as close as possible to the SW pin. For a lower EMI radiation, connecting a resistor and a capacitor in series to the ground would be helpful. 1ohm resistor and 3.3nF capacitor would be recommended in most cases.

升压效率受电感的直流阻抗、开关频率下的等效 ESR、磁心损耗等影响。选择小的 DCR 和 ESR 可提升效率。

电感应尽可能靠近 SW 引脚放置，并靠近 SW 引脚放置 1ohm 串联 3.3nF 到地。

7 Input Capacitor Selection (VIN, VCC pin)

For good input voltage filtering and small voltage ripple, we recommend low-ESR capacitors of 1uF//10uF//10uF//220uF ("//" represents paralleled) be placed as close as possible to the inductor.

The VIN pin is the power supply for the HT71778, a 1uF paralleled with 10uF ceramic capacitor should be placed as close as possible to the VIN pin. A resistor of 100R is recommended between input power supply and VIN pin so that the power supply of HT71778 would be more stable. An extensive power supply such as the logic power supply connecting to VIN would be another choice.

The VCC pin is the output of internal LDO. A ceramic capacitor of 2.2uF is required at the VCC pin to get a stable operation of LDO.

为了良好的储能和滤波以及减小电压波动，建议电源输入端使用 1uF//10uF//10uF//220uF 组合，放置在靠近电感的大电流路径上。

VIN 脚是 HT71778 的电源供电端，1uF 并联 10uF 对地电容放置在靠近 VIN 脚。输入电源和 VIN 脚之间可以串联 1 个 100R 电阻，已稳定 VIN 电压。VIN 还可以有系统中的逻辑电源供电。

VCC 是内部 LDO 输出，接 2.2uF 电容到地。

8 Output Capacitor Selection (VOUT pin)

To be simplified, we recommend low-ESR capacitors of 1uF//10uF//10uF//470uF ("//" represents paralleled) be placed as close as possible to VOUT pin for small output voltage ripple.

In detail, for the require output voltage ripple, use the following equations to calculate the minimum required effective capacitance C_{OUT}

简单来说，升压输出到地滤波电容建议使用 1uF//10uF//10uF//470uF 的组合，尽量靠近 Vout 引脚放置。

具体的，可以根据需要的输出电压纹波，得到需要的输出电容值：

$$V_{ripple\_dis} = \frac{(V_{OUT} - V_{IN_{MIN}}) \times I_{OUT}}{V_{OUT} \times f_{SW} \times C_{OUT}}$$ Equation 8

$$V_{ripple\_ESR} = I_{Lpeak} \times R_{C\_ESR}$$ Equation 9

Where

- Vripple_dis is output voltage ripple caused by charging and discharging of the output capacitor.
- Vripple_ESR is output voltage ripple caused by ESR of the output capacitor.
- V_{IN_MIN} is the minimum input voltage of boost converter..
- V_{OUT} is the output voltage..
- I_{OUT} is the output current.
- I_{Lpeak} is the peak current of the inductor.
- f_{SW} is the converter switching frequency.
- R_{C_ESR} is the ESR of the output capacitors.

其中：

- Vripple_dis 是对电容充放电引起的输出电压纹波.
- Vripple_ESR 是输出电容ESR引起的输出电压纹波.
- V_{IN_MIN} 是最小输入电压.
- V_{OUT} 是输出电压.
- I_{OUT} 是输出电流.
- I_{Lpeak} 是电感峰值电流.
- f_{SW} 是开关频率.
- R_{C_ESR} 是输出电容 ESR.

9 Loop Stability (COMP pin)

The HT71778 requires external compensation, which allows the loop response to be optimized for each application. The COMP pin is the output of the internal error amplifier. An external compensation network comprised of resister R_C, ceramic capacitors C_C and C_P is connected to the COMP pin.

To be simplified, R_C is 56kΩ, C_C is 3.3nF, and C_P can be floating. But notice that this setting can only be adopted in most cases. In detail, the compensation network parameters can be calculated as follows.

(1) Set the cross over frequency, f_c

The first step is to set the loop crossover frequency, f_C. The higher crossover frequency, the faster the loop response is. It is generally accepted that the loop gain cross over no higher than the lower of either 1/10 of the switching frequency, f_{SW}, or 1/5 of the RHPZ frequency, f_{RHPZ}. It's proper to use a fixed parameter of 10kHz for f_C.

HT71778 需要外部补偿，在 COMP 引脚外接 Rc, Cc, Cp。简单来说，R_C=56kΩ, C_C=3.3nF，C_P 悬空可以满足大部分应用。以下是补偿网络的计算过程：

(1) 设置交叉频率 fc

Fc 越大，响应越快。一般其设置为开关频率的 1/10 或 1/5 的 f_{RHPZ}，或直接为 10kHz.

$$f_{RHPZ} = \frac{R_O \times (1-D)^2}{2\pi \times L}$$ Equation 10

(2) Set the compensation resistor, R_C.

(2) 设置补偿网络 Rc

$$R_C = \frac{2\pi \times V_{OUT} \times R_{sense} \times f_C \times C_O}{(1-D) \times V_{REF} \times G_{EA}}$$ Equation 11

(3) Set the compensation resistor, C_C.

(3) 设置补偿网络 Cc

$$C_C = \frac{R_O \times C_O}{2 \times R_C}$$ Equation 12

(4) Set the compensation resistor, C_P.

(4) 设置补偿网络 Cp

$$C_P = \frac{R_{ESR} \times C_O}{R_C}$$ Equation 13

If the C_P is less than 10pF, it can be left open.

如果 Cp 小于 10pF，可以悬空。

- R_O is the output load resistance.

其中 Ro 是输出负载；

- D is the switching duty cycle. 1 - D = V_{IN} / V_{OUT}

D 是占空比，1 - D = V_{IN} / V_{OUT}

- R_{sense} is the equivalent internal current sense resistor, which is 0.091 Ω.

R_{sense} 是内部等效电流感应电阻，0.076 Ω

- C_O is output capacitor.

Co 是输出电容

- V_{REF} is the reference voltage at the FB pin, which is 1.204V.

VREF 是 FB 电压，1.204V

- G_{EA} is the amplifier's transconductance, which is 204uA/V.

G_{EA} 是跨导，204uA/V

- R_{ESR} is the equivalent series resistance of the output capacitor.

R_{ESR} 是输出电容的等效串联电阻。

10 Selecting the Bootstrap Capacitor (BOOT pin)

The bootstrap capacitor (C_{BST}) between the BOOT and SW pin supplies the gate current to charge the high-side FET device gate during each cycle's turn-on and supplies charge for the bootstrap capacitor. The recommended value of the bootstrap capacitor is 0.1μF to 1μF. C_{BST} should be a good quality, low ESR, ceramic capacitor located at the pins of the device to minimize potentially damaging voltage transients caused by trace inductance. A value of 0.1μF can be used in most cases.

BOOT 和 SW 之间需放置一个 C_{BST} 电容，用于高端管开启时的栅极驱动。一般使用 0.1uF~1uF，大部分情况下可使用 0.1uF 电容。

11 Protection Function

11.1 Under-voltage Lockout (UVLO)

The UVLO circuit prevents the device from malfunctioning at low input voltage and the battery from excessive discharge. The HT71778 has both VIN UVLO function and VCC UVLO function. It disables the device from switching when the falling voltage at the VIN pin trips the UVLO threshold V_{IN_UVLO}, which is typically 2.3V. The device starts operating when the rising voltage at the VIN pin is 200mV above the V_{IN_UVLO}. It also disables the device when the falling voltage at the VCC pin trips the UVLO threshold V_{CC_UVLO}, which is typically 2.1V.

HT71778 具有 VIN 和 VCC 欠压保护。当 VIN 小于 V_{IN_UVLO}（典型 2.3V）时，器件停止开关，直至 VIN 大于 V_{IN_UVLO}（典型 2.5V）,器件重新工作。当 VCC 小于 V_{CC_UVLO}（典型 2.1V）时，器件同样停止工作。

11.2 Over-voltage Protection

If the output voltage at the VOUT pin is detected above 22 V (typical value), the HT71778 stops switching immediately until the voltage at the VOUT pin drops the hysteresis value lower than the output overvoltage protection threshold. This function prevents overvoltage on the output and secures the circuits connected to the output from excessive overvoltage.

当 VOUT 电压高于 22V (典型值)，HT71778 停止工作，直到 VOUT 低于 21.5V （典型值）。

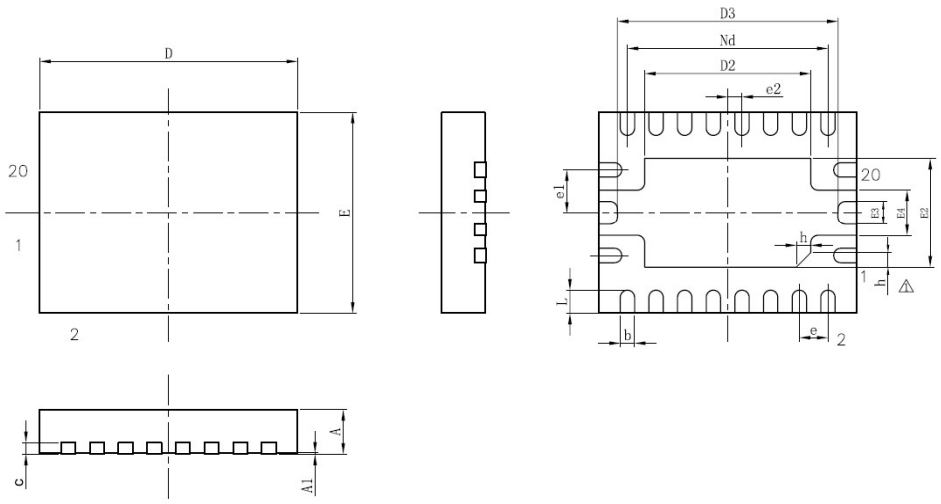
11.3 Thermal Shutdown

A thermal shutdown is implemented to prevent damages due to excessive heat and power dissipation. Typically, the thermal shutdown happens at a junction temperature of 160°C. When the thermal shutdown is triggered, the device stops switching until the junction temperature falls below typically 140°C, then the device starts switching again.

芯片具有过温关断保护功能。当结温大于160°C（典型值），芯片关断；当结温低于 140°C（典型值），芯片恢复工作。

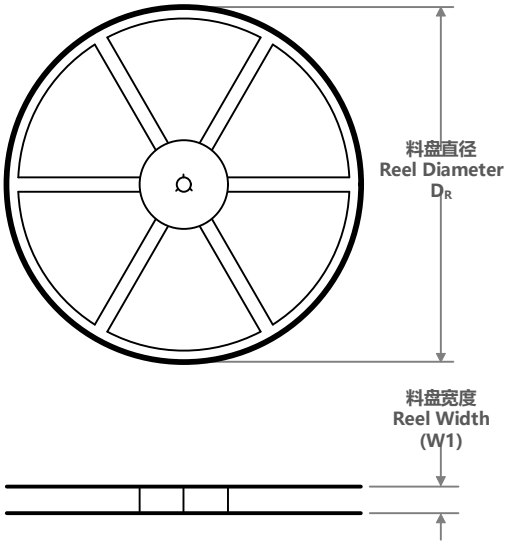
■ PACKAGE OUTLINE

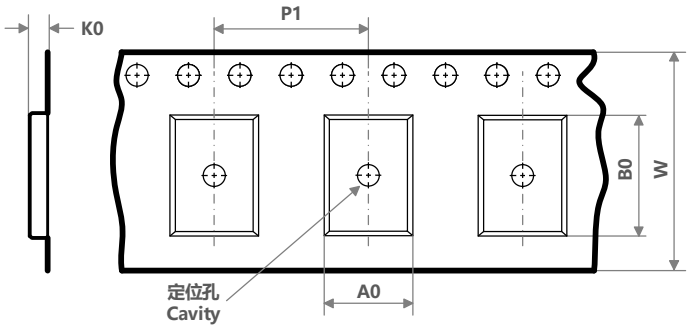
DNE (QFN3.5×4.5-20L)



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0. 70	0.75	0. 80
A1	—	0.01	0. 05
b	0. 18	0.25	0. 30
c	0. 18	0.20	0. 25
D	4. 40	4. 50	4. 60
D2	3. 10	3. 20	3. 30
D3	3. 85REF		
e	0. 50BSC		
e1	0. 75BSC		
e2	0. 25BSC		
Nd	3. 50BSC		
E	3. 40	3. 50	3. 60
E2	2. 10	2. 20	2. 30
E3	0. 35REF		
E4	0. 75REF		
L	0. 35	0.40	0. 45
h	0. 20	0.25	0. 30
载体尺寸 (mil)	134*94		

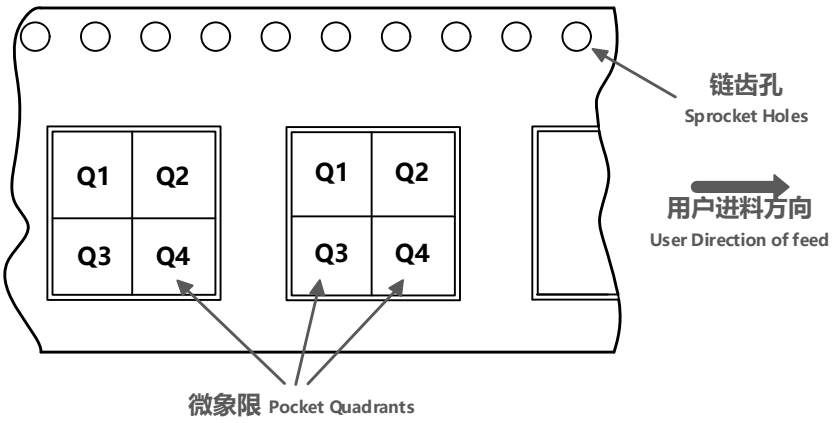
■ TAPE AND REEL INFORMATION





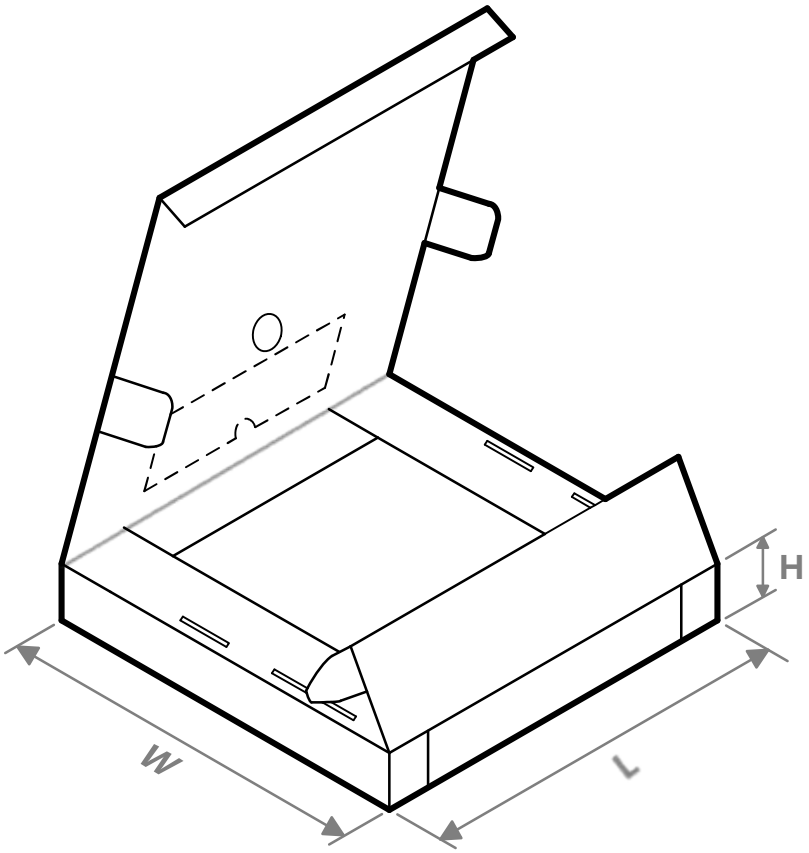
A0	Dimension designed to accommodate the component width; 料槽宽度
B0	Dimension designed to accommodate the component length; 料槽长度
K0	Dimension designed to accommodate the component thickness; 料槽厚度
W	Overall width of the carrier tape; 载带整体宽度
P1	Pitch between successive cavity centers; 相邻槽中心间距

编带 PIN1 方位象限分配
Quadrant Assignments for Pin1 Orientation in Tape



器件料号 Part No.	封装类型 Package Type	封装标识 Package Code	引脚数 Pins	SPQ	料盘直径 D_R(mm)	料盘宽度 W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 象限 Quadrant
HT71778DNER	QFN3.5 ×4.5	DNE	20	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

■ TAPE AND REEL BOX INFORMATION



器件料号 Part No.	封装类型 Package Type	封装标识 Package Code	引脚数 Pins	SPQ	长度 Length (mm)	宽度 Width (mm)	高度 Height (mm)
HT71778DNER	QFN3.5×4.5	DNE	20	TBD	TBD	TBD	TBD

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