

118 is programmed preferably as an interrupt service routine (ISR). The analog multiplexer control lines corresponding to a desired lead are first selected in step 122. The multiplexer control line values are not changed unless the user selects a different lead or calibration signal. The process is delayed 100 microseconds in step 124 to ensure that the data from the leads have bubbled through the multiplexer and the amplifier section, and are present at the A/D converter inputs.

The program then initiates A/D conversion in step 126 as has already been described, waiting at least 15 microseconds in step 128 to ensure that conversion has been completed by the converter. The converted ECG waveform (i.e., digitized waveform) is read in step 130, stored in step 132, and then plotted on the display of the NINTENDO GAMEBOY device in step 134. A circular buffer is maintained in which the converted ECG waveform is stored for display. The converted points are plotted in a window on the screen from left to right, and then cleared for the next segment.

The rate at which this occurs depends upon a time scale factor selected by the user. This factor lets the user view the signal over longer or shorter periods of time (i.e., zooming in or out if desired). The NINTENDO GAMEBOY device is capable of displaying only 144 pixels across the screen at a time, so the scale factor is required to display longer lengths of time. The scale factor is determined by plotting more than one converted (Y) value for each particular time (X) value. Qualitatively, this has proven more visually representative of the ECG waveforms than only plotting, for example, every other digitized point.

#### Other Implementation Issues

As has been described, the overall ECG-monitoring device according to a preferred embodiment is divided into isolated and non-isolated sections. All parts of the circuit that come into contact with the host body are optically isolated from the NINTENDO GAMEBOY device, and the non-isolated section of the circuit. Separate power supplies for each section are necessary to achieve this. The isolated section requires  $\pm 6$  volt supplies, while the non-isolated section requires  $\pm 6$  and  $\pm 5$  volt supplies. In one embodiment, two nine-volt batteries and two regulator integrated circuits (e.g., 7806, 7906 devices) comprise the isolated supplies, and two nine-volt batteries and three regulator integrated circuits (e.g., 7805, 7806, 7906 devices) comprise the non-isolated supplies. The NINTENDO GAME platform (a type of cartridge-based portable video game system platform) device itself uses four AA batteries.

It is contemplated that further refinement of the design disclosed herein may result in reduction of the power consumption and the size of the requisite battery pack. For example, if charge-pump inversion integrated circuits are added, the number of nine-volt batteries and regulators necessary may be reduced by one-half. Such integrated circuit inversion devices convert a positive into a negative potential or vice-versa at a very high efficiency, at the low currents involved. One nine-volt battery could be regulated to the required positive six-volt level, then inverted to negative six volts. This eliminates one battery and one regulator with the added expense of the inversion device. This alternative design may also be accomplished on the non-isolated section.

A further contemplated alternative embodiment that reduces power consumption is the utilization of surface-mount components directly on a printed circuit board of the cartridge, instead of discrete components. As a general rule, surface-mount components require less power than do dis-

crete components. If power usage is sufficiently reduced, the NINTENDO GAMEBOY device itself may be able to supply sufficient power to at least the non-isolated section of the circuit.

The parts used in building the ECG-monitoring device are all commonly available, from such sources as Digi-key Corp., of Thief River Falls, Minn., and Newark Electronics, of Troy, Mich. The AD 625 instrumentation amplifier in particular is manufactured and directly available from Analog Devices, of Norwood, Mass. Like all the other components, however, the invention is not particularly limited to any delineated component herein.

The ECG-monitoring device according to the preferred embodiment as has been described is believed to be inexpensively manufactured. Much of the savings associated with the device is based on the fact that a mass-produced platform, the NINTENDO GAMEBOY device, containing many of what are usually expensive components (screen, CPU, RAM, etc.), is utilized. As has been described, it is believed that the NINTENDO GAMEBOY device costs approximately fifty dollars. The component cost of the cartridge device described herein at the time of the filing of this application is approximately \$125, and in quantities of 100 or more it is believed should decrease to \$75 or less, bringing the total system cost with NINTENDO GAMEBOY device to \$125. This is the component cost, and does not include manufacturing, packaging, or other costs. Further refinement of the design may also reduce costs.

#### Conclusion

A portable modular diagnostic medical device has been described. The device is portable in that it is based on a portable handheld multipurpose computerized platform. The device is modular in that different cartridges having different diagnostic medical functionality can be plugged into the device. Clinicians are able to take this portable instrumentation device to remote locations easily. The device is simple to operate. In the preferred embodiment described, ECG waveforms are displayed on the screen on-line in real time. This provides immediate and direct access to data without requiring transmission to other support hardware. The device is relatively inexpensive as well.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill within the art that any arrangement which is calculated to achieve the same purpose may be substituted for the specific embodiments shown. This application is intended to cover any adaptations or variations of the present invention. For example, the invention has been shown in relation to a NINTENDO GAMEBOY device. However, any portable handheld multipurpose computerized platform conforming to the claimed invention is amenable, such as a personal digital assistant (PDA). For further example, the invention has been shown in relation to an ECG device. However, any predetermined diagnostic medical function is amenable to the invention. Therefore, it is manifestly intended that this invention be limited only by the claims and equivalents thereof.

I claim:

1. A portable and modular electrocardiogram (ECG) medical device comprising:

a preprogrammed cartridge comprising:

a housing;

a connector partially disposed within the housing;

a plurality of leads, each lead detecting a lead signal;

an analog circuit to measure an ECG from the plurality of leads;