INSTRUMENTATION FOR THE CHARACTERISATION OF ENERGY STORAGE DEVICES AND MULTI-CELL SYSTEMS

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Abstract

The 1470 battery test system is a unique system which is designed specifically for running multi-channel high speed pulse and impedance tests on batteries, supercapacitors and fuel cells. Of course, multi-channel battery test systems have been around for some years, but the Solartron system has been specifically designed for GSM mobile phone applications. The 1470 system is designed with state-of-the-art high performance data acquisition components and has the ability to connect to frequency response analysers for impedance tests on any channel using a built-in multiplexer.

The system is targeted at research, development and quality assurance applications. Impedance (ac testing) is now widely recognised as giving valuable information regarding the prediction of the cycle life of secondary (rechargeable) batteries and is also useful for non-destructive tests on primary cells. The 1470 system not only allows the impedance of the whole cell to be tested, it can also test individual battery components including electrodes, separators and electrolytes by the use of auxiliary voltage inputs. The 1470 system integrates impedance testing over a wide frequency range with standard charge / discharge cycle analysis.

Introduction

The world battery manufacturing capacity is estimated to be over 40 billion dollars worth of batteries and is growing at 10% per year. Approximately half of this output is for high power batteries as used in electric vehicles, fork lift trucks, standby power systems etc. The remainder is for commercial applications such as mobile phones, laptop computers, power tools, toys, watches, camcorders etc.

For some years now, battery manufacturers have been investing heavily in battery test equipment. In the field of research and development, the equipment is used for investigating the performance of new electrode materials, electrode shapes/designs, separator materials, electrolytes etc. Further to this another important area is for the validation of claims made in product advertisements (i.e. manufacturer X's batteries last two times longer than manufacturer Y's batteries). For quality tests it is important to verify batches of batteries to make sure that they are performing as expected. In production, equipment is used for the formation of batteries and for doing instant tests to verify whether the battery is working correctly before shipment.

Battery manufacturers invest heavily on test equipment, however, the capabilities of currently available equipment on the market is limited either to high performance single channel units such as the Solartron 1260/1287, or relatively low performance multi-channel systems. It is worth noting that it is not only the battery

manufacturers themselves who are interested in the performance of batteries. Manufacturers of laptop computers, mobile phones, camcorders and palmtops are all trying to find the best batteries to use with their products to make sure that they get the best battery cycle life, shortest charge times, best standby performance, longest discharge capability, smallest weight, best performance in different climatic conditions. Test equipment is also an important consideration for these companies.

Discussion

The 1470 battery test system is a unique system which is designed specifically for running multi-channel high speed pulse and impedance tests on batteries, supercapacitors and fuel cells. Of course, multi-channel battery test systems have been around for some years, but the Solartron system has been specifically designed for GSM mobile phone applications. The 1470 system is designed with state-of-the-art high performance data acquisition components and has the ability to connect to frequency response analysers for impedance tests on any channel using a built-in multiplexer.

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In recent years, mobile phones have grown in popularity to the extent where millions of phones are being produced every year. In particular, the digital version of these phones (GSM - Global Standard for Mobile telecommunications) are becoming very popular. During transmission of data to the base station, the phone battery sees a pulse load which is at 218Hz (approximately 5msec square wave duration). To test multiple batteries simultaneously, it is necessary to have special high speed acquisition hardware and software with data compression techniques to reduce the data throughput to the PC.

The system is modular in design (8 channels per unit and up to 12 units per system giving a total channel count of 96). In practice however, any number of PCs can be added to the system giving a limitless number of test channels. The battery test units are designed both for bench top operation and also fit into a standard 19” rack and are smaller than many units which are currently on the market.

Constant voltage, current, power and load test strategies are available. The system makes use of analogue control loops for smooth control of applied signals (these are a similar design to that used in Solartron’s research grade potentiostats e.g.1287). The maximum applied levels are up to 10V and at least 3A per channel (maybe higher than 3A). The system is designed with multiple voltage and current ranges allowing resolution of very low level voltage and current signals; 3 microvolts /

1.5 nanoAmps (this is close to the performance of a single channel research grade potentiostat). The data acquisition sample rate is high (dual 16 bit / 10kHz analogue to digital converters per channel for simultaneous voltage and current sampling). The data is collected by a digital signal processor (one per battery channel), which allows compression of data and testing against safety or step termination limits.

The 1470 makes use of techniques which are not found on other commercially available battery test system. The signal processor per channel architecture allows very fast capture of pulse waveforms (e.g. digital phone GSM pulses - Global Standard for Mobile telecommunications). The processor per channel allows data to be collected on all channels in the system at the fastest data rate. The DSP processor helps the PC and communications link to keep up with the required data rate, by compressing the data, (only sending varying data back to the PC, constant data is reduced to a background rate).

The limiting factor of the system is designed to be in the communications link back to the PC and in the speed of the PC itself, not in the battery tester. In this way as PCs, and communications standards such as Ethernet continue to develop, the system will automatically make use of the greater processing power which is becoming available.

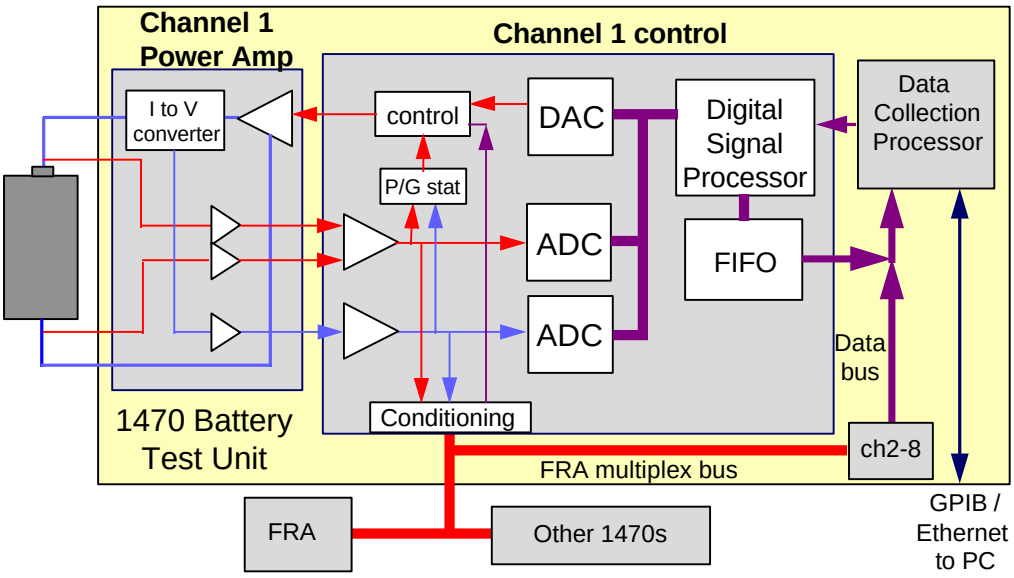

Fig. 1 Schematic of 1470 Battery Tester design

The schematic (Fig.1) shows an FRA added into the system linked to the battery tester. The FRA connects to the FRA multiplexer bus via a connector on the rear of the 1470. All channels within a 1470 are connected to this multiplexer bus. The PC software selects which channel actually forms a connection with the FRA via switches in the block named “conditioning” (see Fig. 1). Only one channel can be connected to a particular FRA at any time.

The other purpose of the “conditioning” block is to reject DC from the output signals to the FRA (FRAs only measure the AC components of the signal), and to provide an attenuation feature to allow the FRA to apply low level AC signals to the battery.

If only one FRA is available for the whole system (comprising of many 1470 battery test units), it is necessary to connect all of the 1470 FRA multiplexer connections together so that all channels in the system can be served by the single FRA. If more FRAs are available, then it is preferable to connect one FRA to each separate 1470 unit (in this case the multiplexer connections from each 1470 are not connected together). In this way each FRA only serves the eight channels inside its allocated battery test unit.

In future there will be an option card available for the battery test unit which will allow impedance to be run on all channels simultaneously (this option will be retro-fitable). The diagram (Fig. 2) shows a single FRA connected to a complete multi-unit battery test system (in this case comprising 96 channels). The multiplexer bus connects between units allowing impedance to be run on any channel.

The FRA needs its own GPIB interface since its communications to the PC are relatively slow compared to the speed of data transfer used by the 1470 battery test units. It is important not to slow the transfer speed of the 1470 units so the communications interfaces should be kept separate. The PC should therefore be configured with two GPIB interface cards (in future this can be one Ethernet card for the battery test units and one GPIB card for the FRAs).

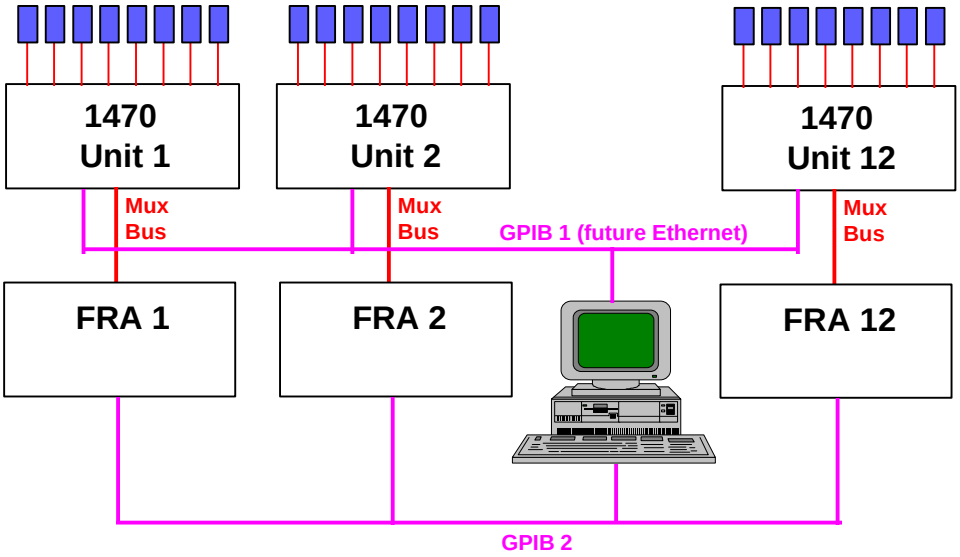

Fig. 2 Connections between the 1470 Battery Tester and FRA's

Multi-terminal tests can be made on cells using the 14701 option card. This card contains 8 auxiliary input voltage channels. The auxiliary channels acquire data at the same rate and precision as the main voltage measurement channels (10kHz / 16 bit). This allows additional voltage probes to be connected to various points within a battery. These inputs are all differential voltage inputs which allows the user to connect to any two points within the battery and measure the voltage difference between those two points. The current is measured by the main channel to which this auxiliary voltage input is allocated. The allocation of auxiliary channels is set up in the PC software and can be varied from one experiment to the next.

Not only can these voltage inputs measure the DC voltage drop between the points to which their high and low inputs are connected, they can also output buffered voltage signals to an FRA to allow measurement of impedance between these two

points. This is done be connecting the outputs from the auxiliary voltage card together with the relevant main channel current output to the FRA multiplex bus. This allows the FRA to make impedance measurements of the anode, cathode, separators, electrolyte etc.

In addition, the auxiliary voltage channels can be used to connect across individual cells in a battery pack to allow the impedance of each cell to be monitored.

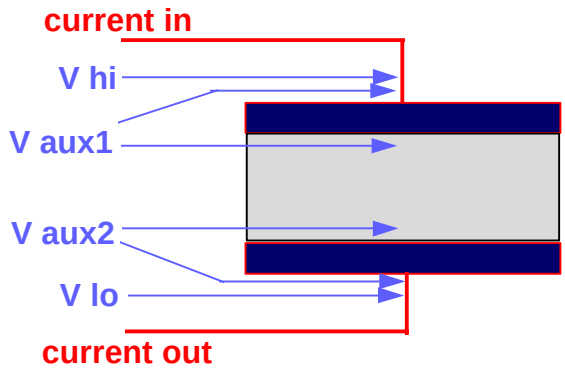

Fig. 3 Auxiliary Voltage Channels available

The "CellTest" software is designed to run on the Windows NT or Windows '95 operating system, this allows better protection in the event of software failure and allows multi-tasking to be used (i.e. having data acquisition tasks running in parallel with user interface software). The acquisition software can be made high priority to ensure that data is collected at the required rate.

The software allows multiple projects to be set up within the 1470 battery test software, allowing each user to have their own project (or projects) and test channels in the system to be allocated to particular users. These users can run their own experiments with their own preferences for screen layout without affecting other users on the system. All active projects permanently acquire data while their schedules are running, but only the active project displays the data on the screen. It will be easy to switch between active projects to view the real-time or historical data displays related to a particular project.

Impedance test software is fully integrated into the schedules. Impedance data can be acquired from any channel to which an FRA is currently attached. The data can be presented in Bode or complex plane format within the 1470 software package or can be exported to ZView for further analysis and equivalent circuit fitting.

It is planned to allow control of Eurotherm temperature controllers to allow batches of batteries to be cycled while being environmentally tested (at high or low temperature). This allows automatic evaluation of the performance of batteries over their rated range of temperatures.

The software permanently monitors the status of each schedule which is running and in the event of power fail attempts to recover from the point in the schedule where power fail occurred.

Electrochemists also have a requirement for multi-cell analysis, in applications such as determining the performance of novel gas sensors, corrosion/coatings research, membrane development, and the analysis of the performance of new materials to act as electrodes/separators in batteries/fuel cells. The 1470 has been modified to operate with CorrWare, this product , called the 1480 Multistat will enable multi-cell systems

to be studied in a cost effective manner, the electrochemist will also be able to utilised the considerable performance and impedance capability.

Conclusion

The development of leading edge technology such as the 1470 Battery Tester provides researchers and manufacturers with instrumentation capable of qualifying battery performance and studying cell reactions for emerging battery technologies, such as NiMH, lithium polymer batteries (LPB) and plastic lithium ion (PLI) systems. In conclusion, it is apparent that new instrumentation is critical to evaluating reliability of everyday technology such as consumer batteries, and in the development of novel fuel cells and supercapcitors