HUAWEI Module

Power Supply Design Guide

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About This Document

Revision History

Document Version	Date	Chapter	Descriptions
01	2011-10-12		Creation
02	2014-11-07	2.1	Updated the power pin of HUAWEI modules
		2.3	Updated power supply requirements in not 2G mode
		3.3	Added the type of the recommend capacitor with high capacity
		4.4	Added the type of the filtering capacitor

Contents

1 Overview

This document mainly describes the power supply design for Huawei modules. This document also provides Huawei modules' requirements for power supplies, which can be used as reference for designing power supplies for Huawei modules. This document is composed of four chapters:

- Power Supply Requirements
- Power Supply Design Requirements
- External Power Supply Circuits
- Recommendations for the Layout and Routing of External Power Supply Circuits

2 Power Supply Requirements

2.1 Power Pin Definition

Table 2-1 The power pin of HUAWEI modules

HUAWEI Modules	Power Pin Name	Power Supply Voltage
LGA modules	VBAT	3.3 V–4.2 V (typically 3.8 V)
LCC modules	VBAT	3.3 V–4.2 V (typically 3.8 V)
Mini PCIe modules	VCC_3V3	3.0 V–3.6 V (typically 3.3 V)
M.2 modules	3.3V	3.135 V–4.4 V (typically 3.3 V)

All power supply pins and ground pins must be connected.

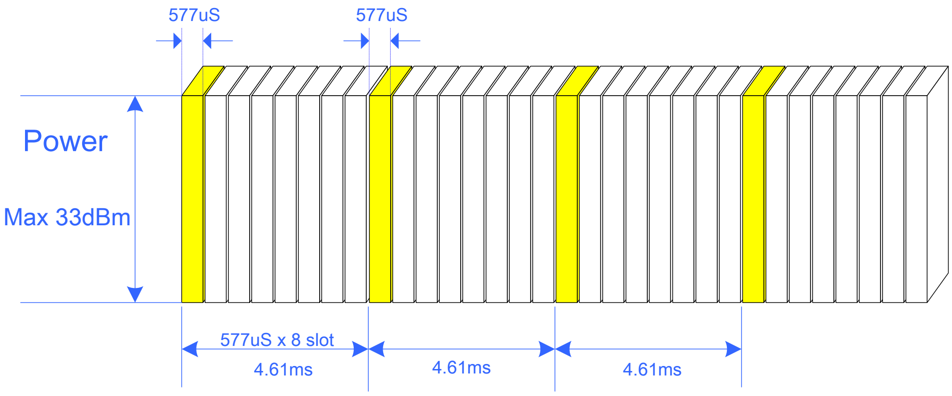
2.2 Power Supply Requirements in 2G Mode

This section describes the electrical characteristics of Huawei modules operating in 2G mode. The power consumption of Huawei modules is related to their transmitted power (the transmitted power is the power that a wireless terminal transmits to a base station, also known as uplink power). The greater the transmitted power, the higher the power consumption.

The Global System for Mobile Communications (GSM) uses time division multiple access (TDMA). Using this method, Huawei modules transmit power only during the time slots allocated by base stations. In the GSM, each transmission period is divided into eight time slots and each time slot lasts 577 µs. Modules transmit power during one of the eight time slots. Therefore, the transmission period is 4.615 ms and the transmission time is 577 µs in each transmission period. This transmission mode of GSM wireless terminals is called "burst". The power transmitted by Huawei modules during the allocated time slots is dependent on the received signal strength. The stronger the received signal strength (the signal strength of the base station), the less the transmitted power. The weaker the received signal strength, the greater the transmitted power. The maximum transmitted power is 33 dBm (GSM-900).

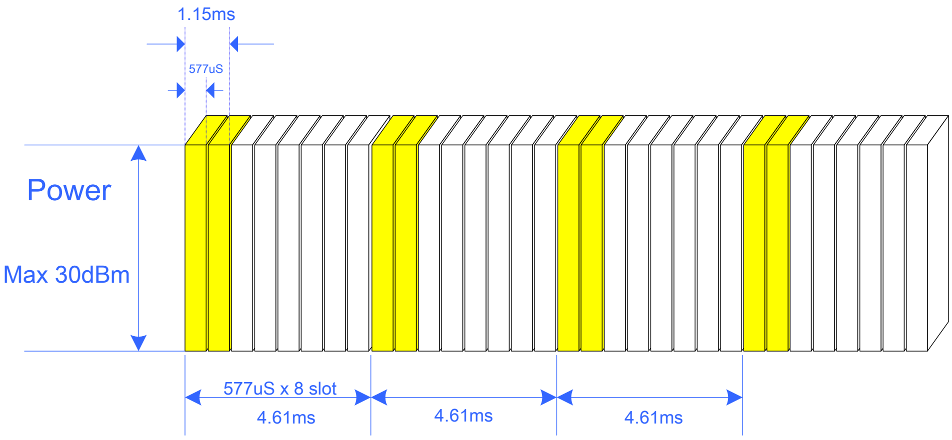
Figure 2-1 illustrates the power transmitting mode in GSM.

Figure 2-1 Power transmitting mode in GSM



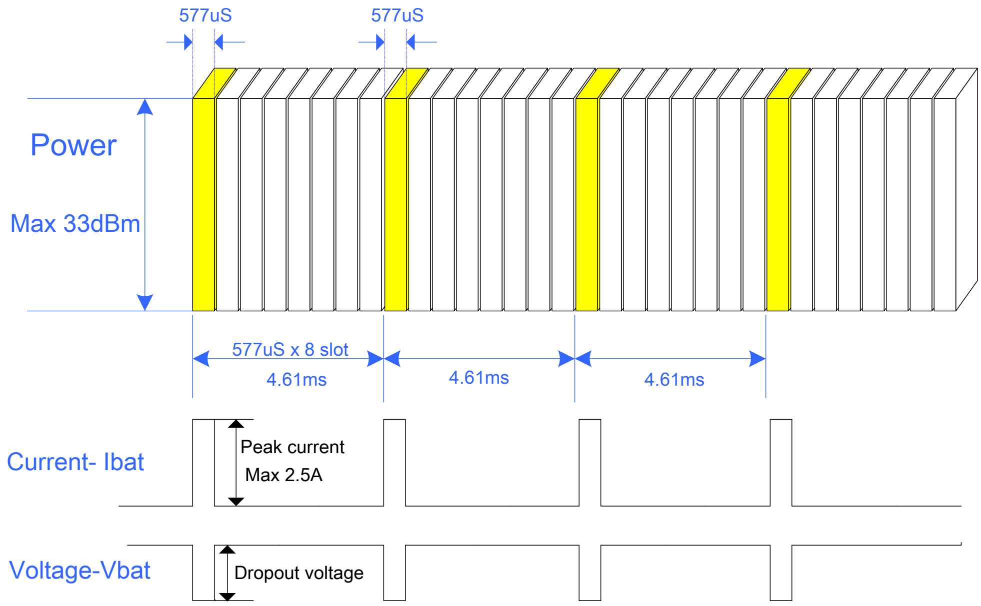
For general packet radio service (GPRS), the uplink transmission uses two or more successive time slots, as illustrated in Figure 2-2 .

Figure 2-2 GPRS uplink transmission



Because of the characteristics of TDMA used in GSM, Huawei modules' power consumption changes periodically with bursts in accordance with the transmission periods, as illustrated in Figure 2-3 .

Figure 2-3 Huawei modules' power consumption changes



We can see from Figure 2-3 that during transmission time slots, the power amplifier (PA) of the module's GSM unit amplifies power for transmission. If the received signal strength is weak, the transmitted power may reach 33 dBm, and the transient electric current supplied to the module can reach 2.5 A (IBAT). As a result, the power supply voltage may drop.

The power supply voltage may drop, if:

- The power supply does not have good transient response performance and its output cannot reach 2 A–3 A within several milliseconds.
- The internal resistor of the power supply (that is, the output impedance of the power interface) is great. When the current is great, the voltage on the resistor reduces outside the range specified by the module.

At the end of a transmission time slot, the PA shuts down, and the electric current and voltage recover until the next transmission time slot comes after 4.615 ms.

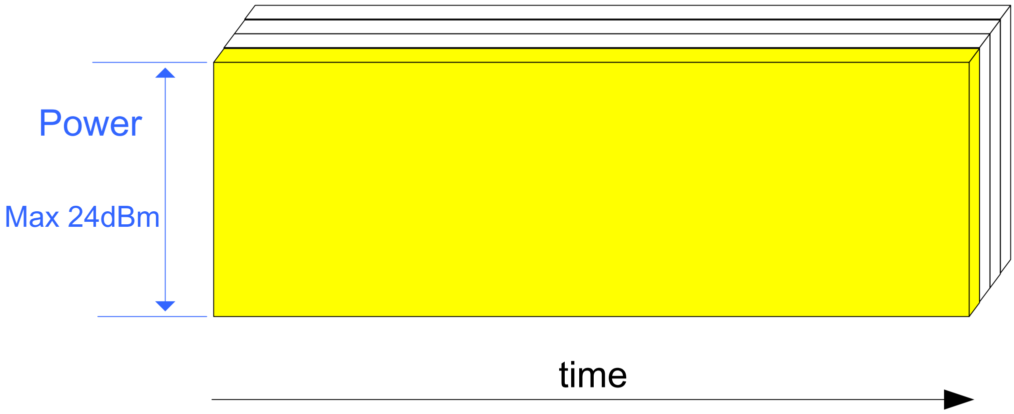
Therefore, Huawei modules operating in 2G mode must have good transient response performance and small internal resistance to prevent voltage drop. Considering the product cost and that Huawei modules can operate within a certain range of voltages, the minimum voltage of the power supply after dropping should not be less than the minimum voltage specified by the module.

2.3 Power Supply Requirements in not 2G Mode

WCDMA and FDD-LTE telecommunications use code division multiple access (CDMA). Therefore, on these networks, the transmitted power is not related to the time.

Figure 2-4 shows the transmitted power of a Huawei module operating on the WCDMA and FDD-LTE network.

Figure 2-4 Transmitted power of the WCDMA and FDD-LTE system



For Huawei modules operating on the WCDMA and FDD-LTE networks, when the transmitted power reaches the maximum transmitted power, the required maximum current from the power supply is approximately 1100 mA. Therefore, power supplies with an average output of at least 1.5 A are required.

TD-SCDMA and TDD-LTE telecommunications use time division multiple access, which is the same as GSM. But the transmitted power of TD-SCDMA and TDD-LTE is much less than that of GSM, so their requirements of the power supply are the same as WCDMA and FDD-LTE.

CDMA telecommunication uses code division multiple access, so its requirement of the power supply is the same as WCDMA and FDD-LTE.

2.4 Power Consumption

Different Huawei modules have different power consumption, depending on their platforms. For specific power consumption specifications and test conditions, refer to the modules' hardware guides.

3 Power Supply Design Requirements

3.1 Introduction to Peripheral Power Supplies

Peripheral power supplies provide power for Huawei modules. For Huawei modules operating in GSM calls and GPRS data transmission on GSM networks, the transmitted power of Huawei modules can reach 33 dBm (2 W). To prevent unacceptable voltages drop, power supplies must have good transient response. These factors must be considered for designing power supplies for Huawei modules.

When designing peripheral power supplies, focus on the following:

- Reducing Internal Resistance
- Adding Energy Storage Capacitors
- Improving Transient Response of the Power Supply IC

3.2 Reducing Internal Resistance

A main method to reduce the internal resistance of peripheral power supplies is to use power supply integrated circuits (ICs) with the ability to output great currents. The greater the output current, the smaller the internal resistance. Power supply ICs with 2.5 A outputs at minimum are recommended.

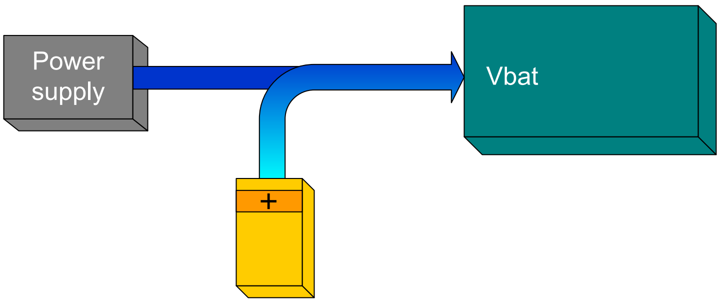
If using low-dropout (LDO) regulators in peripheral power supply ICs, use LDO regulators with low dropout voltages. Because the input currents of LDO regulators are equal to the output currents, LDO regulators with low dropout voltages are equivalent to LDO regulators with small internal resistance.

If using DC-to-DC (DC-DC) converters in peripheral power supply ICs, pay attention to the following switch parameters in the manuals: Negative Channel Metal-oxide Semiconductor (NMOS) Switch On Resistance and Positive Channel Metal-oxide Semiconductor (PMOS) Switch On Resistance. The switch on resistance must be small. If peripheral diodes are required for the DC-DC power supply ICs, use Schottky diodes with low voltage drop. The equivalent series resistance (ESR) of peripheral power inductors for DC-DC power supply ICs must be as small as possible. Minimize the power loss and internal resistance in the DC-DC power supply ICs.

3.3 Adding Energy Storage Capacitors

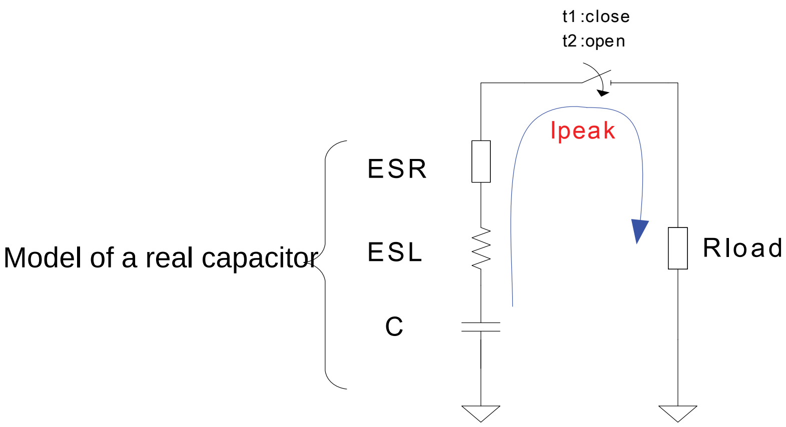
If a peripheral power supply cannot provide a transient output of 2 A currents, you must add a capacitor with sufficient capacitance to storage energy for current compensation. See Figure 3-1 .

Figure 3-1 Add and energy storage capacitor



A real capacitor is equivalent to the combination of one ideal capacitor (C), one equivalent series inductance (ESL) and one ESR that are connected in series. Figure 3-2 illustrates the model of a real capacitor.

Figure 3-2 Model of a real capacitor



Assume that the original voltage on the ideal capacitor is **Vo** and the peak current is $\mathbf{I_{peak}}$. When the power supply switch is turned off, the capacitor starts to release electric charge. Before the switch is turned on, the voltage on the load ($\mathbf{V_{load}}$) can be calculated using the following formula:

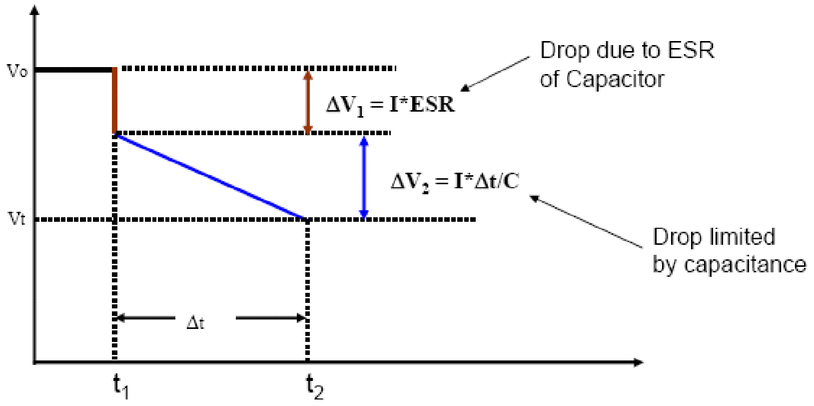
V_{load} = Vo – (ESR x I_{peak}) – (ESL x $I_{peak}/\Delta tL$) – (I_{peak} x $\Delta t/C$)

= Vo – V_{ESR} – V_{ESL} – V_C.

In the previous formula, the voltage drop (V_{ESL}) caused by the ESL only occurs and exists at moments when the switch is turned on or off. $\mathbf{\Delta t}$ is the time for the current changes from 0 to $\mathbf{I_{peak}}$, usually lasting several µs. When the current is stable, V_{ESL} is 0. The ESL of ceramic capacitors and tantalum capacitors is very small and can be ignored. The ESL of aluminum electrolytic capacitors is large because aluminum electrolytic capacitors have long pins. Therefore, aluminum electrolytic capacitors are not recommended. In addition, note that ESL also exists on the traces connecting the capacitor pins and the power supply. To reduce the voltage drop caused by ESL, the traces should be as wide as possible.

Unlike V_{ESL}, V_{ESR} and V_C cause voltage drop throughout the peak current duration. Figure 3-3 shows a simple analysis of V_{ESR} and V_C.

Figure 3-3 Simple analysis of V_{ESR} and V_C



V_{drop} = (ESR x I_{peak}) + (I_{peak} x Δt/C)

From the previous formula, we can infer that the greater the ESR of capacitors, the greater the voltage drop. Therefore, capacitors with small ESR should be used. We can also infer that the smaller the capacitance, the greater the voltage drops. Therefore, capacitors with large capacitance should be used.

Capacitors with ESR smaller than 0.1 Ω should be used (note that aluminum electrolytic capacitors have large ESR and are not recommended).

The following describes how to calculate the capacitance of the decoupling capacitor used in the power supply for a Huawei module operating on a GSM network. Assume that **t1** is the time when the voltage starts to drop, which is also the time when the PA of the Huawei module starts amplifying power. Assume that **t2** is the time when the PA of the Huawei module stops amplifying power. Then the duration between **t1** and **t2** is a time slot during which the power is transmitted. For GSM, Δt = t2 – t1 = 577 µs, which is equal to a transmission time slot. For GPRS class 10, Δt = t2 – t1 = 577 µs x 2 = 1.15 ms, corresponding to two transmission time slots.

Provided that a capacitor with 0.1 Ω ESR is used, then I_{peak} = 2.5 A (at maximum power) and Δt = 1.15 ms.

Then the voltage drop caused by ESR is:

V_{ESR} = ESR x I_{peak} = 0.1 Ω x 2.5 A = 0.25 V.

The discharge process of capacitors is a differential process, so:

V_c = I_{peak} x Δt/C = 2.5 A x 0.00115/C = 0.0029/C.

V_{drop} = 0.25 + 0.0029/C.

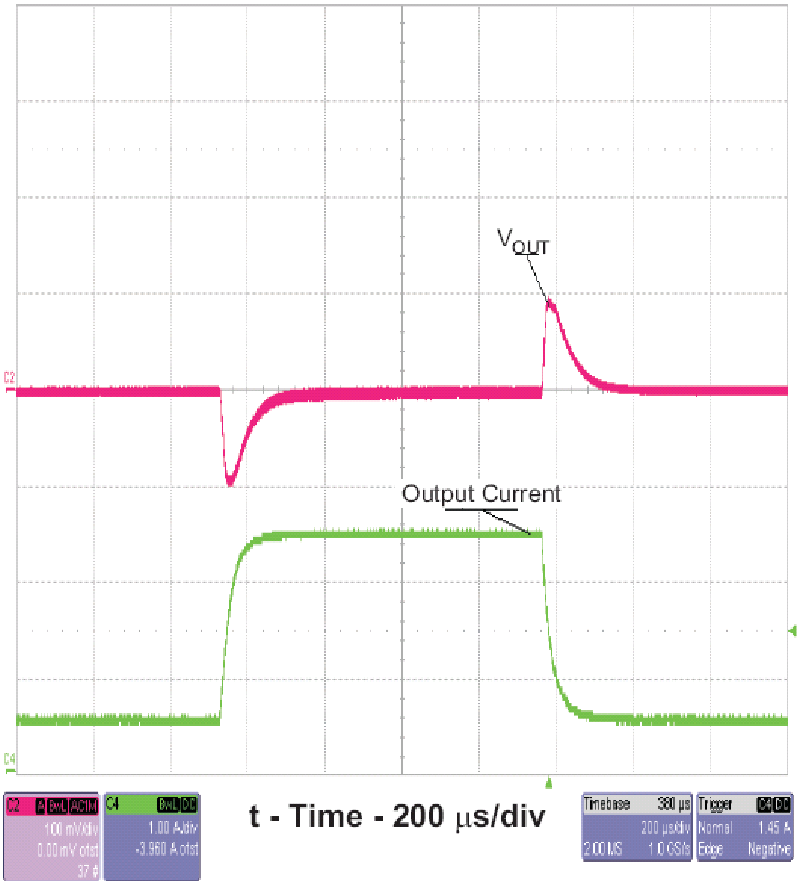
Provided that the allowed maximum V_{drop} is 0.3 V, then C = 58 mF.

Obviously, 58 mF is too large. This is the result of a model in which the voltage drop is compensated only by the capacitor and the power supply IC is ignored. The previous calculation should be revised based on the conditions in real application.

The result also reveals that the ESR must be smaller. Currently, the minimum ESR of tantalum capacitors is about 0.05 Ω. If smaller ESR is required, use capacitors connected in parallel. For example, if we use AVX's TCJB157M006R0070 (150 µF, 6.3 V; nominal ESR: 0.07 Ω) and connect ten such capacitors in parallel, then the capacitance of these ten capacitors is equivalent to 1500 µF and the ESR is equivalent to 0.007 Ω.

Δt is related to the transient response duration of the power supply IC. Provided that the transient response duration of the power supply IC is 100 µs (that is, the power supply IC can output a 2 A current in 100 µs), then the valid period for current compensation from the capacitors is 100 µs. Figure 3-4 shows the transient response performance of a power supply IC.

Figure 3-4 Transient response performance of a certain power supply IC



From Figure 3-4 we can discern that when the transient current suddenly reaches 2 A, the response duration is about 50 µs. Therefore, the capacitors need to compensate the current only during this 50 µs. Obviously, **Δt** is approximately equal to the transient response duration of the power supply IC.

Figure 3-5 Transient response duration

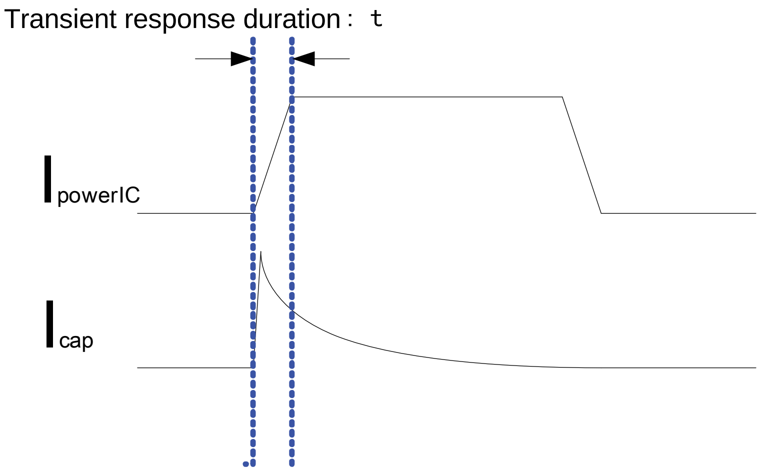


Figure 3-5 illustrates that the peak current is provided by the compensation current ($\mathbf{I_{cap}}$) from the capacitors when the power supply IC is in the transient response duration. After the transient response duration, the capacitors can stop the output current. Note that Figure 3-5 does not consider the case that the power supply IC will charge the capacitors after the transient response duration.

In conclusion, if ten 150 μF capacitors are connected in parallel and Δt = 100 μs, then:

$$V_{drop} = (ESR \times I_{peak}) + (I_{peak} \times \Delta t/C)$$

$$= (0.007 \times 2.5\ A) + (2.5\ A \times 0.0001/0.0015)$$

$$= 0.184\ V$$

V_{drop} is smaller than 0.3 V, meeting the requirement.

NOTE

The previous calculation does not consider the transient response of the component that supplies power to the power supply IC. Therefore, **Δt** should have a greater value in actual applications.

From the previous description, we can see that the voltage drop is dependent on the ESR, transient response duration of the power supply (**Δt**), and capacitance of the capacitors. Therefore, the capacitance, ESR, ESL and transient response duration must be taken into account during the power supply design.

For different network modes, it is all recommended to use four (at least two) TDK ceramic capacitors (C3216X5R0J107MT0A0N with 1206 package). Its capacitance is 100 μF and withstand voltage is 6.3 V.

3.4 Improving Transient Response of the Power Supply IC

In actual application scenarios, the transient response duration of peripheral power supply ICs must be determined. Designers need to obtain the information about the transient response duration from the manual of the power supply ICs to be used. The shorter the transient response duration, the smaller the capacitance of energy storage capacitors can be.

Connecting a large capacitor to the input to the power supply IC can also improve the transient response of the IC. If the transient response of the component that supplies power to the power supply IC is slow, the transient power supply cannot be ensured even though the power supply IC has fast transient response.

4 External Power Supply Circuits

4.1 Choosing the Power Supply IC

Huawei modules can be used in many application scenarios. Different application scenarios have different requirements. Therefore, the following requirements are provided for reference only.

- Requirements for DC-DC converters

  Currents of modules operating in GSM mode changes a lot in a very short moment, and the input voltages of modules also fluctuate greatly. Therefore, DC-DC converters selected must have fast transient response.

- Operating temperature

  Pay attention to the ambient temperature in the operating environment of modules. Make sure that the ambient temperature is appropriate. It is not recommended that the modules be used under temperature exceeding their rated operating temperature.

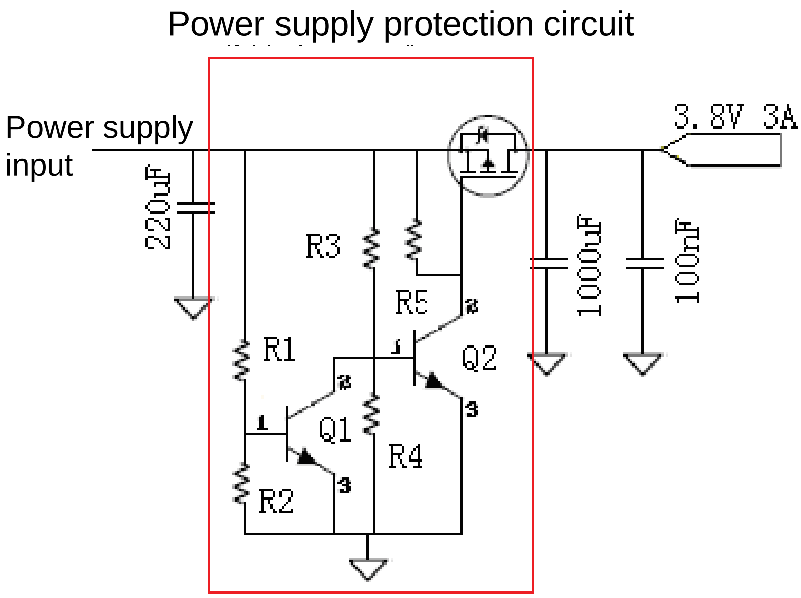
- Derate the power supplies' voltages and currents before using them (85% of original ratings is recommended).

  Either DC-DC converters or LDO regulators can be used for supplying power to Huawei modules.

4.2 Power Supply Protection

The components of Huawei modules, such as the PA, are designed for using one Li-ion battery. These components are sensitive to high voltages. To provide stable voltages, two-stage power supplies are preferred, that is, reduce the voltages output from DC-DC power supply ICs before they are input to LDO regulators; then LDO regulators supply power to modules. If two-stage power supplies cannot be used due to environmental restrictions, protection should be provided for the power supply systems of modules. Figure 4-1 shows a power supply protection circuit.

Figure 4-1 Power supply protection circuit



When the input voltages are within the normal range:

Use the 3.8 V input voltage as an example. The voltage on electrodes of Q1 is obtained from the voltage split by R1 and R2. Make sure that the Q1 electrode voltage is not high enough to turn on Q1. The voltage on electrodes of Q2 is obtained from the voltage split by R3 and R4. Make sure that the Q2 electrode voltage is high enough to turn on Q2. After Q2 is turned on, the PMOS transistor on the main power supply line is turned on and the power is supplied to the module.

When the input voltages are not within the normal range:

Use the 4.3 V input voltage as an example. The voltage on electrodes of Q1 is obtained from the voltage split by R1 and R2. Make sure that the Q1 electrode voltage is high enough to turn on Q1. Make sure that the Q2 electrode voltage is not high enough to turn on Q2 after Q1 is turned on. After Q2 is turned off, the PMOS transistor on the main power supply line is turned off. This provides overvoltage protection for the module.

NOTE

Figure 4-1 is a schematic. Except the components marked with parameters, all components in the schematic must be selected based on specific applications. When selecting components, consider the temperature impact on the turn-on voltages for the base and emitter of a triode.

4.3 Power-on and Power-off Sequences

For Huawei modules, the power-on and power-off sequences are more important. Before the modules are completely powered on, do not perform controls and communications of modules, and do not apply high voltages to the modules' control signals; doing so may cause the modules cannot power on or power off.

4.4 Choosing the Filtering Capacitor

The energy storage capacitors with high capacity are recommended to use at least three TDK ceramic capacitors (C3216X5R0J107MT0A0N with 1206 package). Its capacitance is 100 μF and withstand voltage is 6.3 V.

And according to the circuit recommended by HUAWEI, capacitors with different capacity (such as 100 nF, 33 pF and 22 μF) should be added for filtering of different frequencies.

5 Recommendations for the Layout and Routing of External Power Supply Circuits

Recommendations for the layout and routing of external power supply circuits include:

- Arrange the input bypass capacitors for the DC-DC converter as close as possible to the input pin of the power supply IC. Arrange the output capacitors as close as possible to the inductors. This can suppress ripples effectively. Route power supply traces as wide as possible, to meet the requirement for providing great current when the transmitted power is great.
- The filtering capacitor for the VBAT power supply should be as close as to the power pin of the module.
- Connect diodes that can protect against overvoltage and reverse connection to the connector through which external power supply is provided. This can protect power supply circuits in abnormal situations.
- Arrange the inductor as close as possible to the output pins of the power supply IC. The traces connecting the power IC and the inductor must be as short as possible, to avoid switch interference.
- Route all signal traces at least 2 mm away from the area under the power supply IC's power inductors and large-current diodes. Traces of sensitive analog signals and clock signals must be at least 5 mm away from power inductors, to reduce interference.
- Use two different traces for the power ground and the signal ground, and use single-point grounding. Ensure that the current on a ground return does not flow to the signal ground.
- If modules are used in harsh environment, reverse voltage protection is required for external power supply circuits.

6 Acronyms and Abbreviations

Acronym or abbreviation	Expansion
3GPP	3rd Generation Partnership Project
CDMA	Code Division Multiple Access
DC/DC	Direct Current to Direct Current
ESL	Equivalent Series Inductance
ESR	Equivalent Series Resistance
GPRS	General Packet Radio Service
GSM	Global System of Mobile communication
LDO	Low Dropout Regulator
LGA	Land Grid Array
LTE	Long Term Evolution
NMOS	Negative Channal Metal-oxide semiconductor
PA	Power Amplifier
PCB	Printed Circuit Board
PMOS	Positive Channal Metal-oxide Semiconductor
WCDMA	Wideband Code Division Multi Access
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division-Synchronous Code Division Multiple Access