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dependent in being rewritten with random contributions from speed variations of the drum surface. Even using stationary blocks, a guard space must be left between blocks to allow for the case of initially writing a block at a time of minimum surface speed, and rewriting at a time of maximum surface speed. The guard space depends not only on the maximum fractional speed variations but also on the maximum block length that is allowed. A similar space allowance must be left between the last block on a track and the first.

It is the use of stationary blocks that enables the HD File Drum to be adapted to variable word and block length organization without wasted space, except for that consumed by stationary blocks. Note that while wholly variable block lengths are possible in the initial formation of a track, a block must not be increased in length thereafter without reforming the entire portion of the track that follows. A system using fixed block markers on an auxiliary track has been worked out, however, that dispenses with stationary blocks. The system is particularly valuable for fixed block organization.

Fig. 15 shows the major elements of a file system which uses HD File Drums. Output and input arrows at the left run to and from the controlling computer. Code converters are used to transfer between the balanced eight bit code of the file, and the system code if it is different. The output information is shown on two alternate lines. One method uses a buffer store that possesses the capacity of the maximum block length to be transferred and that is operable from either the system clock phase or the self-clocked phase depending on the operation being performed. The alternative method uses a smaller capacity synchronizer that accepts information at the self-clocked phase and passes it on at the system clock phase.

The size of the synchronizer in the latter case is dependent upon the allowed maximum variation in the phases of the two clocks, as well as on the maximum block length to be transferred. One form of such a synchronizer was previously described.16

References


Transistorized Modular Power Supplies for Digital Computers

THEODORE C. GAMS
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POWER supplies for digital computers are characterized by unusually rigid reliability requirements. After reliability, size and cost are the next most important considerations. Simplicity of design and ease of servicing are considered as part of the reliability problem, since computer down-time, particularly in large installations, may cost from $10.00 to $100.00 per minute. In military digital computers, reliability may be of in calculable value.

The design of high-reliability digital-computer power supplies is made practical by the relatively poor regulation performance that may be tolerated, of the order of ±1% to ±10%, in contrast to analog computer and tele metering system power supplies, which require regulation performance on the order of ±0.01% to ±0.1%.

In order to evaluate a power supply meaningfully in terms of regulation, however, it is necessary to construct a definition of "total regulation." The total regulation of a power supply includes the following factors:

1. Static load regulation.
2. Static line regulation.
3. Dynamic load regulation.
4. Dynamic line regulation.
5. Peak-to-peak ripple.
6. Thermal drift.
7. Interaction.

When total regulation is so expressed, the circuit designer may then assume that, under the worst possible simultaneous combination of all these factors, the power supply voltage can never fall below a predetermined minimum or above a predetermined maximum value. Fig. 1 readily illustrates the concept of total regulation.

The transistorization of digital computer circuitry has led to three unusual complications of the power supply design problem.

1. Transistor circuits demand very much lower voltages, and correspondingly higher currents, than vacuum-tube circuits performing the same functions. The resultant lower impedance level required of the power supplies, therefore, reduces the advantages gained by the lower total power requirements of transistorized equipment, and may actually increase the power supply size, weight, and cost over those formerly required. Table 1 contains a typical comparison example for reference.

2. Since transistorized circuitry is very much more compact than equivalent vacuum-tube circuitry, the power supply is often the largest element in the system, and can often be several times as large as the computing element it powers. This leads to attempts to miniaturize the power supply, often at the expense of reliability and economy.

3. The efficiency of the power supply is now of much greater concern than it was previously, since it is often responsible for more heat dissipation than any of the actual computer circuitry. This condition was seldom encountered before transistors and magnetic-core storage were adopted for digital computer use.

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Gams—Transistorized Modular Power Supplies
Three Modern Power Supply Techniques

The general acceptance of germanium transistors as reliable devices, when properly derated and pretested, has permitted the use of efficient, compact, series-regulated and shunt-regulated power supplies for voltages as high as several hundred volts, currents as much as 200 amperes, and power levels up to and above 2 kilowatts (kw). Recent circuit improvements have realized complete freedom from overload and short-circuit failures. Fig. 2 illustrates a typical series-regulated transistorized power supply.

In many applications, particularly when a multiplicity of closely-spaced voltage levels must be furnished to a variety of loads, the transistorized shunt-regulator technique may be more attractive than the series-regulator technique. This configuration eliminates the necessity for protecting the transistors against short-circuit or overload stress, and permits operation from a common unregulated supply. Fig. 3 shows a typical shunt-regulated power supply, and Fig. 4 illustrates a typical array of several shunt regulators operating from a common unregulated supply.

When the regulation allowance is sufficiently broad, and/or the size allowance permits, brute-force circuitry still offers practical solutions to power supply requirements. For the practice of "floating" nickel-cadmium batteries across the output of brute-force supplies in place of massive capacitor banks, to achieve low dynamic impedance, freedom from line-transient regulation, and, under ideal conditions, the ability to complete a problem after total line failure.

When neither brute-force nor a pure transistorized technique is applicable, a third circuit has found favor. This employs the same kind of transistor correction amplifier employed in the pure transistor circuitry, but substitutes magnetic-amplifier gates for the power transistor series or shunt regulators. By designing the rectifier plate transformer appropriately, the short-circuit current can be limited to protect the rectifiers, permitting dependence on primary circuit breakers or fuses. Is some cases, protection may be omitted entirely.

Effect of Input Frequency—Motor Alternator

Freedom from severe line voltage fluctuations, and relief from the effects of momentary line failures, can be achieved by the introduction of a motor-alternator set of adequate rotational inertia between the power line and the power supply system. In addition, the power frequency may then be raised to 1800 cycles per second.

Table I. Comparison of Typical Digital Computer Power Supply Requirements: Vacuum-Tube Versus Transistor Circuitry

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Amperes</th>
<th>Impedance</th>
<th>Total Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>+200...</td>
<td>4.0</td>
<td>1.5</td>
<td>3</td>
</tr>
<tr>
<td>+100...</td>
<td>3.0</td>
<td>0.75</td>
<td>3</td>
</tr>
<tr>
<td>-200...</td>
<td>3.0</td>
<td>0.75</td>
<td>3</td>
</tr>
<tr>
<td>-100...</td>
<td>3.0</td>
<td>0.75</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Power = 2,761 watts
(Heater Power = 2,300 watts)

Relative Power Ratio: 3:2:1
Relative Size Ratio: 2:1
Relative Cost Ratio: 1:1

Table II. Comparison of Typical Digital Computer Power Supply Designs: Cost, Size, Weight, Versus Power-Line Frequency

Supply Under Consideration Has 16 Output Levels, Total Output of 6,200 Watts, Average d-c Impedance Level of 0.02 Ohms. Average Load Dynamic "Step" Is ±20%. Line Dynamic Step Is ±10%. Transistorized Circuitry Throughout

<table>
<thead>
<tr>
<th>Cost</th>
<th>Size</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dollars</td>
<td>Cubic Feet</td>
<td>Pounds</td>
</tr>
<tr>
<td>At 60 cycles per second</td>
<td>11,000</td>
<td>60</td>
</tr>
<tr>
<td>At 600 cycles per second</td>
<td>6,900</td>
<td>19</td>
</tr>
<tr>
<td>At 800 cycles per second</td>
<td>6,600</td>
<td>17</td>
</tr>
<tr>
<td>At 2,000 cycles per second</td>
<td>6,700</td>
<td>15.5</td>
</tr>
</tbody>
</table>

Fig. 1. Concept of total regulation

Gams—Transistorized Modular Power Supplies

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400, 800, or even 2,000 cycles per second (cps), greatly reducing the size and cost of the rectifier, filter, and regulator elements. Modern motor-alternators do not require the elaborate maintenance techniques normally considered necessary for older machines, and the acoustical problem has been successfully solved. Over 5 kW, the motor alternator almost always pays for itself in reduced power supply cost, and should be considered for its many other advantages. Modern tubeless voltage-regulating circuits are available to hold the alternator frequency and output voltage within close limits, over wide ranges of load and input voltage, and the response characteristics of these regulators is often better than the response of static line regulators of comparable power capacity. Table II illustrates some of the advantages of motor-alternator applications.

**Modulization**

Analysis of almost any set of required voltage and current levels for a computer load will suggest to the designer that certain basic circuits and groups of components are repeated with little or no variation from design to design.

It will further be noticed that the number of unique designs can be reduced by producing flexible modules, each covering a number of different desired voltage levels, at current ratings and with regulation characteristics which will satisfy all the requirements of each voltage level.

The individual ranges may be made manually selectable by taps or switches, or automatically selectable by proper wiring of the socket into which a module plugs. Ranges may be extended by adding additional pluggable (series or shunt) regulator elements.

The process of selecting the minimum number of economical, reliable, easily

---

*Fig. 2. Typical series-regulated transistorized power supply*

*Fig. 3 (left). Typical shunt-regulated power supply*

*Fig. 4. Typical array of several shunt regulators operating from a common unregulated supply*
If the distribution problems become too difficult to handle with large "central" power supplies, a common solution is found in the (noncritical) distribution of unregulated d-c power, with smaller modulized regulators located at each of the several racks of load equipment. In this instance, a system such as that outlined in Fig. 4 is often preferable.

Proposed Definitions of Computer Power Supply Electrical Parameters

These definitions were prepared by the NJE Corporation for consideration by the National Electrical Manufacturers Association Subcommittee on Computer Power Supplies, Semiconductor Section.

REGULATION

The regulation of a power supply is defined as the algebraic sum of all the components listed, measured individually, with all uninvolved parameters held at nominal. For convenience, a "norm value" of output voltage is selected at nominal input conditions, with all other supplies in the system inactive, at a nominal load current, arbitrarily selected as the average of the maximum and minimum load rating, at nominal ambient temperature. Positive-going voltage variations from the norm are considered as positive regulation components, and negative-going voltage variations from the norm are considered as negative regulation components. The total regulation is then stated as "plus or minus" a given percentage, and it is understood that the arithmetic sum of all positive regulation components must be less than the given percentage, and the arithmetic sum of all negative regulation components must be less than the given percentage. Definitions of the individual components follow:

Distribution, Circuit Blocks, Load Protection

Certain precautions (e.g., protection against reversal of voltage due to inadvertent short-circuitry of a positive output lead to a negative output lead), are necessary in connecting the power supply system to the complex load geometry common in modern high-speed digital computers. If these precautions are not observed, catastrophic failures of thousands of transistors, diodes, or core assemblies can occur.

Further, the low internal impedance that has been painstakingly designed into the power supplies can be multiplied many times by the distribution system. Transmission lines having characteristic impedances of the order of 100 micro-ohms are not uncommonly required.

Intolerable interaction can occur if the distribution system is not properly designed.

maintained modules to cover a set of required outputs involves a very delicate balancing of many factors. It can be influenced by as abstruse a consideration as the cost of preparing elaborate instruction-manual literature on the smallest number of circuit configurations.

In most regulated systems, it is practical to design one universal correction amplifier, incorporating a suitable reference power supply, as a standardized plug-in sub-module for all regulating circuits in the system. Another common plug-in sub-module is a power transistor array mounted on a pluggable heat-sink. A typical "universal" amplifier is illustrated in Fig. 6. In this instance, it was considered desirable to mount the amplifier power supply, as well as a universal-output control circuit, on a separate (pluggable) chassis, shown in Fig. 7. This chassis provides the choice of locally or remotely controllable marginal-checking facilities, as well as remote sensing, etc.

Through the use of modern modulization techniques, one recent large transistorized computer power supply system provided more than 150 outputs from only 11 basic designs. Analysis of the expected component life of that system indicates that 85% of all anticipated failures can be corrected by substitution of one or more of only three of the 13 sub-modules.
1. Static Load Regulation is the variation from norm of the output voltage as the load current is varied slowly from a rated minimum to rated maximum, expressed as a percentage of the norm.

2. Static Line Regulation is the variation from norm of the output voltage, as the line supply voltage (in 3-phase systems, line-to-line, all three phases varied simultaneously with no significant phase-to-phase unbalance) is slowly varied from rated minimum to rated maximum, expressed as a percentage of the norm.

3. Peak-to-Peak Ripple is the maximum periodically-occurring excursion of the output voltage under a passive (resistive) unvarying rated maximum load, expressed as a percentage of the norm. To avoid confusion with induced noise (from sources external to the power supply) the periodicity referred to above is restricted to those frequencies which are integral harmonic multiples of the line frequency.

4. Dynamic Load Regulation is the difference between the maximum instantaneous excursion of the output voltage in response to a unit-step change of output current (indeinitely maintained) between the rated minimum value and the rated maximum value and the static excursion which remains after all transient recovery behavior has effectively disappeared, expressed as a percentage of the norm. Unit-step changes are taken in both directions (minimum to maximum and maximum to minimum) to obtain both positive and negative components of dynamic load regulation.

5. Dynamic Line Regulation is the difference between the maximum instantaneous excursion of the output voltage in response to a unit-step change of line voltage current, indefinitely maintained, between the rated minimum value and the rated maximum value and the static excursion which remains after all transient recovery behavior has effectively disappeared, expressed as a percentage of the norm. Unit-step changes are taken in both directions, minimum to maximum and maximum to minimum, to obtain both positive and negative components of dynamic line regulation.

6. Instability is the variation in the output voltage which occurs under “norm” conditions over a period of _ _ _ minutes of warmup time under norm conditions, expressed as a percentage of norm.

7. Thermal Drift is the variation in the output voltage which occurs under “norm” conditions as the ambient temperature, measured at least 4 inches from the coolest surface of the power supply, is slowly varied from rated minimum to rated maximum, expressed as a percentage of norm.

8. Interaction Regulation is the variation in output voltage of any particular supply of a system of supplies, under “norm” conditions, as all the other supplies normally connected to the same power source, motor-alternator or line, simultaneously experience a unit-step change in load current from rated minimum to rated maximum, expressed as a percentage of the norm. As previously, unit-step changes are taken in both directions.

The Shiftrix-Machine Organization for High-Speed Digital Computation

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The need for higher speed computation demands continuous scrutiny of machine organization concurrent with the search for higher speed switching and storage elements.

Every digital computer operation may be decomposed into a set of micro-operations whose decision points are conditional upon the information in the operands and instructions. Between the extremes of strictly serial and extravagantly parallel methods, the machine designer is guided by some combination of formal synthesis, intuition, and learned weighting factors.

This paper focuses its attention on an arithmetic organization which utilizes a shifting matrix between an operand and the accumulator. Part I considers the multiplication process. Part II describes the use of the “Shiftrix” in other machine operations. Part III discusses possible mechanizations.

A block diagram representation of a conventional parallel multiplier is shown in Fig. 1.

In a binary multiplication involving two positive n-bit operands, the least significant bit of the multiplier is observed; the multiplicand is added to the existing partial product if the multiplier bit is a “one”; and the resulting partial product is shifted one place to the right, independent of the state of the multiplier bit. The multiplier is shifted right at the same time permitting the partial product bit to enter the left end of the multiplier register and bringing the next multiplier bit into control position. This process is iterated and the counter tallies the number of shifts. The control stops the iteration process when a preset count is reached.

In multipliers using a fixed operation time an addition of zero or the multiplicand occurs at every step. The multiplication process, exclusive of memory access time and negative operand corrections, requires a time interval

\[ t_s = n(t_s + t_{\text{add}}) \]  

where

\[ t_s = \text{the time interval required to perform an addition} \]

\[ t_{\text{add}} = \text{the time interval required to shift the partial product and multiplier} \]

Multipliers using a variable operation time conventionally expend the addition time only when required by the state of the multiplier digit. The resulting operation time is

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