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A MULTIFUNCTION BATTERY TEST FACILITY

P. P. ANDREEV* and D. P. TONCHEV

Central Laboratory of Electrochemical Power Sources, Bulgarian Academy of Sciences, Sofia (Bulgaria)

Introduction

The design of automatic battery test techniques is directed at present towards the development of more sophisticated ATEs, with a wide range of capabilities that can handle not only existing national and international standards but also future modifications, or even recently established standardized data bases. Furthermore, for maximum efficiency, such test systems should allow both manufacturers and research workers alike, the means to develop their own test procedures in a highly customized fashion. Undoubtedly, the aim of minimum human intervention, reliable operation, versatile reprogramming of complex test routines, as well as fast and accurate data acquisition, handling, and concise presentation, call for an automatic test facility that functions under dedicated computer control. In this respect, the designer faces the challenge of making the correct compromise between the power-handling capacity, the level of precision, the stability of operation, and the degree of reliability. The work reported here describes some of the hardware solutions to the design of a multifunction battery test facility (MBTF).

Multiple feedback loop control

The basic charge/discharge module used throughout is based on the principle of linear feedback control. This does not offer the highest possible efficiency, but on account of the inherently high precision, low (if any) EMI, good reliability, and predictable response, such control is readily adaptable to the different charge and discharge operational modes. An additional advantage of such an approach is that the local computer burden of continuous control over a number of feedback loops is transferred to the multiple analogue servo loops, whereas the computer is used to set the initial conditions only. An example of the simplest possible dual channel analogue control is shown in Fig. 1.

Applying the practices of standard electronic design, and usage of advanced integrated operational amplifiers, will virtually remove most of the

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*Author to whom correspondence should be addressed.

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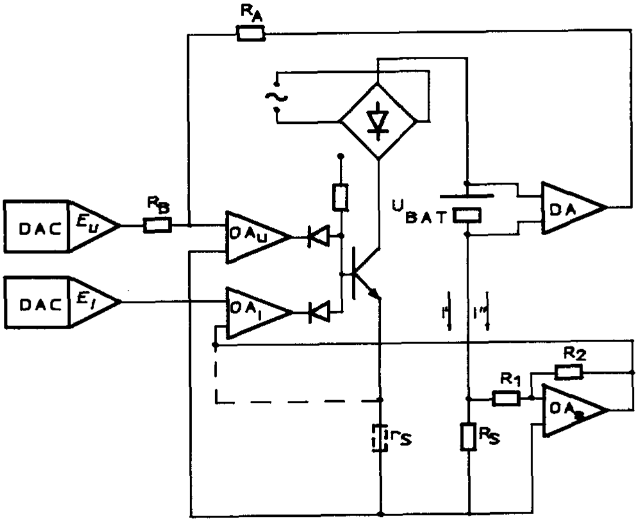


Fig. 1. Automatic crossover voltage–current source.

disturbing influences such as line voltage variation, load change, temperature deviations, etc. [1]. More attention should be given to the design of the current shunt, which is a sensitive and critical component [2], as well as to the thermal feedback artifacts, in the development of precision high-power electronic circuitry [3]. Another important consideration concerns the stability of the current source with regard to load changes. If the common circuit configuration is used (illustrated by the dashed lines in Fig. 1), then the base current of the power regulator flows through the shunt resistor, but is diverted from the load current which is naturally due to the open loop output control. The current flowing into the load is then:

$$I' = \frac{\beta}{1+\beta}\frac{E_I}{r_s} \qquad \beta = f(I, t^0, \ldots) \tag{1}$$

where β represents the 'current gain' of the power transistor and is a function of the load current and temperature.

A significant improvement [4] over the 'classical' current/voltage source is also presented in Fig. 1. This results in a highly stable feedback-controlled load current of:

$$I'' = \frac{R_2}{R_1}\frac{E_I}{R_s} \tag{2}$$

where R_2/R_1 represents the gain of the shunt amplifier OA_s.

The 'voltage feedback' signal is derived from the differental amplifier, DA, connected to the shunt resistor R_s, without any degradation in voltage accuracy, such that the battery voltage is:

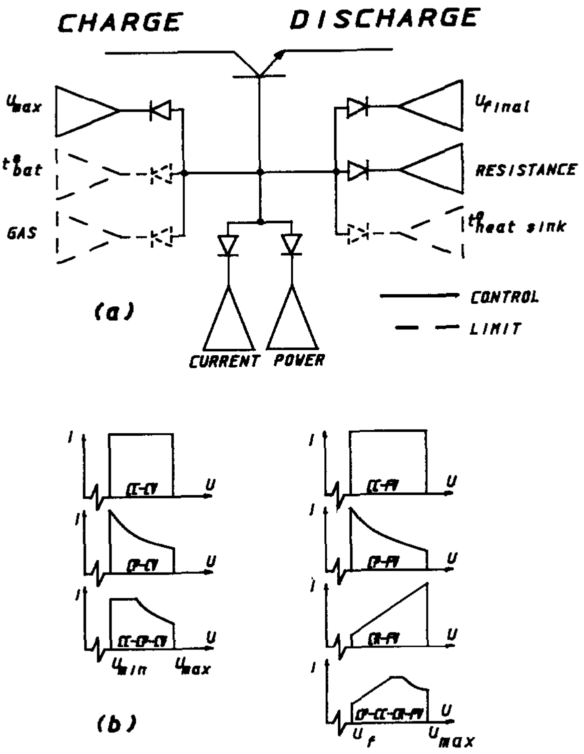


Fig. 2. Multiple crossover source-sink. (a) Multiple 'OR' gated linear feedback control circuit; (b) examples of mixed operational modes.

$$U_{BAT} = K_{da} \frac{R_A}{R_B} E_u \tag{3}$$

where K_{da} is the differential amplifier gain and R_A/R_B is the gain of the voltage amplifier OAu.

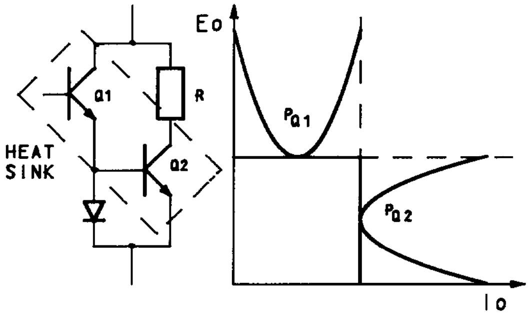
The more sophisticated multiple 'OR' gated feedback control and limit-terminating loops [5] are shown in Fig. 2(a). Charge and/or discharge patterns are presented in Fig. 2(b). It can be seen that the MBTF can be easily programmed to implement the well-known 'constant current' charge to a set upper voltage, where it automatically changes over to a precise voltage regulation with a current-limiting feature. The 'constant-power/constant-voltage' configuration performs in a similar fashion. Neither the common 'constant-current/final-voltage-limit' discharge pattern nor the 'constant-power/final-voltage' and 'constant-resistance/final-voltage' operations present any difficulty. In addition, any 'mixed' operational mode can be custom-devised and performed accordingly, a hypothetical example being the discharge sequence: 'constant-power/constant-current/constant-resistance/final voltage'.

Reliability considerations

The power regulator is the component that is most susceptible to malfunction. Design efforts towards widening the scope of applications result in severe thermal loading of the power transistors. This involves not only high temperatures but also stresses due to thermal cycling [6]. A design limit of 70% of the maximum power transistor junction temperature, the size, the volume and weight of the power stage, and the convenience of the cooling method have all led to the choice of the economical parallel transistor regulator circuit [7] and to a stepwise, load-dependent cooling fan motion control.

Figure 3 is a diagram of the parallel regulator which helps to spread the thermal load over a combination of active and passive components. With a proper choice of the passive *R* value, the maximum power dissipation in transistors Q1 and Q2 will be approximately one-fourth the maximum power under the worst-case conditions. Furthermore, the operation of this circuit ensures that both transistors are not required to dissipate maximum power simultaneously, thus a common heat sink will have a maximum temperature rise associated with the heat dissipated by one, not two, of the power transistors. It is, then, apparent that the main economical advantage of the parallel transistor regulator is the lower number of power transistors that share a common heat sink of reduced size, volume, and weight.

As far as reliability is concerned, another critical component that may lower the Mean-Time-Between-Failures (MTBF) performance is the electromechanical power switch for the charge/discharge reversing action. Thus,



- $P_{Q1max}=P_{Q2max}=\frac{Eo_{max}\cdot Io_{max}}{4}$
- $P_{Rmax}=Eo_{max}\cdot Io_{max}$
- LINEAR CONTROL
- COMMON HEAT SINK
- DISTRIBUTED THERMAL LOAD

SMALLER SIZE AND WEIGHT

Fig. 3. Economical parallel linear transistor regulator.

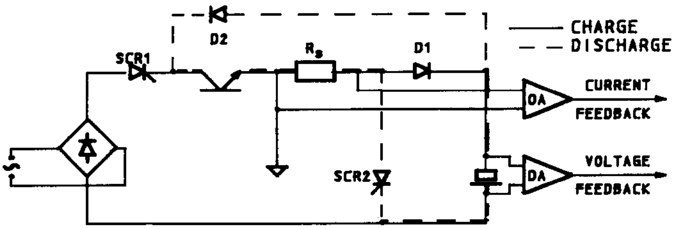


Fig. 4. Solid-state charge/discharge switchover circuit.

for better reliability and a higher MTBF value, a novel solid state charge/ discharge switchover circuit has been applied [8].

In Fig. 4, the battery charge path is shown by complete lines from the main power source via the SCR1, power regulator, current shunt, and diode D1. By contrast, the discharge path (represented by dashed lines) comes from the battery via diode D2, power regulator, current shunt, and SCR2. The compromise paid for somewhat lower efficiency is justified by achieving a faultless, solid-state switchover operation.

Modular construction

The mechanical construction is housed in standardized 19 in. cabinets to give maximum flexibility and convenience from the user point of view. The raw power source is provided separately and may be either manufactured by special order or built 'in-house'. It can be a common three-phase power rectifier whose power output depends on the number of MBTFs used as chargers or cyclers. On the other hand, if the discharge power handling capabilities of the basic MBTF are inadequate for a certain application, there is no difficulty in parallelling power regulators, as they can be added as separate modules. In those cases where the MBTF is used for reserve or rated capacity tests, a single unit without a raw power source is appropriate.

Computer control

The built-in computer operates as a specialized, intelligent controller performing standardized test routines in accordance with most of the common standard documents' data base. Nevertheless, users may define their own test procedures in dialogue with the system software. The latter is still in an early stage of development but will be menu oriented through a soft panel control. Such a computer-aided test (CAT) solution will also maintain the modular principle in terms of software. The local monitor screen displays the present state of the particular MBTF, the test terminating conditions, and the basic test parameters (*e.g.*, voltage, current, power, etc.). Historical data

TABLE 1

Basic parameters of multifunction battery test facility

Charge/discharge current (A)	0 - 100
Charge voltage (V)	10.0 max.
Discharge voltage (V)	4.0 (final)
Charge/discharge power (W)	0 - 1500
Discharge resistance (Ω)	0.05 - 50
Time base	$1\ \mathrm{s}\ \mathrm{min}^{-1}\ \mathrm{h}^{-1}$
Number of cycles	1 - 9999

TABLE 2

Features of multifunctional battery test facility

Basic charge and/or discharge control	
constant current	CC
constant voltage	CV
constant power	CP
constant resistance	CR
final voltage	FV
Mixed charge and/or discharge control	
automatic charge crossover	CC-CV
automatic charge crossover	CP-CV
automatic charge crossover	CC-CP-CV
automatic discharge crossover	CC-FV
automatic discharge crossover	CP-FV
automatic discharge crossover	CR-FV
automatic discharge crossover	CP-CC-FV
automatic discharge crossover	CP-CC-CR-FV
Charge and/or discharge terminating conditions	
charge:	time, voltage, current, A h, W h, temp., gas
discharge:	time, voltage, current, A h, W h, temp.
Display on to a local computer monitor	
function	
graphics plot	
voltage, current, time, power, resistance	
Computer controlled tests	
basically according to all national and international standards: BDS, GOST, IEC, DIN, SAE, AABM, British Standards	
examples:	
life cycling test	
overcharge life test	
rated capacity test	
reserve capacity test	
charge acceptance test	
customized test patterns, etc.	

can be clearly presented in tabular or graphical form. Raw data are easily transferred to a host computer with advanced analytical, statistical, and graphic capabilities, plus a variety of hard copy peripherals. Centralized control of the MBTFs by the host computer is also possible.

Conclusions

A new computerized multifunction battery test equipment has been designed with the prototype basic parameters presented in Table 1, and features summarized in Table 2.

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