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# The Mitsubishi PCM Recording Format

*The PCM recording format described here permits physical butt-splicing, as well as more-sophisticated electronic editing techniques.*

THERE EXISTS TODAY a large and expanding consumer demand for higher quality audio playback capability. In the past decade, the ability of the professional recording studio to keep pace with this demand has been very successful. Refinements in the areas of noise-reduction techniques, auxiliary analog hardware, maintenance procedures, and new formulations of magnetic tape have all nurtured this ability, but only up to a certain level. A law of diminishing returns exists that states that, the more an analog signal is processed, the less it resembles the original. The reasons for this are many and varied, but are primarily due to the modulation noise caused by inhomogeneities in the distribution of the magnetic domains and distortion arising from non-linearity of magnetic characteristics. Another problem associated with analog recording is the vague sound image caused by wow and flutter.

Perhaps a decade ago, engineers began to apply pulse-code modulation (PCM) techniques to audio design. PCM promised to free the audio signal from the types of analog problems just described, and to provide the listener with sound quality of an unparalleled dimension. In the early days of digital audio, hardware was expensive to build and maintain, complicated to operate, and generally unreliable. Supported by contemporary advances in semi-conductor technology, this is no longer the case. Digital recording techniques now offer a real and obvious alternative to analog in the recording studio. But for PCM playback to become popular in the home, a large catalog of digitally-encoded master tape software must first become available. To this end, Mitsubishi Electric has designed and is now marketing, a complete line of professional-type PCM audio components. Included in this chain are; a multi-channel recorder, a two-channel recorder, a digital mixer, an electronic editor, and a digital delay for disc mastering. (See the author's "The Mitsubishi Digital Audio System" in our February, 1980 issue for more information on the complete system—Ed.)

*Mitsubishi X-80A 2-Channel Digital Recorder*

## THE X-800 32-CHANNEL PCM RECORDER

Mitsubishi's multi-channel PCM tape recorder can record 32 channels of audio on one-inch tape, at a tape speed of 30 ips. To eliminate as much tape use as possible, we have designed our recorders using a fixed ferrite head. This allows reduced tape speeds, while still retaining the ability of high-density data storage and retrieval, typically greater than 30,000 bits-per-inch. In this type of high-density recording, we cannot expect every track to be in optimum condition all the time, especially when the recorder has to play back tape that was poorly stored, or was originally recorded on a slightly-misaligned deck. In this case, data errors tend to occur on a few particular tracks, while the remaining tracks are still in good condition.

In order to rectify this type of situation, we have devised what we call the "semi-separate" format (FIGURE 1). With this format, one audio channel is recorder on one track, and for error correction, two parity tracks are provided for every sub-group of eight-channels. In addition, each channel has its own CRC (cyclic redundancy check) code. Thus, we have a two-dimensional error-correction system, rather than the one-dimensional method found in some early PCM recorders. As a result, the signal can be recovered from a poor or weak tracks. In an extreme case where one track dies, recording, playback, and punch-in and punch-out on the track is still possible. Note that 40 digital tracks are required in order to record 32 audio channels.

## ERROR CORRECTION AND CONCEALMENT

Other large data losses are from such things as nodules in the tape coating and scratches or creases in the tape. In order to cope with these defects, signals are inter-leaved when recorded. (For more details on these error-correction techniques, see "Correcting tape Errors in Digital Magnetic Recording" in our November, 1980 issue of db—Ed.)

FIGURE 2 shows the largest error from dust that can be corrected, and the largest defect that can undergo error-concealment by one-sample interpolation (replacement of the bad sample with the average value of preceding and successive error-free samples). FIGURE 3 shows the correctability of this format for ordinary random error. Typically, these errors are caused by amounts of small dust or defects on the tape surface. The mean time between the occurrence of a miscorrection and error concealment is shown against the average bit error rate, $P_e$, and the average burst error length, B. In a bad case, with an average bit error rate of $10^{-4}$, and an average burst length of 200 bits, the mean time between the occurrence of error concealment is about 8.3 hours. The mean time between mis-correction (giving rise to an audible "pop" noise) is 21.6 years. These are reasonable, and quite practical, values.

In FIGURE 4, we can follow the signal path from input to output. Here, eight channels of audio pass through anti-aliasing low-pass filters, having a sharp cutoff frequency of 20 kHz. Then, the signals are sampled at a rate of 50.4 kHz and held in a sample/hold. This output is then converted into 16-bit linear PCM signals by A/D converters. A few channels out of each eight-channel group may be cross-faded with playback PCM signals at the fader, when the deck is in the "punch-in/punch-out" mode. The eight signals at the fader output are then combined at the RSC (Reed-Solomon Code) coder to make

*Mitsubishi X-800 32-Channel Digital Recorder*

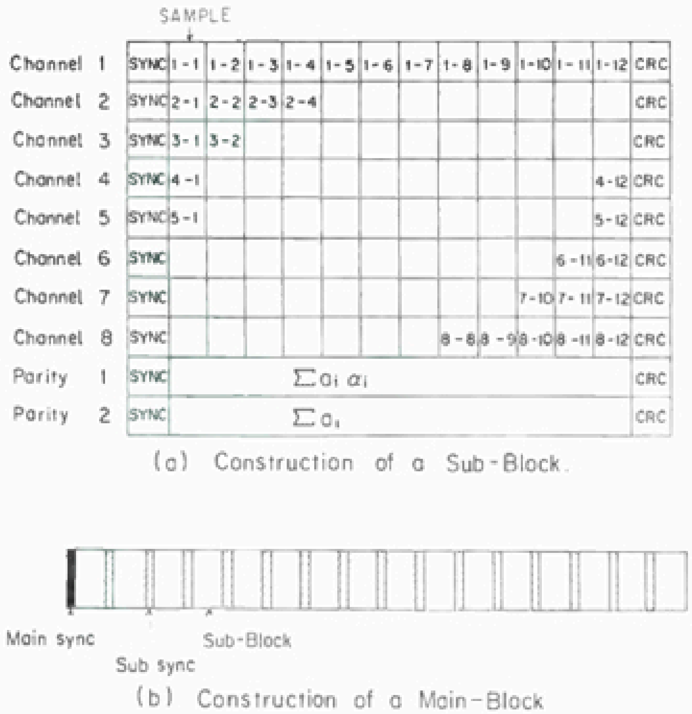



*Figure 1. Construction of a Block; 1a. Construction of a Sub-Block; 1b. Construction of a Main-Block.*



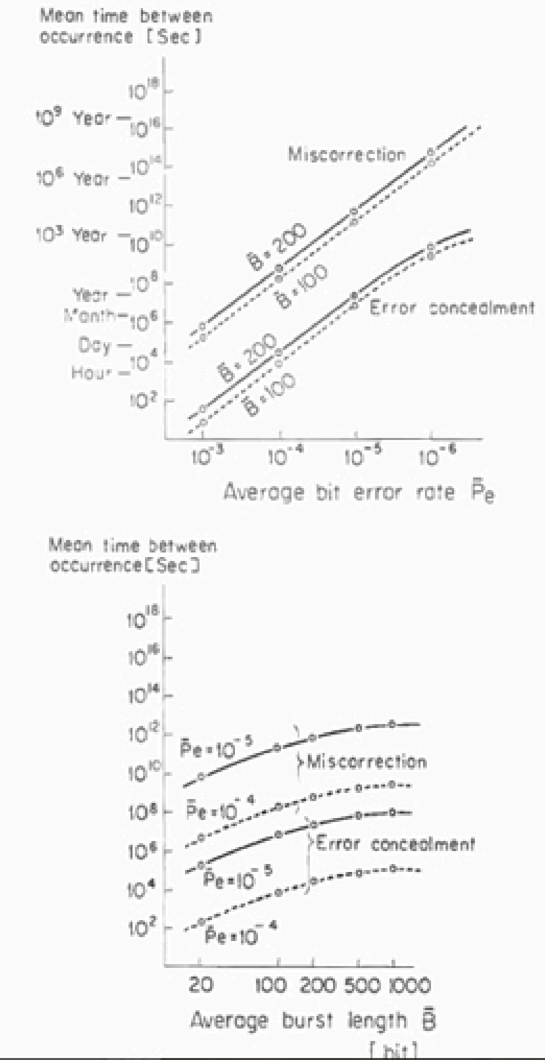

*Figure 2. Error correction and concealment.*

the signal format of the "semi-separate" format, and then interleaved. After passing through the modulator and write-compensation process, the data is stored on tape. During playback, the signals first pass through playback compensation and demodulation. Time-base error is corrected by the TBC, and error signals are corrected by the RSC decoder. Finally, the signals pass through a delay circuit whose delay is equal to the time in which the tape runs between the sync playback head and the record head.

## THE X-80 TWO-CHANNEL PCM RECORDER

In the case of our two-channel PCM recorders, this error-correction scheme is again used, to even more useful advantage. The tape employed is identical to the type used on the 32-channel deck, but in a quarter-inch variety, at a speed of 15 ips. There are ten tracks in this configuration; one track for monaural analog cueing, one track for SMPTE coding, six PCM tracks for encoded audio signal data, and two tracks for

*Figure 3. Error correcting capability of RSC code.*



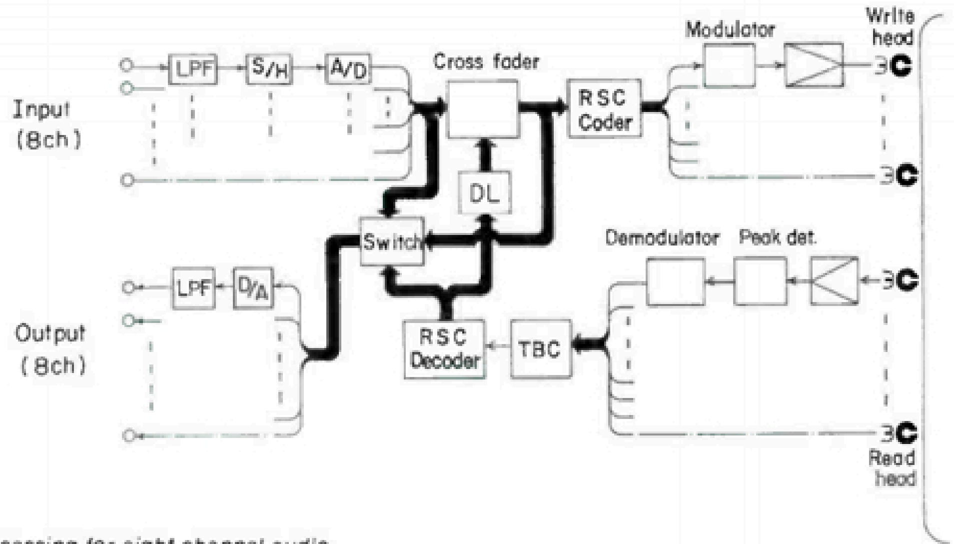



*Figure 4. Signal processing for eight channel audio signals.*

parity checking (FIGURE 5). By again interleaving the data, the tape can be edited by the cut-and-splice method. This is of immense value to the user, but would not be possible without a very powerful error-correction capability. The methods used are very similar to the ones used in typical analog splicing, except that care must be taken in the handling of this precision tape. One cues the proper material by monitoring the analog signal, marks the exact point with a fluorescent video-type marker (to reduce the chance of contaminating the tape) and cuts vertically using the supplied splicing block. The two sections are then joined, using a specially-formulated video splicing tape, used in this case to insure good tape-to-head contact.

FIGURE 6 shows the effects of two types of splicing tape. Note that when thick splicing tape is used, the signal deteriorates in the vicinity of the splice due to poor head-to-tape contact. The signal loss caused by the splicing tape is seen in the middle of each photograph in the figure. When played back, the error/loss is detected and is automatically cross-faded over the splice, insuring that no audible signal discontinuity, or "click" noise is heard.

One of the problems to be solved in making cut-and-splice editing possible is to keep the capstan-servo system locked in sync when encountering a splice. The capstan of the fixed-head type PCM tape recorder is driven by a phase-locked loop (PLL) type servo. The purpose of this is to lock the synchronization of

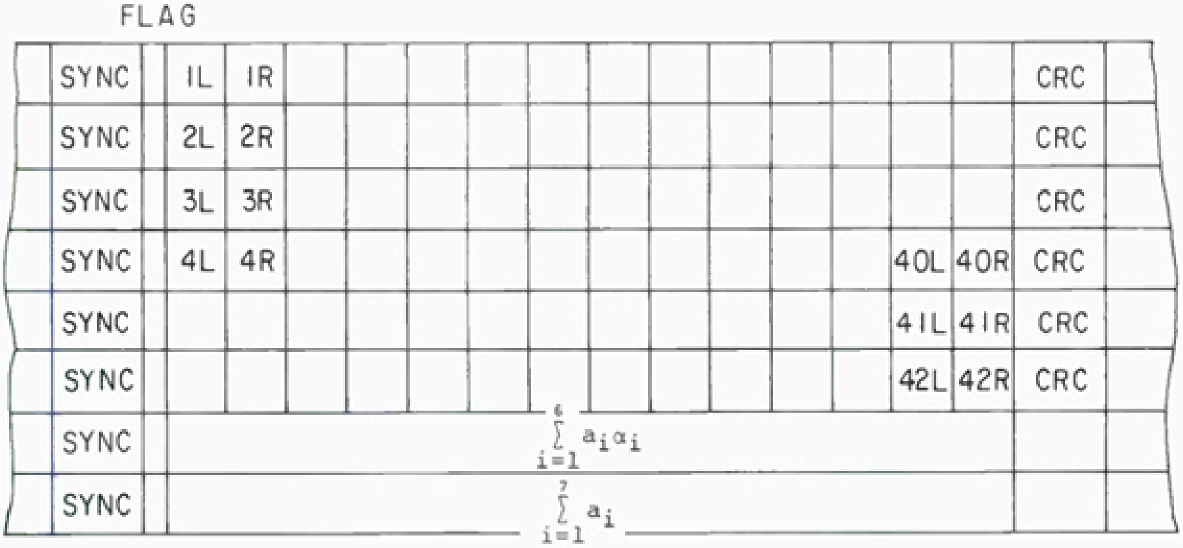


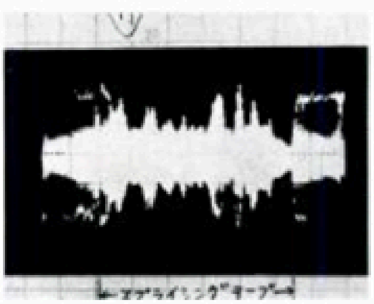

*Figure 5. Signal block configuration.*

the reproduced signal to an internally-generated reference signal, in this case by a quartz-crystal oscillator. In the case of the X-80, the phase of the reproduced sync signal is locked to the phase of the reference signal. The phase jump at the splice point varies from zero degrees. That is to say, there is no phase jump to ± 360 degrees. We devised a phase selection system to cope with this problem. As illustrated in FIGURE 7, two sub-sync signals, separated by 120 degrees, are generated by the reproduced sync signal. Usually, one of them is selected to be used for the servo-lock of the capstan. When there is a phase jump at the gap, another sync signal is selected to minimize phase jump. Using this method, jump is suppressed to less than ±60 degrees, and phase lock is assured. With the ability to splice edit and the high-precision of the semi-separate PCM format, we feel that reliability and stability are beyond question, thus making digital recording very accessible to the user.

## FUTURE PROSPECTS FOR PCM

When PCM recorders are used in conjunction with digital delay to master lacquers, incredible fidelity is possible. Our efforts in the very near future (a few months) will include the unveiling of a digital mixing console, and a PCM electronic editor. The mixing console will offer full fading and panning ability, and the editor will have the ability to tie up to three 2-channel decks together in perfect synchronization and edit multi-channel material. With these units in the field, we have effectively completed a chain of high-quality professional PCM audio components that will allow the recording studio and the musician the opportunity to use completely-digital recording techniques. Our efforts will then be aimed at the perfection of the digital audio disc system for home use. Only then will the consumer finally be able to take advantage of true playback—a very promising and exciting ability. ■

*Figure 6a. Effect of thick splicing tape*



*6b. Effect of thin splicing tape.*

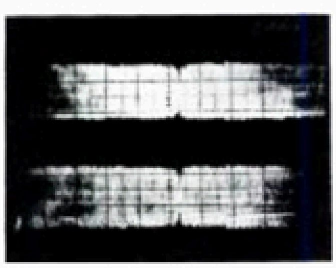


*Figure 7. Phase selection of servo system.*