TPS65720 Power Management IC (PMIC) for Wearable and Fitness Devices

TEXAS INSTRUMENTS

Introduction

People are turning more toward wearable devices to improve their everyday life by tracking things like fitness activity, health and medical behavior. As the demand grows for more features like smaller size and longer battery life, designers are facing new and bigger challenges. Texas Instruments offers a variety of robust, versatile, and highly-efficient solutions in a small package to enable superior performance for a wide range of wearable electronic devices.

The TPS65720 is a small PMIC targeted for wearable and other portable low-power consumer end equipment. It contains a USB-friendly, 300-mA Lithium-Ion or Li-Poly battery charger, a highly-efficient step-down converter, a low-dropout linear regulator, and additional supporting functions. The output voltages can be set using a resistor divider. The device can be controlled by an I^2C interface or hardware pins. Several settings can be customized by the use of non-volatile memory, which is factory programmed. The 2.25-MHz step-down converter enters a low-power mode at light loads for maximum efficiency across the widest possible range of load currents. For low-noise applications, the PMICs can be forced into fixed-frequency PWM mode using the I^2C compatible interface. The 2.25-MHz switching frequency allows using smaller inductors and capacitors. The DC/DC converter in the TPS65720 provides an output current of up to 200 mA and up to 400 mA from the TPS65721. The ICs also have one 200-mA LDO, which operates with an input voltage range between 1.8 and 5.6 V, allowing it to be supplied from the output of the step-down converter or directly from the system voltage. The ICs offer a low shutdown current of less than 1 µA. Battery voltage is brought out as the third regulated output in TPS657202.

Low-Noise Applications

As shown in **Figure 1**, a typical RF transceiver receives data through an antenna, duplexer, a low-noise amplifier and band-pass filter. The high-frequency signal is then fed into a mixer and down-converted into a base-band signal. To maintain the signal integrity of the received signal, the power supply for the receiver chain must not produce unpredictable spurious frequencies that can result in unacceptable signal-to-noise (S/N) ratio and cause high bit-error rates.

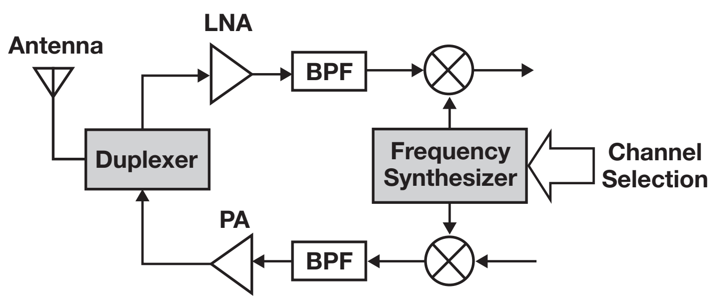
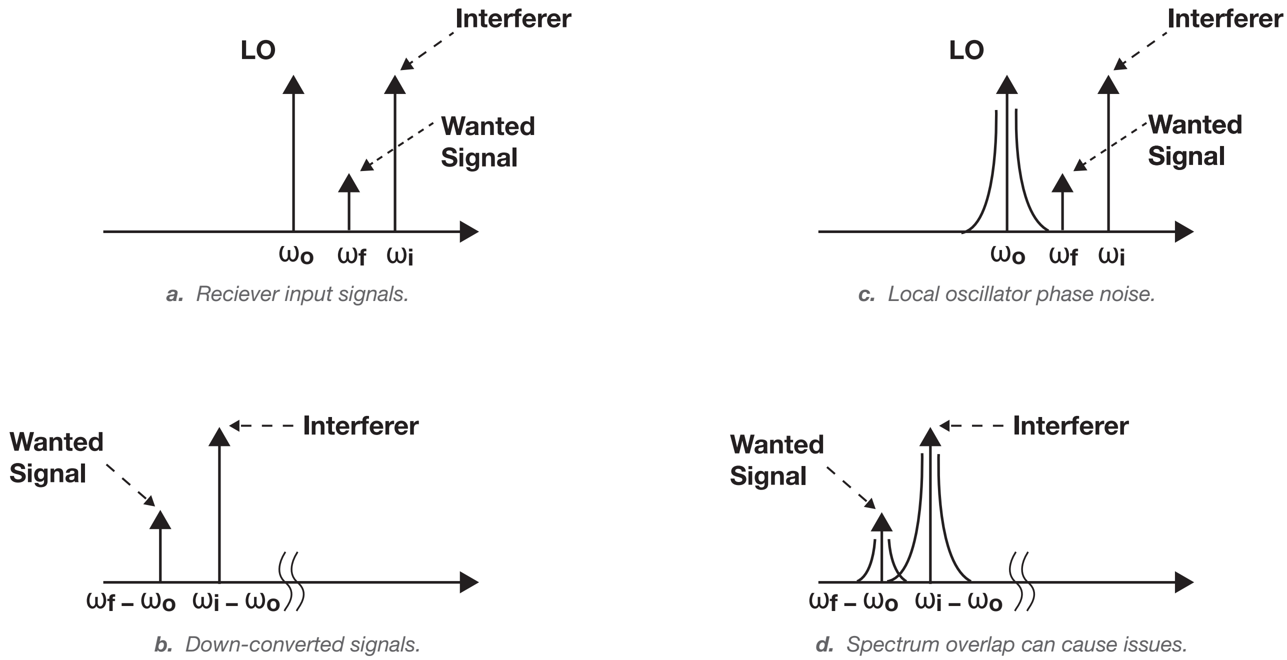


Figure 1: *A typical RF tranceiver diagram.*

The down-conversion is basically achieved through the non-linearity property of the mixer, ω_baseband = $\omega_f - \omega_o$, where the ω_baseband is the angular frequency of the down-converted base-band signal, ω_f is the angular frequency of the RF carrier, and ω_o is the angular frequency of the local oscillator. The local-oscillator signal is usually generated through a phase lock loop (PLL) with very low phase noise. The high quality of the PLL output signal is generated based on a crystal oscillator as its reference. The PLL output is then fed into a phase frequency detector (PFD), charge pump, oscillator, and feedback divider. Phase lock is then achieved by comparing the phase of the feedback clock to that of the reference clock. Thus, a low phase-noise clock with angular frequency of ω_o is generated at the output of the PLL.

As shown in **Figure 2a**, three signals show up in the receiver signal path—the received signal with angular frequency of ω_f, the local oscillator, ω_o, and the interferer, ω_i. After passing through the RF mixer, the down-converted signals shown in **Figure 2b** appear as independent frequencies without considering the phase noise of the local oscillator. In reality, the local-oscillator signal usually has Gaussian-shape phase noise as shown in **Figure 2c**. The interferer signal can come from the leakage of the transmitted path through the duplexer, or from supply-generated spurious frequencies of a switching mode power supply (SMPS). The interferer signal is mixed by an RF mixer with the output of the local oscillator. In **Figure 2d**, the down-converted signal is barely seen due to the interferer and its phase-noise tail generated from mixing with the local oscillator, which can cause an unacceptable S/N ratio and high bit-error rates for the base-band



a. *Reciever input signals.*

c. *Local oscillator phase noise.*

b. *Down-converted signals.*

d. *Spectrum overlap can cause issues.*

Figure 2: *Effects of spurious frequencies to signal integrity.*

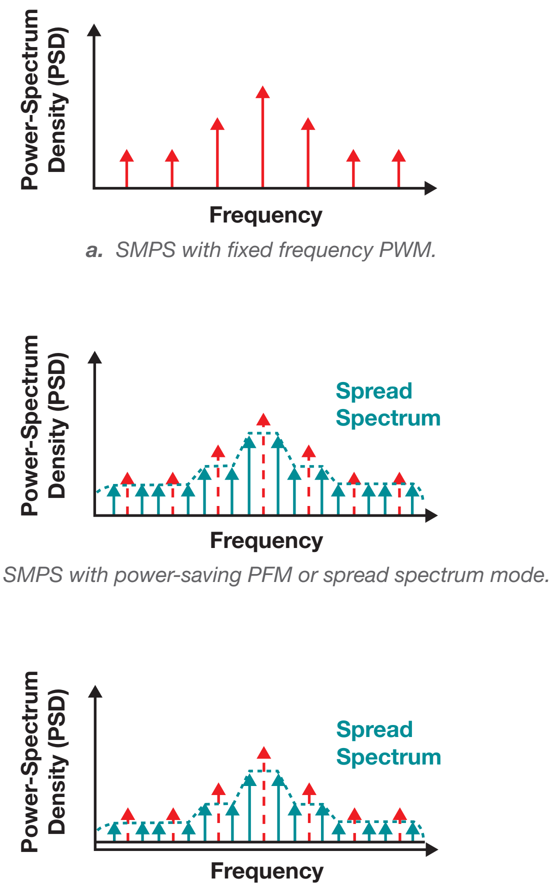
signal. Usually, the received RF signal is at a very low energy level, which means that a small amount of phase noise from the local oscillator and the interferer from the SMPS can cause issues for the receiver chain.

In order to achieve high efficiency during a light-load condition, most SMPSs have a power saving mode or PFM mode. In the PFM mode, unnecessary circuits are turned off, and the SMPS does not switch on until its output voltage drops below a threshold voltage. The switching frequency depends on the load conditions and it is usually in a very low frequency range (below a few kHz) and spread all over a frequency range once the loading condition varies. Due to its low-frequency nature, it is very difficult to find an ultra-high-Q band-pass filter to remove a spurious tone with such a low frequency. Therefore, PFM-mode operation and the hysteretic type of switching regulators are not preferred power supplies for low-noise applications.

For low-noise applications, the TPS65720 offers superior performance and a small footprint for wearable and fitness devices that require wireless connectivity. Also, the TPS65720 can be forced into PWM mode with a fixed switching frequency of 2.25 MHz. With a high-Q band-pass filter, the SMPS-generated spurious frequencies can be filtered out. Without the interferer present in the receiver path, the down-converted base-band signal can have much better S/N ratio and low bit-error rate.

The TPS65720 also provides a linear charger and a low dropout regulator (LDO) for low noise, small-footprint, and long-duration applications. **Figure 3** shows typical spurious frequencies and noises generated by a SMPS, a linear charger, and an LDO. The power spectrum density (PSD) of spurious tones generated by a SMPS is shown in **Figure 3a** during fixed-frequency, PWM mode of operation. The PSD plot shows the fundamental and its higher-order harmonics. As mentioned, the fundamental and harmonics can be easily filtered by a high-Q band-pass filter in the receiver path.

If the SMPS operates in the PFM mode, hysteretic mode or with a spread-spectrum function, then the PSD of spurious tones will be lowered, which results in lower EMI in the system (**Figure 3b**). However, it is very difficult to filter the low-frequency spurious harmonics. The linear charger and LDO have much lower noise compared to the spurious tones generated by SMPS, as shown in **Figure 3c**. Therefore, TPS65720 is very suitable for wireless low-noise applications such as smart watches, fitness and wearable devices, and *Bluetooth*® headsets.



a. *SMPS with fixed frequency PWM.*

b. *SMPS with power-saving PFM or spread spectrum mode.*

c. *Noise level for LDO and Linear Charger.*

Figure 3: *Typical spurious frequencies and noise.*

Compact Size

The TPS65720 and TPS657202 are available in a small 25-ball, wafer chip scale package (WCSP) with 0.4-mm ball pitch and the TPS65721 in a 4 × 4-mm QFN package with 0.4-mm pitch to support lower-cost manufacturing of PCBs. A typical bill-of-materials (BOM) is listed in **Table 1** for *Bluetooth*® handset applications. All the resistors can be 0402 sizes for the feedback dividers for DCDC1 and LDO1 and the 22-pF capacitor can be 0402 size for the feed-forward capacitor for DCDC1. With these components, the total size of all the external components in the BOM table is approximately 10.57 mm^2.

Component	Part Number	Value	Size
PMIC	TPS65720	—	2 x 2 mm
Linear Charger			
Bypass Capacitor	GMK107BJ105K	1.0 µF	0603
Output V_{SYS} Capacitor	GRM155R60G475ME47D	4.7 µF	0402
Current-Limit Resistor	Any	Varies based on application	0402
Battery Temperature NTC Thermistor Sensor	Various	—	—
DCDC1			
Output Inductor	GLFR1608T2R2M-LR	2.2 µH	1.6 x 0.8 mm
Output Capacitor	GRM155R60G475ME47D	4.7 µF	0402
Feedback Resistors	Any	2 x 300 kΩ	0402
Feed Forward Capacitor	Ceramic X5R	22 pF	0402
LDO1			
Input Capacitor	GRM155R60J225ME15D	2.2 µF	0402
Output Capacitor	GRM155R60G475ME47D	4.7 µF	0402
Feedback Resistors	Any	300 kΩ and 240 kΩ	0402
		Total =	10.57 mm^2

Table 1: *Typical BOM for a Bluetooth*® *application.*

Conclusion

The TPS6572x family of small PMICs are targeted for wearable and fitness devices, or other portable low-power consumer end equipment. For low-noise applications, its step-down buck converter can be forced into fixed-frequency PWM mode via the I^2C compatible interface. The IC allows the use of small inductors and capacitors to achieve a small power solution. The low-noise LDO and linear charger with a charging current of up to 300 mA provide a suitable solution for wearable and fitness devices that require a small footprint and long duration of operation.

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