Choosing the Best Capacitor for Wireless Devices and Charger Control Circuits

For small portable wireless devices size is the predominant factor in selecting the capacitor, although the DC leakage and/or ESR are critical electrical parameters which must not be overlooked.

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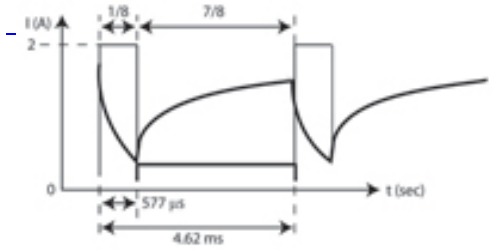


[1]

Figure 1. Sending GPRS Transmissions. The capacitor contributes minimum voltage during the transmission. This capacitor supplying the current drawn during the transmission is the key.

There are many types of portable battery operated wireless devices and a wide range of choices of charger control circuits that reliably power the devices. Careful selection of passive components, such as tantalum and MLCC capacitors, can improve the overall performance capability of the charger control and energy storage system in these portable devices.

Multiple DC voltage levels are required for proper operation of portable wireless devices, but they cannot be supported purely from the battery. The voltages vary and are usually too high or too low for standard batteries to support, especially when the battery is in the discharge mode. Capacitors used in the switching power supply become an important component to facilitate multiple voltages during the load changes.

Due to space constraints imposed by the design, this presents a difficult task for the passive component world, especially for capacitors. For example, capacitors that are used in a wireless General Packet Radio Service (GPRS) for boosting the power amplifier must be able to work as an efficient power line bulk capacitor to hold up power during changes in the load (see Figure 1). These capacitors must deliver an output around 2 A at 3.3 V and 4.3 V DC at a frequency of 216 Hz with a 12.5% duty cycle. It is easy to do the calculations that show a 2000&#181F to 3300&#181F capacitor bank is needed; fitting it into the required space is more difficult. Off the shelf commercial devices with such ratings are uncommon.

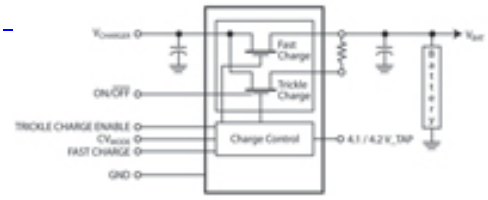
Many wireless devices are found in critical applications such as for medical monitoring devices. Because of the importance of high reliability in medical devices, there are tradeoffs in commercial vs. medical grade passive components and new

developments that have helped performance. The three most common types of bulk capacitors used in portable wireless medical devices are multilayer ceramic capacitors (MLCCs), aluminum electrolytic, and solid tantalum electrolytic. Below, we discuss some general selection criteria for capacitor technologies and improvements in packaging options that are now available.

A Typical Battery Charger Implementation

Battery charger circuits are commonly implemented with an IC such as that shown in Figure 2, which is a small dc-to-dc switching regulator that provides synchronous pulsed switching for the battery charger. The device has many features including providing isolation between the external power source and the battery (V bat) during shut down. A complete solution using this type of IC requires input and output capacitors, and in the following sections we explain the main criteria in selecting these.

Input Capacitors



[2]

The input capacitors provide low impedance to the battery charger/regulator circuit. The capacitor size is based upon how much ripple can be handled by the input and can be calculated from C =(I input *&Deltat)/&DeltaV , where I input is the input current, &Deltat is the turn on time for high side FET and &DeltaV is the peak to peak voltage. Usually a 0.1-&microF MLCC is also added to the input to filter the high-frequency noise placed close the Vcc pins.

The converter provides a load current and voltage. As the load changes and current increases, the voltage decreases. The regulator maintains a constant voltage but cannot respond fast enough to changes in load current, so a bank of bulk capacitors are used to hold up the drooping voltage during these changes. When the converter switches the current through the inductor it cannot change instantaneously so a parallel bank of capacitors is placed across the load to pull up the voltage. In most cases a combination of MLCC and tantalum capacitors are used to minimize the overall bulk capacitance ESR. Because the impedance of the MLCC is low, it charges first and is then followed by the bulk tantalum capacitor.

Output Capacitors

The selection of the type of output capacitor is based upon determining the right ESR to fit ranges for stable load line and an evaluation of the following objectives:

1. Reducing power consumption 2. Lowering the ripple voltage by making the capacitor ESR low enough to meet the output voltage ripple and transient conditions 3. Meeting the system load line requirements. Typical values are 330 &microF to 470 &microF electrolytic and a low-ESR MLCC in parallel.

The portable device circuit requires output capacitors that are often powered by the primary or secondary batteries and are needed to reduce voltage undershoot and overshoot conditions during load transients. To be an effective noise filter the capacitor equivalent series resistance (ESR) is the important parameter for consideration. The output capacitor will need to handle the ripple current and voltage in the circuit. Excessive heating of the capacitor package needs to be controlled so that the maximum permissible power dissipation is not exceeded during circuit operation. A determination is needed to make sure the permissible ripple current seen by the output capacitor is not exceeded.

Table 1. Tantalum Capacitor Power Dissipation and Capacitance Ranges

Case size	Series	Maximum Power (W)	Maximum capacitance at 4 V (µF)	Maximum capacitance at 6.3 V (µF)	Maximum capacitance at 10 V (µF)
0603	290D	.025	47	33	15
0805	292D	.025	33	33	15
1206	572D	.060	220	100	47
A	293D	.075	100	47	22
B	593D	.085	150	100	47
D	TM8	.085	100	68	47
E	TM8	.095	150	100	68
F	TM8	.075	220	150	100
E	194D	.095	22	15	15
R	595D	1.5	1500	1000	680

[3]

Table 1 is a summary of various packages with their permissible maximum power ratings by case series at + 25 &degC and f = 100 kHz. For applications where the temperature rise is above + 25&degC, further derating is recommended. You can typically find capacitor manufacturer recommendations for power derating on their product datasheets.

To calculate the maximum allowable ac ripple current, use the formula $P = Irms^2 \times ESR$, where P is the permissible maximum power for the tantalum case size, and ESR is determined for the capacitor at the operating frequency. For tantalum capacitors also proper voltage derating guidelines need to be followed and should not exceed manufacturer recommended ratings. The operating voltage of the output capacitor needs to be determined by the voltage circuit conditions. It can be determined by adding any ripple voltage noise to the dc voltage by the formula V rated = V peak + Vdc. The allowable ripple voltage can be calculated by E = I x Z, where Z is the impedance of the capacitor. Overall a lower ESR helps to reduce output ripple noise. Large bulk capacitors are also often added to the circuit for power-up situations under no-load conditions when the battery is not installed and the line current is the energy source. Guidelines for derating need to be followed in selecting the rating for the bulk tantalum capacitor when the line current is the energy source.

Wireless Devices Battery Runtime and DC Leakage

For rechargeable secondary batteries DC leakage (DCL) may be important so as to have more runtime between chargers, however the overall operating current needs may tolerate some leakage from the output capacitors. An evaluation of circuit current requirements under different use conditions and understanding the DCL of the capacitor can greatly improve the efficiency of battery operating life. In

particular, measurements of the DCL or IR can indicate the capability of the capacitor's dielectric and the quality of the dielectric layer.

The DCL currents can flow through or across the surface of the capacitor when voltage is applied. For most capacitors, (ceramic, tantalum), the DCL current results from intrinsic leakage that flows through the dielectric material. This current is used to calculate the insulation resistance of the component. For capacitors made with an oxide film, such as tantalums, the DCL currents are comprised for the most part from a combination of either surface leakage flowing through the dielectric, dielectric absorption (DA) current that flows because of polarization of the dielectric material, or from intrinsic leakage current that flows through the dielectric material. Similarly, MLCCs, with a barium titanate based ceramic dielectric have a DC leakage comprised mainly from leakage flowing through the dielectric MLCCs have good low DCL capability but in some cases tantalum capacitors can provide about the same level of DCL in less space.

Conclusion

There are many possible capacitor options for use in portable applications. In selecting the right type of capacitor, the DC leakage and /or ESR are the predominant electrical parameters to consider in the selection of the capacitor for the application. For small portable wireless devices size is the predominant factor in selecting the capacitor. High reliability and battery operating life in some medical applications may eliminate the use of some capacitors, especially in life support applications.

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