WHITE PAPER

Optimizing Power System Design in Wearables

The impact of load switch technology on wearable designs

Introduction

Load switches provide an essential role in extending battery life in wearables and virtually every portable electronic device, including watches, fitness trackers, heart monitors and so many others. Yet, for all of the advances that have been made in the design and capabilities of wearable electronics, these devices, by and large, utilize the same load switches designed for tablets and other devices that have much larger battery capacity where leakage current and ON resistance are less of a concern. As a consequence, wearables often require frequent recharging.

This article discusses the design practices for decreasing the power consumption and increasing the battery life of wearable devices. It then shows how to select the latest ultra-low leakage current load switches that can improve wearable applications by easily extending operating time from days to weeks between recharging.

Typical Wearable Applications

Designers of wearables are continually challenged with extending battery life in ever-smaller and more feature-rich products. And a key element in meeting these requirements are load switches that perform the essential battery-management tasks with minimum footprint and nearly zero leakage current and/or ON resistance. However, the common power management techniques, including power management ICs and IC load switches meant for laptops and tablet computers, simply can't meet these demands.

An example of a typical wearable application (Figure 1) includes several environmental sensors, GPS, display, memory, wireless connectivity and a fast and feature-rich microcontroller (MCU). In order to extend battery life, the circuitry includes a number of load switches to place the device in "sleep" mode and to turn off functions until needed. In this respect, the example shown in the block diagram is not materially different than that of a typical hand-held tablet or mobile phone. The difference lies in the size and performance of these devices.

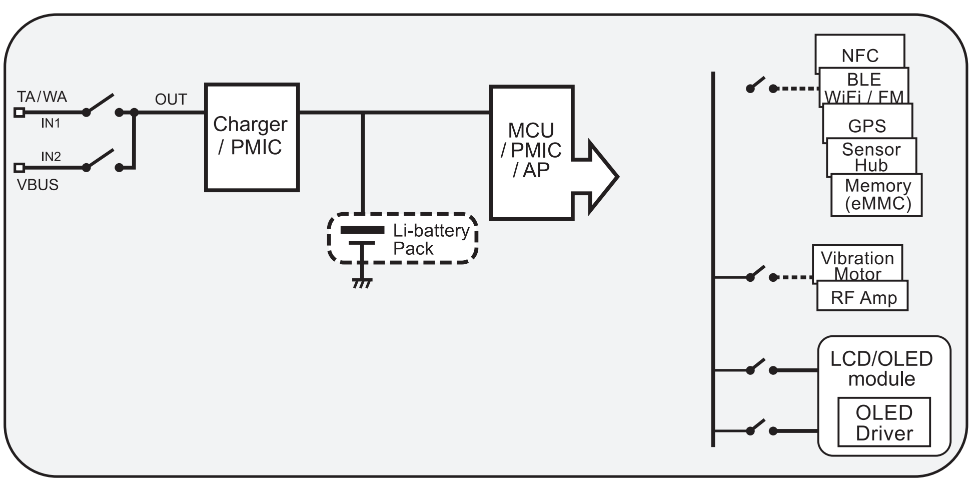

***Figure 1**. An example of wearable application with multiple possible subsystems*

Many of the functional devices utilized in wearables (including connectivity, sensing and MCUs) come with power-saving modes that offer developers a false sense of lower-power control. Table 1 shows examples of low-power mode current drawn by a typical mix of ICs and modules.

Inertial Sensor (6-Degrees of Freedom Module)	6 µA
Connectivity (Low Energy Bluetooth Module)	0.7 µA
GPS IC	5 µA

Table 1. *Typical low-end wearable functions and the power they draw.*

Table 2 describes the current drain of other features required in higher-performance applications.

Touch Controller	2,5 µA
Pulse Sensor (controller)	500 µA

Table 2. *Typical devices that do not offer the needed low standby current.*

Together with the MCU/APU and other devices, standby current can really add up. All the required features can turn a device into a "power monster."

Power Management ICs

A popular battery saving strategy employs power management ICs, such as dedicated PMICs, LDOs and buck converters or, as an alternative, a MOSFET power switch. Table 3 shows typical currents for the "Low Power" modes of power ICs commonly used in modern wearables. Turning power off at the source would seem to solve the problem. Even though this can be adequate for some implementations, the power drain of these devices is typically not acceptible for today's (and tomorrow's) breed of wearables.

LDO Regulator w/Enable	0.5 µA
3-Channel Buck with Load Switch	0.3 µA
PMIC with Load Switch	10 µA
Single Buck Converter	0.07 µA
MOSFET as a Power Switch	1 µA

Table 3. *Typical power management ICs' low-power modes are too high for use in wearables.*

Load Switch Selection

Designers of wearables need to consider load switch selection criteria. The following are examples to compare the performance of available devices.

There are several questions to ask when choosing a load switch for each wearable design:

- Operational Mode - Mostly ON or OFF?
- Voltage range - Can one switch fit all power rails?
- Type of a load - Capacitive, resistive or inductive?

Mostly ON vs. Mostly OFF — Resistance (R_{DS}) vs. Leakage Current (I_{SD})

Depending on whether the subsystem is ON or OFF, different parameters of the load switch become important. Most switches are optimized for one but not for both conditions.

In the case of a "Mostly OFF" subsystem, the current standby I_{SD} (standby current leakage) becomes the most important parameter to consider. The best devices on the market are well under 1µA. Table 4 lists a number of devices that meet this criterion. Marking a significant improvement, the latest low-leakage-current load switches, such as the GLF71301 device, offers best-in-class I_{SD} at 7nA (Table 4).

	Test Condition	GLF GLF71301	Toshiba TCK10xG	Fairchild FPF1204	On Semi NCP333
Vcc		1.1V - 5.5V	1.1V - 5.5V	1.2V - 5.5V	1.2V - 5.5V
I_{OUT} Max (A)		1.5A	1A	2.2A	1.5A
I_{SD} Typ (nA)	*3.6V, 25C*	7	50	12	105
R_{ON} Max. (mΩ)	*5.5V*	38	73	55	55
	3.3V	47	84	65	74
I_Q Typ (nA)	*3.6V, 25C*	1	77	700	560
PKG	*WCLSP 0.4mm Pitch*	.77mm x .77mm	.79mm x .79mm	.76mm x .76mm	.76mm x .76mm
Pin Compatible?		✓	✓	✓	✓

Table 4. *For "Mostly OFF" subsystems, select a device with I_{SD} of under 1 uA.*

If the subsystem is "Mostly ON," then the ON resistance of the switch, R_{ON}, becomes paramount. Look for a R_{ON} of less than 100 mΩ at the max operating range. Table 5 offers a sampling of some of the devices offering the lowest R_{ON}. As shown in Table 5, the GLF71321 shows the best R_{ON} performance (17 at 5.5V and 21 at 3.3V).

	Test Condition	GLF GLF71321	Fairchild FPF1038/9	Vishay SiP32459
Vcc		1.1V - 5.5V	1.2V - 5.5V	1.5V - 5.5V
I_{OUT} Max (A)		4	3.5	3
I_{SD} Typ (nA)	*3.6V, 25C*	12	18	13
R_{ON} Max. (mΩ)	*5.5V*	17	24	26
	3.3V	21	29	26
I_Q Typ (nA)	*3.6V, 25C*	1	430	3200
PKG	*WCLSP 0.5mm Pitch*	.97 x 1.47	1 x .1.5	.96 x 1.46
Pin Compatible?		✓	✓	✓

Table 5. *For "Mostly ON" subsystems, select a device with R_{ON} of under 100 mΩ.*

Voltage Range

Most wearables have several different voltage rails, ranging from 1.1V for the CPU core to 5.0V for higher voltage peripherals. A load switch with a wider range of voltage rail options can help manage inventory and used throughout. All of the devices listed in Tables 4 and 5 meet this criterion.

Factors Affecting Battery Life

It should be clear from the information presented in Tables 4 and 5, that both I_{SD} and R_{ON} will have a significant effect on battery life. Another factor to take into account is the quiescent current (I_Q) of the device. This is the "overhead" current drawn by the device when in the "ON" state. A quick review of these same two tables revieals that the GLF devices are up to several hundred times lower than the others.

Other Design Considerations

System Power Protection —

Load switch technology is also used for power protection of wearable systems. Over Current, Overvoltage, Undervoltage and Overtemperature, as well as system protection features such as Reset and Deep Sleep, which are integrated with the switch technology, greatly enhance system performance. The basic switch technology is also used as Power Mux devices due to the low "ON" resistance and easy control.

Load Type —

Depending on the type of load (capacitive, inductive, resistive), inrush current and other factors must be considered. Furthermore, if there are different types of subsystems controlled a single device, the load switch manufacturer must offer a choice of different slew rates.

Number of subsystems and power sequencing —

With wearables, space will be at a premium, so choosing the smallest, lightest devices is essential. Using a single load switch with multiple channels and power sequencing would be in order. A very limited number of manufacturers offer a choice of 2- or 3-channel devices. In addition, manufacturers need to offer 3- and 4-channel load switches that include a power ON/OFF sequencing option upon request.

The Future of Wearables

It is estimated that by 2025 there will be over 1 trillion IoT devices in operation and a significant portion of these devices will be of the wearable variety. Consumer demands for products with more functionality and more time between recharges will also increase.

New ultra-low leakage current load switches are setting the standard for efficient power management in wearable devices. By using advanced wearable-optimized switches (Figure 2), battery life can be dramatically increased. These savings will translate into either a smaller battery or a longer battery life and will differentiate wearable products in a very competitive market.

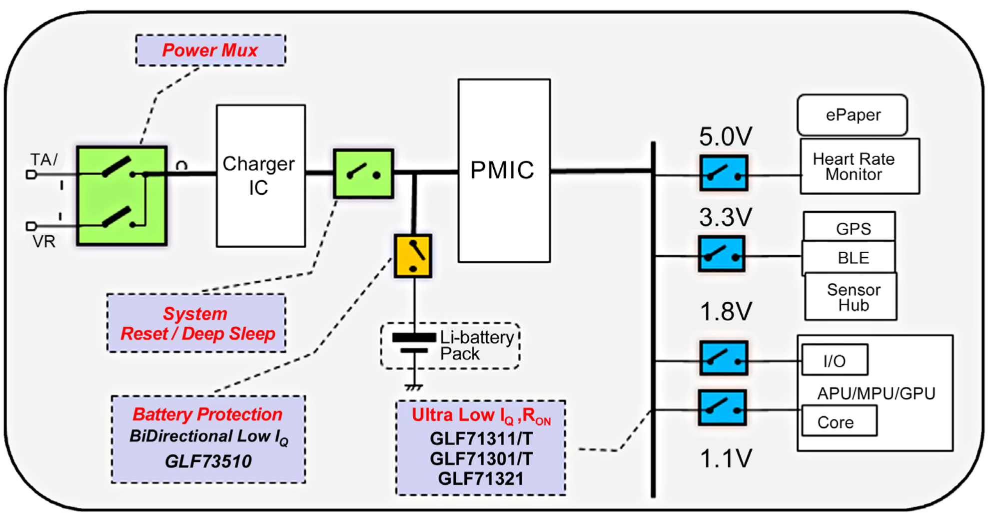

***Figure 2**. New high-performance load switches can add hours or even days to wearable battery life.*