DC Power Supply Ripple and Noise Measurement

With science and technology change rapidly, electronic products category is on increasing day by day and performance was enhancing, which has penetrated each respect of our daily life. Electronic products Internal circuit are highly integrated, computing speed is also faster. The engineers in the design of the next generation of electronic products for ultra-low power (Ultra-Low Power) and faster system clock and the ultimate pursuit of ultra-high data rates, and continued getting low DC voltage power supply, the output voltage accuracy to trend higher.

This trend allows power supply designers face serious challenges, the vast majority of electronic product design teams now need to consider the DC power supply signal integrity issues. Defective switching power supply filter circuit and high-frequency noise generated by the switch-off can cause ripple and noise. This will not only reduce the power efficiency, and may lead to disturbances and failures. In digital circuits, noise DC power supply will also be the system clock and data jitter important contributors.

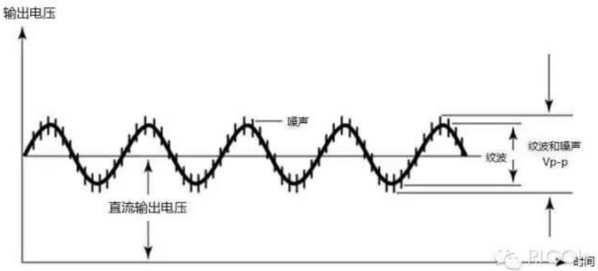
Therefore, to have a measurable DC power testing small changes, and more details can be observed signal precision instruments, but also on how to measure the DC power supply ripple and noise is well aware of the power supply design engineer will be higher basic requirement.

So, in the first, let us first DC power supply ripple and noise to have a preliminary understanding, then do a brief analysis of the measurement frequently encountered or doubt many factors affect the measurement, as well as propose appropriate solutions.

Definition of the power ripple and noise (PARD periodic and random deviation)：

1. Power Ripple:

DC voltage / current, superimposed on the AC component of the DC stabilizing amount, with rms voltage and current (mVrms / mArms) or peak to peak (mVpp / mApp) to represent.



2、 Power Noise：

High-speed switch-off, the voltage / current dramatic changes caused by high-frequency noise.

Ripple and noise is noise on the signal DC level, including periodic and random two components. Among them, the cyclical component of the DC voltage fluctuates slightly up and down, like a horizontal plane as volatility watermarks, so called ripple. Ripple frequency, usually consists of the fundamental switching frequency and harmonics. Noise from the main switch is turned on or off instantly generate high-frequency pulses cause, of course, affect the power of the external electromagnetic field being radiated or conducted interference. Ripple and noise can not be avoided, it can only be through the appropriate design will be reduced to a reasonable level, such as the use of appropriate filter to filter out.

1-Ripple and Noise Disadvantage:

1, lower power efficiency;
2, the electronic products increased heat, reduced product life;
3, strong ripple may cause a surge voltage or current, resulting in burning appliances;
4, causing the electronic products produce harmonic interference grid other equipment is working properly;
5, the interference of digital logic circuits, the circuit affect the normal operation;
6, bring the noise, causing audio, video equipment noise or picture instability.

Ripple and noise sources:
1. Low frequency ripple:
Mainly consists by 50Hz frequency and its harmonics ingredients, small amplitude, easy to filter, linear DC power supply ripple can even do 1mVrms less.
2. High-frequency ripple:
Mainly from the switching circuit, the switch is turned on and off in the process will produce high-frequency interference. At the same time, the diode reverse recovery instant, the equivalent of a resistor and inductor series equivalent circuit, causing resonance. High-frequency transformer leakage inductance, will produce high-frequency interference. High-frequency ripple amplitude is usually larger than the low frequency ripple many.

Under normal circumstances, the size of the high-frequency switching power supply ripple frequency and output filter about. The higher the frequency, the greater the filter inductance and capacitance values, the smaller the output ripple.

3. Common mode noise

Between power devices and heat sink base plate and the transformer primary secondary parasitic capacitance, parasitic inductance of the wire there. When voltage is applied to power devices, resulting in the output of the switching power supply common-mode noise.

4、Switching devices generate ripple

The switch on and off, the inductor current can cause fluctuations in output as RMS current, and therefore the power output can be seen in line with the switching frequency ripple.

5. Ripple and noise control loop adjustment caused

Switching power supply control circuit, not entirely real-time response, there is a certain response time, can not be completely linear regulator. Thereby causing the output voltage will be in an instant fluctuated changes, resulting in the power oscillation, ripple and noise generation.

The main factors affecting power supply ripple and noise test accuracy:

Active oscilloscope probes or standard passive probes are generally 10X attenuation ratio, and connect the oscilloscope, the minimum vertical scale will be from 1mV / div becomes 10mV / div. Ripple and noise measurement results at this time oscilloscope noise floor of a small voltage will influence. Therefore when measuring very weak signals requires the use of 1X passive attenuation ratio of the probe or probe directly to the transmission line signal into an oscilloscope.

2、Probe Grounding Way

Oscilloscope probe: There are ground alligator clip and grounding spring pins two kinds of grounding way can be selected. Ground alligator clip easy to use and, favored by the majority of engineers. But when testing power supply ripple and noise weak signal, we need to consider the impact on the measurement of ground loops. If the ground is too long or ground signal point too far, it may introduce near-field EMI radiated noise high-speed chip.

To reduce the effect of the probe in the vicinity of power by electromagnetic radiation, the following methods can use and reference

① Remove oscilloscope probe cap and ground alligator clip;

② Use grounding spring pins, and ground select signal from the nearest ground point

③ In parallel with the access point probe small electrolytic capacitor or ceramic capacitor

In addition, the oscilloscope probe leads wound on the core in order to reduce the common mode current, this action does not affect the differential voltage test, but will reduce the common mode current measurement error caused by the common mode inductance. In isolated power supply, the common mode current is set by the probe ground lead of the current generation. This makes the voltage drop between the power supply and ground the oscilloscope, the performance of the ripple.

3、Oscilloscope coupling, DC offset range

AC Coupling

Can filter out the DC component of the measured signal oscilloscope to observe only the AC component of the measured signal

Can be used with smaller oscilloscope vertical scale, observe the details of the AC power supply ripple and noise components.

DC Coupling and DC offset range

DC and AC components of the input signal can be observed on an oscilloscope;

Can observe the level of 0V DC output level, but to observe an enlarged detail for power supply ripple and noise, you need to have sufficient voltage bias oscilloscope range.

4、Input impedance

Generally, passive oscilloscope probes are mostly high-impedance input impedance 1MΩ or more, corresponding to the oscilloscope channel also needs to be set 1MΩ impedance input.

When using the 1X transmission line probe if the oscilloscope is set to high impedance input, will result in does not match the impedance of 50Ω coaxial cable, power supply noise caused by the result of reflection, measuring the resultant often greater than the actual test results 50Ω input impedance oscilloscope . When using the 1X transmission line probe, the oscilloscope channel input impedance should be chosen to match the impedance of 50Ω.

Since the oscilloscope select 50Ω input impedance coupling can only select DC coupling. And limited offset range of the oscilloscope, and therefore the output voltage greater power, but also need to increase the blocking circuit.

5、Oscilloscope vertical position (vertical sensitivity)

In general, the minimum vertical scale of the oscilloscope has 2 ~ 4mV / div. There are also smaller in order to measure the voltage signal oscilloscope design, the vertical position can be minimized to 1mV / div (eg Rigol DS4000 / 6000 series), even 500uV / div (eg Rigol DS2000A series).

The oscilloscope can be adjusted by the appropriate vertical scale, the waveform whole show on the screen. Rigol oscilloscope also supports vertical range trimming function, in a smaller scope to further adjust the vertical scale to improve the ENOB (effective dynamic bits). If the input waveform amplitude is slightly larger than the full scale of the current gear, the next gear while using the amplitude of the waveform display and lower, you can use the fine tuning to improve the amplitude waveform display for easy observation of signal details.

The adjustment range of the vertical scale of the probe related to the ratio of the current settings. By default, the probe attenuation ratio of 1X, adjustable range of the vertical scale is 1 mV / div to 5 V / div. If the ratio of the probe attenuation ratio of 10X, the vertical scale adjustment range will be adjusted to 10mV / div to 50V / div.

Example

Oscilloscope test DC voltage of 5V when, in order to observe the details of the changes mV ripple voltage level, must be transferred to the vertical position as much as possible on smaller gear measurement.
And on 1mV / div vertical scale is so small, the dynamic range of the oscilloscope only ± 4-5mV (depending on the vertical scale of the oscilloscope on the number of cells). 5V voltage for the dynamic range of ± 5mV clearly too large to be viewed in the vertical cell number only 8-10div oscilloscope. Hence the need to use the AC coupling filter out the DC component, or to adjust the vertical offset voltage 5V, so that you can observe signal details ripple and noise. In general, the oscilloscope difficult to adjust to such a large bias voltage, and therefore the use of AC coupling majority.

6、Bandwidth Limitations:

Frequency ripple noise caused by the power supply is usually relatively low, thus making the power supply ripple and noise measurement, bandwidth throttling is often used to isolate the effect of high frequency noise on the test results. Parameters bandwidth limitations, most choose to 20MHz; To assess the noise situation on all bands or a part of the band's power, you need to select the bandwidth limitations of other parameters, such as 100MHz / 200MHz / 250MHz.

7、Test Environment

Different test environments, it may give a different test results. You may agree to the following test requirements:
① Temperature and humidity: indoor temperature (20 ± 5) ℃, humidity less than 80%;
② Minimize mechanical vibration and electromagnetic interference affecting the measurement;
③ Measuring instruments and test the power placed in the test environment more than 24h;
④ Before making the final measurement the measuring instrument, more than a half hour warm-up.

8、Other Factors

① When testing is required for measurements in the loaded state;
② To select the power load pure resistive load, electronic load can also be used;
④ Load-pull loads, to make the DC power supply output current is greater than 80% power than the rated output current;
⑤ Wiring as short as possible to minimize the effects of noise measurement system introduced from outside.

Oscilloscope important parameters affecting measurement results

1、Oscilloscope bandwidth selection

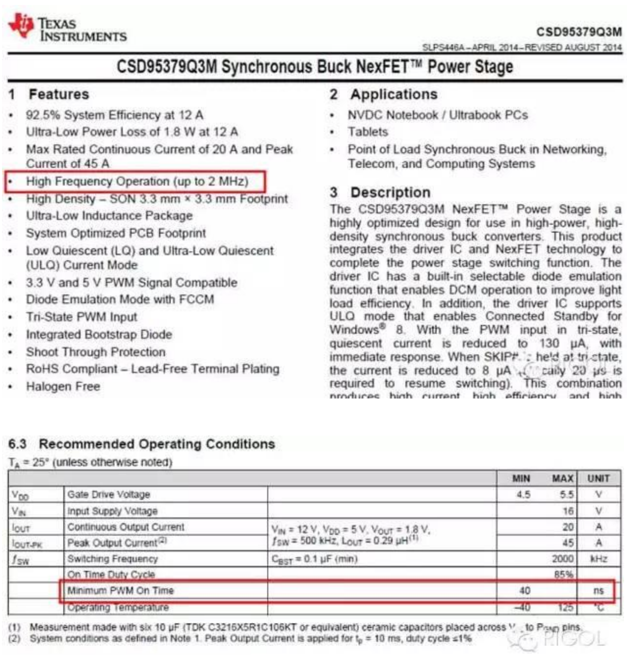
Test power supply noise, we need to consider the frequency response, which is to select the appropriate oscilloscope bandwidth requirements. Sufficient bandwidth, it will not filter out the harmonic components of the power supply noise, but the oscilloscope bandwidth is not better. High-bandwidth oscilloscope due to its high frequency noise of the instrument itself, will reduce power supply noise measurement accuracy

Therefore, when the measurement noise, there is a bandwidth limit selection. In general, the power supply noise test PCB levels, the oscilloscope bandwidth selection in the 500MHz is sufficient; higher frequency of testing, power integrity issues are chip and package design category.

2、Requirements oscilloscope memory depth and sample rate

When engineer is choosing a digital oscilloscope, the sampling rate will generally focus on this indicator. And most vendors market sampling rate of oscilloscopes frequently 1GSa / s or more, it seems very high, but in actual use will find 5ms / div sampling rate base under sharp decline in large, this is because the memory depth is ignored Effect of sampling rate (Please refer to Table 1, different memory depth on the switching power supply

DC 12V output ripple and noise test results).



Texas Instruments

CSD95379Q3M

SLPS446A – APRIL 2014 – REVISED AUGUST 2014

CSD95379Q3M Synchronous Buck NexFET™ Power Stage

1 Features

- 92.5% System Efficiency at 12 A
- Ultra-Low Power Loss of 1.8 W at 12 A
- Max Rated Continuous Current of 20 A and Peak Current of 45 A
- High Frequency Operation (up to 2 MHz)
- High Density – SON 3.3 mm × 3.3 mm Footprint
- Ultra-Low Inductance Package
- System Optimized PCB Footprint
- Low Quiescent (LQ) and Ultra-Low Quiescent (ULQ) Current Mode
- 3.3 V and 5 V PWM Signal Compatible
- Diode Emulation Mode with FCCM
- Tri-State PWM Input
- Integrated Bootstrap Diode
- Shoot Through Protection
- RoHS Compliant – Lead-Free Terminal Plating
- Halogen Free

2 Applications

- NVDC Notebook / Ultrabook PCs
- Tablets
- Point of Load Synchronous Buck in Networking, Telecom, and Computing Systems

3 Description

The CSD95379Q3M NexFET™ Power Stage is a highly optimized design for use in high-power, high-density synchronous buck converters. This product integrates the driver IC and NexFET technology to complete the power stage switching function. The driver IC has a built-in selectable diode emulation function that enables DCM operation to improve light load efficiency. In addition, the driver IC supports ULQ mode that enables Connected Standby for Windows® 8. With the PWM input in tri-state, quiescent current is reduced to 130 μA, with immediate response. When SKIP# is held at tri-state, the current is reduced to 8 μA (typically 20 μs is required to resume switching). This combination produces high current, high efficiency, and high

6.3 Recommended Operating Conditions

T_A = 25° (unless otherwise noted)

			MIN	MAX	UNIT
V_{DD}	Gate Drive Voltage		4.5	5.5	V
V_{IN}	Input Supply Voltage			16	V
I_{OUT}	Continuous Output Current	V_{IN} = 12 V, V_{DD} = 5 V, V_{OUT} = 1.8 V, f_{SW} = 500 kHz, L_{OUT} = 0.29 μH(1)		20	A
I_{OUT-PK}	Peak Output Current(2)			45	A
f_{SW}	Switching Frequency	C_{BST} = 0.1 μF (min)		2000	kHz
	On Time Duty Cycle			85%	
	Minimum PWM On Time		40		ns
	Operating Temperature		–40	125	°C

(1) Measurement made with six 10 μF (TDK C3216X5R1C106KT or equivalent) ceramic capacitors placed across V_{IN} to P_{GND} pins.
(2) System conditions as defined in Note 1. Peak Output Current is applied for t_p = 10 ms, duty cycle ≤1%

Common frequency switching power supply is generally about 200kHz, since the switching frequency is often present in the signal modulation sake, engineers need to capture at least one frequency cycle or half cycle of the waveform cycle even more. Typical switching signal rise time is about 100ns, to ensure accurate reconstruction of the waveform, rising at least five sampling points, the sampling interval is less than 100ns / 5 = 20ns, the sampling rate is 50MSa / s. To observe a single frequency cycle 20ms waveform memory depth that at least 1Mpts.

Sampling rate (50 MSa / s) × sampling time (20ms) = memory depth (1Mpts)

Follows TI's CSD95379Q3M power MOSFET modules, switching frequency up to 2MHz, PWM minimum rise time 40ns, corresponding storage is at least 2.5Mpts. Of course, for engineers, memory depth, the higher the better, in order to reduce the impact of restrictions on storage oscilloscope parameter settings, easy to operate. Most of the mainstream market in the oscilloscope memory depth 2-10Mpts, while Rigol DS4000 / DS6000 series oscilloscopes, the highest memory depth of up to 140Mpts, completely subvert the industry to limit the scope of mainstream models memory depth.

The noise floor of the oscilloscope and the quantization error

The vast majority of the market digital oscilloscope, ADC sampling chip are 8, quantization levels to 256. Oscilloscope ADC digit difficult to improve, mainly because of the higher number of bits of the ADC sampling rate is difficult to improve, difficult to cover user demand for high-bandwidth, high sampling rate. In recent years, some manufacturers have introduced in 10 bits ADC (implemented by hardware) oscilloscope, there by increasing the number of bits of software algorithms to achieve 12 or more, but the price is extremely expensive for most users away!

Engineers how to make good use of existing oscilloscope or a more economical solution, is extremely rare dry! Oscilloscope noise floor varies in different vertical scale under which measurement results would ripple and noise impact. For the signal being measured, suitable vertical scale settings is extremely important. The oscilloscope is generally the smallest gear 1-2mV / div (eg Rigol DS6000 / DS4000 series, DS2000A series even up 500uV / div), try to use smaller gear test to obtain a more accurate test results.

When the measured signal is small, the first crude oscilloscope vertical scale to a suitable position, and then fine-tuning open, occupy more vertical scale of the waveform number of cells, but not beyond the screen outside, this can increase the dynamic effective bits oscilloscope so that the voltage test is more accurate.

Follows a different memory depth on the switching power supply DC 12V output ripple and noise test results (5ms / div timebase, 4.7mV / div vertical scale, 20MHz bandwidth limit, AC coupling)
140 Mpts memory depth sampling rates up 2GSa / s, the measurement results: peak to peak 32.50mVpp RMS 6.821mVrms

14 Mpts memory depth sampling rate of up to 125 MSa / s, the measurement results: peak to peak 32.00mVpp RMS 6.305mVrms

1.4Mpts memory depth sampling rates up 12.5MSa / s, the measurement results: peak to peak 30.00mVpp RMS 3.522mVrms

140 kpts memory depth sampling rates up 1.25MS / s, the measurement results: peak to peak 24.21mVpp RMS 2.205mVrms