

# Exhibit 2008

# Fundamentals of Automatic Control

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To my mother

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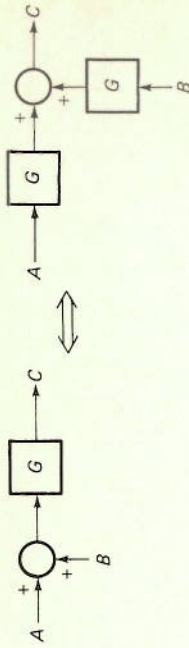


Figure 1-10 Moving summing point around a block

a system diagram to effect simplification is termed *block-diagram algebra* since it is analogous to simplifying algebraic equations. However, reducing a block diagram has the advantage of providing a better understanding of the interrelationships of the various elements in the system as compared to simplifying the system equations.

The combining of cascaded blocks into a single block, as described in Sec. 1-5, is obviously one step toward simplification. As another possibility, it is sometimes useful to move a summing point around a block as indicated in Fig. 1-10. Note that the inputs A and B are introduced through blocks incorporating the function G around which the summing point was moved. Applying the distributive property of algebra, we see that  $C = (A + B)G = AG + BG$ . Thus the two diagrams are equivalent.

Table 1-1 gives a number of transformations useful in simplifying block diagrams. These transformations can be verified by showing that the outputs from the two equivalent diagrams are the same. Note that the original and equivalent identities can be used interchangeably.

### 1-7 CLOSED-LOOP TRANSFER FUNCTION

Since certain functions and types of variables are commonly associated with feedback control systems, a generalized block diagram may be formulated and the associated closed-loop transfer function derived. Some standardization of the symbols and terminology relating to feedback control systems has been achieved and is used in this case.

Figure 1-11 is a general block diagram of a closed-loop control system. It is important that the terms used in this diagram be clearly understood.

### System Variables

The *desired value V* is an external signal applied to the system to command a specific output from the process. The desired value is sometimes called the *system command* or *set point*.



Figure 1-8 Takeoff-point representation

as being combined at a summing point must be in the same plane, two voltages may be combined but a voltage and current cannot be brought together. Any number of variables may be combined at a summing point.

A *takeoff point* is simply represented by a dot as shown in Fig. 1-8.

In the block-diagram representation of a system, let us assume the oven-temperature control described in the preceding section is shown in block-diagram form in Fig. 1-9. In this diagram the various blocks may be identified with elements of the system. In addition the units associated with the transfer function blocks are shown in parentheses.

The diagram tends to clarify the physical understanding of the system and provides a convenient basis for system analysis. We shall use block diagrams as useful in pointing out the similarity between apparently unrelated systems. It should be emphasized that in connecting one block with another represent the flow of information within the system. The main sources of energy for the system need not be included in the block diagram.

### 1-6 SIMPLIFICATION OF BLOCK DIAGRAMS

A block diagram that is initially drawn for a system may contain a large number of blocks and signal paths and be more complicated than necessary. In such cases a simplification may be performed to rearrange the block diagram to a form with fewer blocks. Rearranging

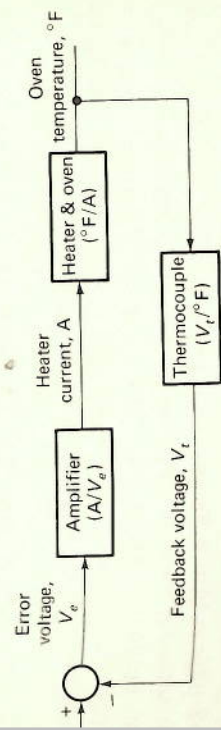


Figure 1-9 Block diagram of oven-temperature control



