Optimizing Power System Design in Wearables

The impact of load switch technology on wearable designs

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Wearable and IoT devices are seeing a sharp rise in demand. Consumers expect smaller devices with more features as well as fewer interruptions and at lower prices. Thus, system designers are challenged to come up with ever more compact, lightweight products that have a longer battery life.

This article addresses the latest available technologies and design practices that can decrease the power consumption and increase the battery life of wearable devices. It also describes the devices that designers need to consider when creating a low-power wearable system.

Wearable Application

An example of a typical wearable application could include a heart-rate monitor, 4-6 environmental sensors, wireless connectivity, and a fast and feature-rich microcontroller (MCU). This variety of applications comprises multiple subsystems and power rails within the modern wearable (Figure 1). This, in turn, creates a challenge and an opportunity for engineering communities to design a more compelling wearable.
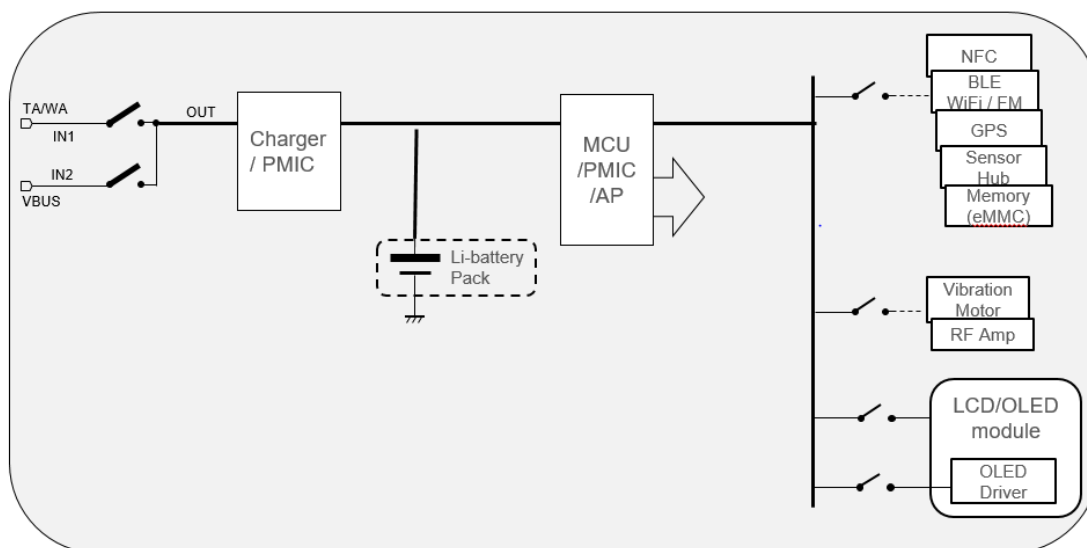

Fig. 1. An example of wearable application design and multiple possible subsystems.

Typical Approaches – and Their Issues

Subsystem Power Modes

Most of the new technologies and devices, such as connectivity, sensing, and processors, come with power-saving modes that offer developers a false sense of lower power control. Figure 2 shows an example of a low power mode current drawn by a typical mix of ICs and modules for a low-end wristband.

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

Figure 2. Typical devices and the power they draw for a low-end wearable.

Together with the MCU/APU and other devices, standby current can add up to 10 micro-amps or more. Such features as biosensors, location tracking, and interface capabilities can turn a device into a "power monster." For designers, creating a high-end device design can become increasingly daunting. Such a high level of standby current from devices used for most wearables isn't an option, due to the inherent size of the battery.

In high-end applications, designers need to look elsewhere to achieve the much lower standby power than the module/IC manufacturers can offer.

Touch controller	2.5 µA
Pulse Sensor (controller)	500 µA
GPS IC	5 µA

Figure 3. Typical devices do not offer the needed low standby current.

Power Management IC Power Modes

The other available option is using power management ICs, such as dedicated PMICs, LDOs, and buck converters. However, Figure 4 shows typical currents for the low power modes of power ICs commonly used in modern wearables, which are still too high. (Fig. 4)

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

Figure 4. Typical power ICs' low-power modes in wearables.

Turning power off at the source, therefore, would seem to solve the problem. But even though this can be adequate for some implementations, it doesn't always offer a solution. Since the PMIC SLEEP turns off *all* of the power, it robs a designer of the flexibility needed to manage several devices while using the same power rail. So, the obvious solution is to be able to turn the power off for each individual subsystem.

MOSFETs

Some designers are tempted to use a discrete MOSFET as a load switch that controlled by a general-purpose input/output, or GPIO. Although this seems like a simple, low-cost solution, this approach comes with some limitations. For instance, typical MOSFET leakage is few hundreds nA but requires a gate driver with a charge pump to bring gate voltage VGS up to 8 to 10V for N-channel or 5 V for P- channel switch.
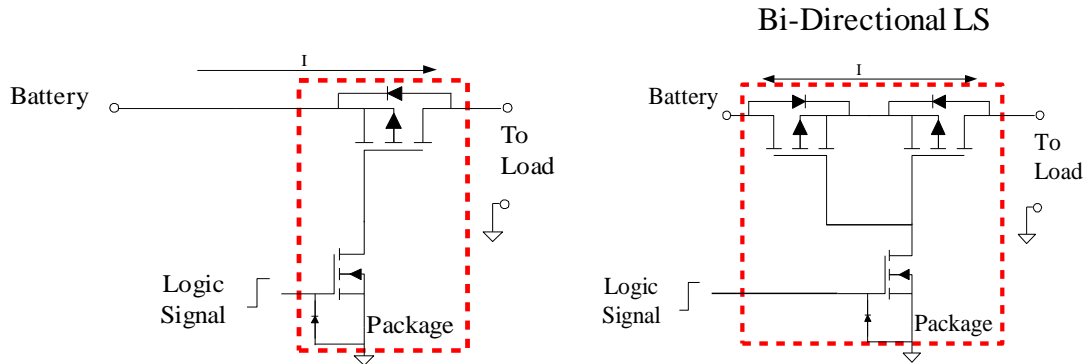

Figure 5. Typical discreet MOSFET implementations.

Additionally, gate drivers come with additional costs, and they are not known for low leakage either. There are some specialized MOSFETs with a gate threshold as "low" as 3 V, but even so, RDS (ON) is usually three times that of a standard MOSFET. A full featured switch requires adding discrete components as well.

	Discrete FET	GLF Integrated Load Switch
Leakage at off	Higher, **~1uA**	GLF71301: Isd= **6 nA** @3.3Vin GLF71311: Isd= **9 nA** @3.3Vin
Enable	Needs high charging/discharging current for Gate	EN pin by logic signal Easy to control the EN pin
Slew rate controlled	Need to use external resistor, cap	GLF Integrated Load Switch
Solution Size	Bigger (two FETs or a FET+R+C)	GLF71301: 0.77mm x 0.77mm GLF71311: 0.97mm x 0.97mm No need external components Okay without Cin and Cout
Ron	Depends on FET size	Best Fit in wafer level package

The Load Switch Solution

Knowing the limitation of the approaches discussed, you would assume that the best solution for wearables would be the integration of MOSFET, driver and control circuitry in a small package. Welcome to the load switch IC world! An optimized integrated load switch IC is much more versatile and efficient than a discrete MOSFET. And it can offer, in some instances, two orders of magnitude in reduction of current leakage compared to any other solution.

Not all load switches are created equal! There are several questions to consider while choosing a load switch for your wearable:

- 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 your 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 for you to consider. The best devices on the market are well under 1uA. The best in class for I_{SD} is GLF 7nA, as shown in Table 4, below.

	Test Condition	GLF	Competitor A	Competitor B	Competitor C
		GLF71301	XXXXX	XXXXX	XXXXX
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
Ron	5.5V	38	73	55	55
Max. (mΩ)	3.3V	47	84	65	74
I_Q Typ (nA)	3.6V, 25C	1	77	700	560
PKG	WLCSP 0.4mm Pitch	.77mmX.77mm	.79mm x .79mm	.76mm x .76mm	.76mm x .76mm
Pin Compatible?		√	√	√	√

Figure 5. Comparison of GLF load switch's low standby current leakage compared to other devices.

If your subsystem is "mostly ON," the ON resistance of the switch, R_{ON}, becomes paramount. Look for an 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}.

	Test Condition	GLF	Competitor A	Competitor B	Competitor C
		GLF71301	XXXXX	XXXXX	XXXXX
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Pin Compatible?		√	√	√	√

Figure 6. Devices by GLF offering very low RON compared to similar devices.

Voltage range

Most wearables have several different voltage rails, ranging from 1.1V for the CPU core to 5.0V for high-voltage peripherals. A load switch with a wider range of voltage rail options can help manage inventory and used throughout a system/platform in applications such as the ePaper display or the HRM module (Figure 7).

System power protection

The load switch technology also used for power protection of wearable systems. Such features as *Over Current, Over* - and *Under Volta*ge and *Over Temperature*, as well as system protection features such as *Reset* and *Deep Sleep* integrated with the switch technology will greatly enhance system performance. The basic switch technology also used in Power Mux devices due to the low "ON" resistance and easy control. The system protection topic deserves separate article and not discussed in this paper.
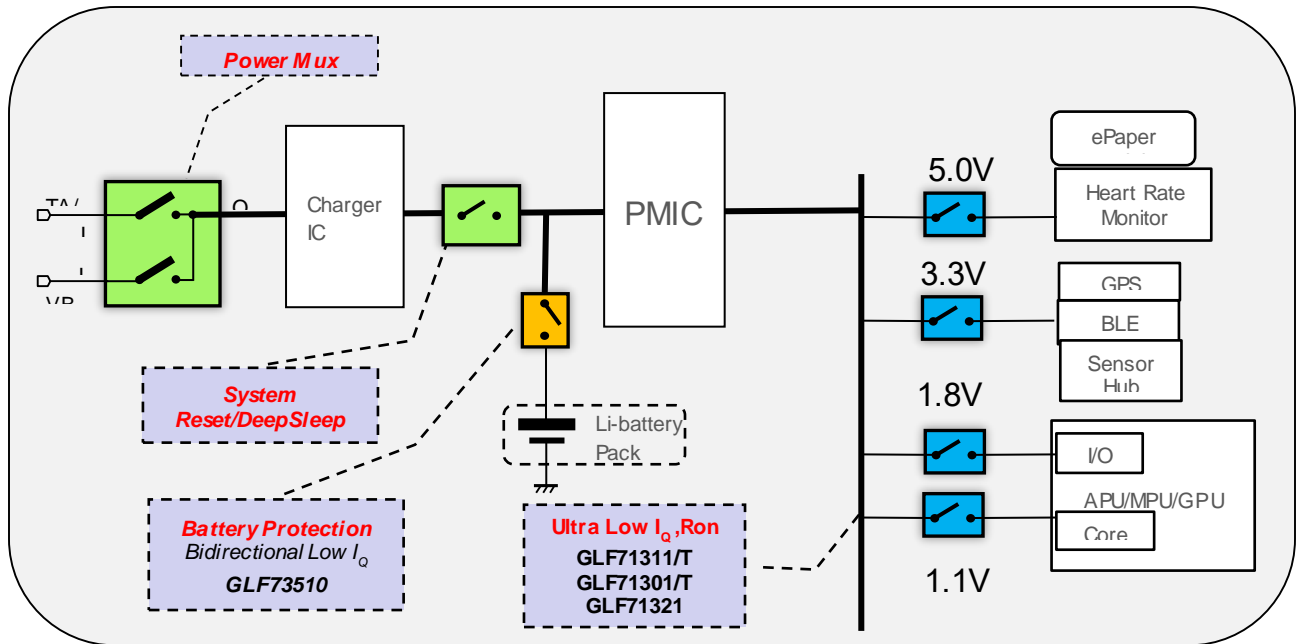
Figure 7. ePaper and heart rate module designs benefit from load switches offering a wide voltage rail range.

Load type

Depending on the type of load, you should expect some artifacts, including inrush current for capacitive load or absence of it for resistive one. Furthermore, you may expect to have different types of subsystems in a single device, and thus you will need to select a load switch manufacturer with a choice of different slew rates.

Number of subsystems and power sequencing

Sometimes your space will be at a premium, and you need to have a smaller, lighter device. Using a single load switch with multiple channels and power sequencing would be in order. Among a very limited number of manufacturers with a choice of 2- or 3-channel devices, GLF offers 3- and 4-channel load switches that include a power ON/OFF sequencing options upon request.

Summary

Now that you have your power architecture together with the smallest, most efficient load switches available, you can save up to 11% of the lifetime of the battery. These savings will translate into either a smaller battery or a longer battery life to differentiate your wearable design in a very competitive market.