VARIABLE SPEED CONTROL OF TERMINAL DEVICES

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HISTORY

The ability of the wearer to control the speed as well as the direction of an electric terminal device has been a goal of external power development since the 1940's, [1]. It would have been strange if this were not so, since the purpose of such development was to replace anatomical function, and there are no constant speed joints in the human body.

By the late 1960's, electronic technology had advanced to the point that systems for below elbow amputees could be commercially developed but not to the point that variable speed control could be accomplished in the restrictive volume of the prosthetic hand. The U.S. Veterans Administration and Fidelity Electronics offered a hand system with proportional control but with the battery and circuits in the lower forearm. This system gained minimal acceptance and has been displaced by Otto Bock's modular system with the electronics in the hand and two over-the-muscle electrode-amplifiers. The simplicity of the Bock system has won in the market in spite of its constant speed motor control.

What is the standard? The market seems to have decided that simplicity is paramount. People want the electronics in the hand, and further they like the small electrode-amplifiers and other conveniences of the Bock system. Thus, we have a *de facto* below elbow standard. One is permitted at most two electrode packages, a battery, and the terminal device. Add one more box no matter how small and you are relegated to the fringes of the market. Is one-speed control part of the standard? No, but low cost is, and until recently so is the Otto Bock hand.

MARKETING A VARIABLE SPEED CONTROL.

We were convinced that users of myoelectrics want variable speed and grip. Some people had been paying substantial premiums for this convenience, so it appeared that the reason it was not widely available was because it violated two obvious rules of this market. It was added outside the hand and it was costly. In the fall of 1992, we were able to test our assumptions by offering the VariGrip Control Module.* This drop-in replacement for the factory electronics converts any adult Otto Bock hand to variable speed control. Although introduced with no fanfare, the product generated an immediate and positive response, and sales have been trending upward ever since. This has encouraged us to continue development of the concept by adding more features to the module. By taking advantage of the most sophisticated production techniques that volume allows, more components can be packaged into the limited space available. This experience has led us to the question: What might happen if variable speed control became the standard? For one thing, the cost premium could go away. The VariGrip adds about $300.00 (about 10%) to the net component cost of a typical BE prosthesis. This isn't a lot, but it's still a premium. If such a system were designed in rather than added on, the production cost should be about the same as the existing electronics.

Hand designs might also change; they could, for example, be much faster. Constant-speed control places an upper limit on the speed of the Terminal Device; Variable Speed control does not. Otto Bock could probably eliminate their automatic transmission since its function (speed reduction) would be under the direct control of the wearer.

The problems and opportunities of an add-on product. So far the add-on module has performed above expectations; however, there are a few problems with the adding on that are worthy of mention. The VG01 module will always fit flawlessly into an old 8E17 Bock hand as an upgrade. It will also work on the 8E37 when supplied with a new coaxial bushing 9E168=4. A new problem will arise when Bock replaces the mechanical switch in 8E37 and one exists right now with the 8E36 hand. These newer hands replace the slide switch with a reed switch activated by a sliding magnet. To be a true drop-in there needs to be a VariGrip module with the reed switch; however, there may be a better solution. Just ignore the switch. For more than a decade the electronics in electrode-amplifiers have been so good that one never needs to turn off an out-of-control hand. A properly fitting prosthesis simply does not require a switch. We are waiting for the market to tell us whether we can omit the switch.

Alternate VariGrip strategies. Two variations of the basic VariGrip are worth mentioning. In the first, the two Bock electrode-amplifiers are replaced by two touch pads. While there is currently only one user with this option, it works well. The second variation is to place the VariGrip in the forearm. If there is room in the forearm, one VariGrip can service both a "switch control" hand and a Greifer. This variation violates our own it-has-to-fit-in-the-hand rule; but to make it easy for the practitioner this variant is offered with all of the required wires and connectors already attached. And it is very small, measuring only 1.37 x 1.06 x .35 in. (35 x 27 x 9 mm). Further, the market is responding by purchasing it.

VariGrip for the UltraLite Hand. The new Centri UltraLite Electric Hands are supplied without any electronics. These hands are the shortest on the market which is ideal for the very-long-limb user; however, there is no extra room in the thin body of the hand so the circuit must be in the forearm. At present these hands are offered worldwide only with a VariGrip controller in the forearm or with no electronics.

What about children? For adults, it's hard to see a downside to variable speed control, but what about juvenile amputees? I would argue that the capability is useful at the age when a child is making the transition from simple grasp to true manipulation; most child development studies put this age at about 5 to 6 years. The question is: would it do any harm to provide the capability at an earlier age? From a manufacturing standpoint, you would like to build one system rather than three or four. Would this place some unforeseen cognitive burden on the very young? Taking VASI's product line for example, my instinct is to put the capability in the 2-6 hand but not in the 0-3. Is this right? How can I prove it?

* VariGrip controls are available from Liberty Technology, 71 Frankland Road, Hopkinton, MA 01748.

ADDING A BATTERY SAVER TO THE VARIGRIP CONTROL

Battery savers were first incorporated into hand prostheses to correct for the inadvertent control signals that result from inappropriate settings of myoamplifier gains and from inattention on the part of the user. After their introduction, these circuits led to additional uses. For instance, the St. Anthony or cookie crusher circuit requires a battery saver, because a close-hand signal is continuously applied except when the hand is being opened.

Old-style battery savers. Older saver circuits have been of two types. The first is a simple timer. The disadvantage of this circuit is that until the timer shuts down a stalled hand can draw excessive current and deplete the battery. The second circuit is the current limiter. Whenever the current goes over a threshold value, the circuit senses that the hand is stalled and it shuts down. These circuits all need logic to reset them for the next user-initiated action in the opposite direction. Some savers operate only on close, while others engage on both open and close.

Battery saving with variable speed control. Neither of the standard schemes are ideally suited to variable-speed, variable-grip control. A time-out clearly fails if the user merely moves slowly employing the slow-speed feature for which the new controller was designed. On the other hand current limiting precludes maximum grip. We have developed a third strategy for VariGrip. The circuit cuts off after a given quantity of charge has gone through the circuit. The value is set large enough to permit the user to close the hand slowly and then to grip maximally. Sometimes this strategy will waste more energy than the current limit strategy, but it never gets in the user's way and the maximum energy per average activation is still set to a satisfactorily low value. It may turn out that one value for the cutoff charge will work for most popular hands and grippers. Experiments are in progress to see what compromises will be acceptable and to determine which devices may require special versions of the controller. Preliminary data suggests that "one size will fit all."

CONTROLLING TWO DIRECTIONS WITH ONE SIGNAL

Not every user has two good sources of myosignal. Since the earliest days, the University of New Brunswick [2] and others [3] have offered one muscle control circuits. The UNB circuit uses two thresholds and signal amplitude to differentiate the two states. Later when Otto Bock created the 8E25 1-site, double-channel hand, it chose to use the speed with which the user initiates the signal to make the selection. To the user the circuits are virtually the same. With either, one gradually increases muscle tension to reach the first state and suddenly makes a big muscle to reach the second. The rate-of-rise circuit; however, needs only the gain control in a proportional electrode amplifier to tune it to the user. This is a distinct advantage. A second advantage is that it is easy to keep the selected function active until the signal goes below quite a low turn-off threshold. Thus the signal can be varied once the function has been selected. The rate-of-rise circuit thus lends itself to variable speed control.

One-site VariGrip control. The new VariGrip controllers will be set up so that they can all function as single-site variable-speed controllers. The prosthetist need only short the two signal inputs together and use one electrode-amplifier instead of two.

USE OF VARIGRIP IN THE BOSTON ELBOW II

For a long time two facts have been apparent—that the Boston Elbow required a separate controller for hands, grippers and rotators and that it would be easier if one could use standard off-the-shelf 6V hardware. A separate controller can handle both jobs easily. The trick is to match the characteristics of the controller to the devices as closely as possible.

The 6V—12V problem. The VariGrip is a nonstandard pulse-width-modulation circuit. In its pure form it simply varies the effective output voltage in proportion to the input signal all the way to the supply voltage which is 12V in the case of the elbow. Experiments have shown that the popular 6V single-motor devices will operate well from zero to about 8.5V with the higher voltage supplying a little more speed or grip than 6V. It is easy to clamp the output of the VariGrip to 8.5V or any other appropriate voltage and this is exactly what has been done.

Running two devices. To run two devices one merely adds a second output bridge circuit and some logic chips. Sufficient logic has been added to accommodate a hand and a wrist rotator with the hand bridge having the battery saver feature. Further logic circuitry permits the inputs to be tied together, so that one control voltage can be used to control two directions. In the Boston Elbow the circuit that sorts out which direction to go is the rate-of-rise circuit. It is not "officially" part of the VariGrip but is located on the same board. The logic to decide whether to run hand or elbow is also a separate circuit.

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