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Wireless Foot Control
Design Considerations

Wireless Foot Switch Design Considerations

Introduction

Medical equipment users and OEMs have long expressed an interest in wireless foot switches. Their interest has been kindled by:

- Their desire to eliminate the “tripping” hazard cables may represent in the application.
- Their desire to have greater freedom in the location of the foot switch relative to the medical device it controls.
- Their desire to eliminate the potential for cable damage (the most frequent cause of foot switch failure … generally the result of carts/tables rolling over the cable).
- The benefits of easier cleaning/storage.

Figure 1.

Wireless designs permit greater freedom of foot control location.

Due to the above, wireless foot switches for the control of medical devices are gaining acceptance and growing in popularity … prompting OEMs to design medical equipment for use with a wireless foot switch or to accept a wireless foot switch as a pre-sale or post-sale option.

Such designs introduce two new elements into the design of the medical device.

The first set of design considerations revolve around the use of wireless foot controls. Here the design considerations are relatively straightforward, driven primarily by:

1. The choice of a safe, wireless protocol for the application.
2. The choice of the batteries to power the foot control.
3. The replacement/recharging technique for ease-of-use.

The second set of design considerations involves the associated wireless Receiver located on, or in, the medical device itself. Here there are a number of less obvious considerations that can greatly influence the Receiver design. Among these are:

- Receiver location.
- Receiver signal protocol to the host device.
- "Pairing" of the receiver and foot control.
- Optimal use of foot control "status" information.

Proper design choices can make installation easier, and optimize the overall wireless performance.

Foot Control Design Considerations

Wireless Protocol Selection

Today's technologies present the OEM with an array of wireless protocols from which to choose. A sampling includes ZigBee®, BlueTooth®, Infrared, WLAN and customized protocols designed expressly for medical applications.

Key selection factors may include:

- Compatibility with the assessed risk in the application.
- Power consumption and power management .
- Response time.
- Inherent safety and reliability.
- Cost.

Low risk applications, such as a medical camera capturing reference images may be adequately addressed with a unidirectional protocol such as Infrared or Zigbee. Alternatively a higher risk application, such as a laser-based surgical instrument or a high-frequency surgical generator, may be better addressed with a bidirectional protocol. The latter may offer better noise immunity, greater encryption possibilities (for "pairing" the foot control with a specific piece of equipment), and the ability to verify the integrity of the communications link in real-time.

Battery Selection

The type of batteries to power the foot control will typically be determined by:

- Required operating voltage of the foot control electronics.
- Space constraints to accommodate the required cell(s).
- Frequency of recharging or battery replacement … this typically influenced by the wireless protocol selected, the power consumption during a typical procedure, and the number of procedures per day.

Required Operating Voltage/Space Constraints

Most wireless solutions will require at least 3.6 volt to operate the electronics. Thus the battery chemistry selection will gate the number of cells required, and (hence) the space requirements. More cells may require a larger access door for replacement … with attendant moisture sealing requirements.

Battery Replacement/Recharging Techniques

Regardless of the type of batteries used, ease-of-replacement may be an important design consideration … especially if done in the field by the user. In applications requiring frequent replacement, fast access without the need for tools may be a design objective. Depending upon the application, maintaining the sealing integrity of the battery compartment may also be important.

Where secondary batteries are chosen, the method of recharging may also be a major design variable. Current techniques include use of a medical-grade, plug-in wall recharger; conductive recharging in a charging cradle or docking station; inductive recharging; or simply replacing the discharged battery with a fully-charged cell from a charging station on the host system.

Wireless Receiver Design Considerations

Receiver Location

OEMs have two options for locating the wireless Receiver module … externally (on or attached to the host system) or internal (integrated within the medical device console).

Whether designed as an optional add-on accessary or as an element of a new product, an externally-mounted Receiver requires the electronics to be housed in a rugged package that can be conveniently attached to the medical device. Here the designer must consider:

- A location that does not interfere with foot control (transmitter) and Receiver communications
- The method for mounting the Receiver to the host device, e.g. docking pocket, magnetic latch, hard mounting with screws, et al).
- Providing power from the host system through the Receiver connector (typically via a pin on the host systems' Receiver input connector).

Figure 2.

Board-level Receivers can be integrated into medical equipment as either a factory option or field-upgrade.

An internally-located Receiver can consist of a PCB assembly that is mated to the host system electronics, or a packaged (housed) unit that can be quickly installed. Here the designer must consider:

- Space constraints that may affect the dimensional requirements for an internally-located Receiver.
- Whether to integrate the Receiver electronics with the host electronics during initial production or whether to have the Receiver electronics as a discrete device to be connected to the host electronics during final system assembly.
- If a discrete device, how power will be supplied to these electronics.

Internally-located Receiver modules generally cost less, as they typically do not need a housing, mounting hardware, a cable (from the receiver housing to the foot switch input connector or the mating female connector).

Figure 3.
Fully-enclosed receiver modules with status LEDs are one option for OEM consideration.

Receiver Signal Protocols

Medical device designers have several protocol choices when interfacing the Receiver to the host system. The Receiver can present the control signals (and other transmitted data, such as battery charge status, number of recharge cycles experienced, foot switch identification information, et al) to the host device.

The received data can be presented to the host electronics in a wide variety of protocol formats. These include, but are not limited to, Serial RS232, I2C, USB, or simply as discrete contact closures and/or analog voltage or current for variable controlled functions such as speed, power, et al. Close collaboration with the foot switch supplier will result in an optimal interface that is easy to integrate.

“Pairing”

Unlike cabled foot switches, which are “tethered” and hence dedicated to controlling the medical device to which they are connected, wireless units (theoretically) have the ability to control any device with the required Receiver electronics. Therefore it is essential that the wireless foot switch communicates with, and controls, only the specific device with and for whom its use is intended.

The acceptance and use of wireless foot switches has been greatly accelerated by the development of safe, reliable techniques for “pairing” the transmitter (foot control) and its Receiver.

“Pairing”, or the marriage of a foot control to a specific mate, can be achieved in a number of ways. Current techniques include:

1) Introducing a foot control to its intended mate over a dedicated IR channel used expressly for establishing a mated pair. This typically involves actuating the foot control in the presence of its mate, in so doing establishing a handshaking protocol in which the receiver accepts and stores the unique identity of the foot control (e.g. model, number, serial number, et al). Following this handshaking, the Receiver will recognize commands solely from its “paired” mate.
2) Introducing a foot control to its intended mate over its wireless RF link. This typically is accomplished by placing the Receiver in a “pairing mode” during which time one or more control functions are actuated on the foot control and the units are subsequently paired.
3) Using a “pairing cable”. Here the pairing is achieved by plugging the foot control into the Receiver system, during which time the first actuation of the foot switch enables the pairing process. Once paired, the cable can be stored for later use to pair a different/replacement foot control … or for use as a back-up cable to allow the foot switch to be used in a hard-wired (non-wireless) mode.

For most applications, pairing is limited to one foot control for one receiver. However, for selected applications it is possible to pair two like foot controls to a single medical device. For example, where two surgeons on opposite sides of the operating table are involved in the same procedure. Here programming will typically recognize only one foot switch at a time … ignoring any signals from its other paired mate until permitted to do so by the system’s program.

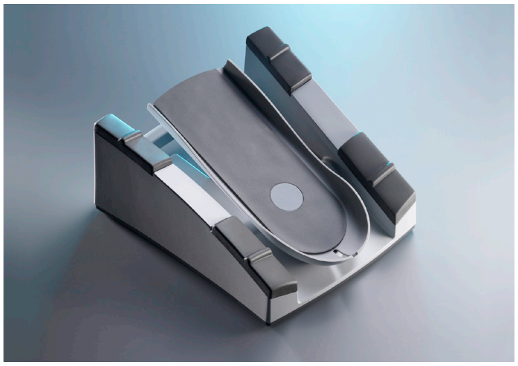

Figure 4.
Wireless operation lends itself even to the most complex foot control requirements.

The diversity of pairing techniques allows for a great deal of flexibility in the use of a population of like foot controls in the same facility… with consideration for ease-of-field replacement and without compromising system safety.

Summary

Consideration of these factors early in the design cycle (e.g. location, communication protocol and pairing) will result in a wireless foot switch or wireless hand control system that:

- Takes optimal advantage of each of the potential benefits of a wireless control system.
- Facilitates easy field service.
- Assures optimum performance of the wireless control unit(s).
- Takes maximum advantage of the availability of non-control information provided within a message frame … e.g. foot control identity, battery charge status, transmission anomalies, number of experienced recharge cycles, et al.
- Can by implemented at the lowest cost.

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