given gain level, the other one is gain-switched. After time for the gain change to settle, the second amplifier may be selected by the selector switch, and so on, alternately.

The gain table, Table 2, indicates how the post-amplifiers are gain-switched off line, whether gain is being increased or decreased. When gain is increasing, the off-line amplifier is switched at least one gain step before it will be brought on line. Since gain can be increased only following an examination period of at least 30 ms, the post-amplifier has more than 30 ms to rise to the new level. When gain is decreasing, the off-line amplifier is switched three gain steps before it will be called on. Since gain can drop at 1-ms intervals, a minimum of 3 ms is always provided for the signal to stabilize at a lower level.

It may be noted that, although offsets and switching transients are largely avoided by the choice of chopper-stabilized d-c amplifiers, there is no serial amplification of whatever small offsets or transients there may be.

Furthermore, the use of digital gain control prevents low-frequency distortion which may amount to 2 or 3% at 5 or 10 cps, even in a good AGC amplifier.

Through the measures described, plus careful attention to every detail of design and fabrication, harmonic distortion in the automatic gain-ranging amplifier is specified at 0.1%--an order of magnitude better than most seismic amplifiers.

NOISE REDUCTION

Noise is any unwanted signal which interferes with the measurement of the wanted signal. In the present instance, some of it originates within the amplifier and some outside. Part of the outside noise, caused by sources of a seismic nature, is actually wanted signal so far as the amplifier is concerned. The seismic signal should be separated into wanted and unwanted components at a later stage, computer processing.

The undesired outside noise, then, may include radio-frequency interference, 60-cycle pickup, and common-mode voltage. As an experienced manufacturer of low-level data acquisition systems, the techniques for reducing these signals to insignificant proportions are well known to SDS Data Systems and have been fully utilized in the design of this system.

Noise within the amplifier originates largely from the thermal motion of electrons, although there may be pickup from one component to an adjoining one. Pick-up may be reduced to an insignificant level, however, by good design. Good design involves the proper mounting of components, location of elements, and shielding. For example, twisted-pair, shielded wiring is used in interconnecting cables and some elements are completely protected with electromagnetic shields. A certain minimum of thermal noise is inescapable, however; this minimum is inherent in the principles of physics.

Thermal noise is proportional to temperature, source resistance, and bandwidth. Temperature and source resistance, of course, are fixed by the nature of the application. The effect of bandwidth on noise can be reduced by limiting the bandwidth and, in seismic applications, low-cut and high-cut filters do limit the bandwidth. Nevertheless, under values of these three factors met in seismic work, theoretically minimum thermal noise will be about 0.05 microvolt, referred to input.

Active components introduce some additional noise. The noise contribution of the transistors, however, has been substantially reduced by the use of silicon planar passivated units. The latest available, this type has a noise figure on the order of 1.5 db, less than half the noise figure of the transistors in use as recently as a year ago.

Thus, by careful attention to design factors, the total noise specification has been held, typically, to 0.1 microvolt rms, referred to input. Under certain circumstances, noise may be as much as 0.2 microvolt rms, referred to input.