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APPLICATION NOTE

DOUBLE DENSITY RECORDING ON MODEL 70 AND MODEL 270 DISKETTE DRIVES

1.0 DOUBLE DENSITY RECORDING TECHNIQUES

1.1 General

Diskette drives throughout the industry have made use of double frequency code because this code has simple encoding and decoding, compatibility with IBM 3740 systems, and excellent timing margins. However, this code is limited to 1.9×10^6 bits per surface in the IBM 3740 format, 2.52×10^6 bits in an efficient 32 hard sectors format, or 3.2×10^6 bits unformatted.

User pressure on the diskette drive manufacturers has been to increase the storage on the diskette. One way this has been successfully accomplished is by use of double density recording codes. Both MFM and M^2FM code have been successfully used to provide 5.05×10^6 bits per surface in a 32 hard sectors format.

1.2 Recording Codes

Successful double density recording has been accomplished on flexible disk drives with MFM and M^2FM techniques. Other techniques are also available, but they require much more complex encoding and decoding logic in the controller. Therefore PerSci has elected to use MFM and M^2FM as the double density codes for its diskette drives. Both of these codes are readily decoded with the aid of phase locked loop (PLL) type data separators, such as the PerSci double density data separator.

1.2.1 MFM Code

Double frequency code, widely used in diskette drives, encodes serial binary information, or "information bits", in the following manner:

Double Frequency Rules

1. Clock bit rule: a transition occurs at every cell boundary.
2. Data bit rule: a transition occurs at the center of a cell if the information bit is a 1, a transition does not occur at the center of a cell if the information bit is a 0.

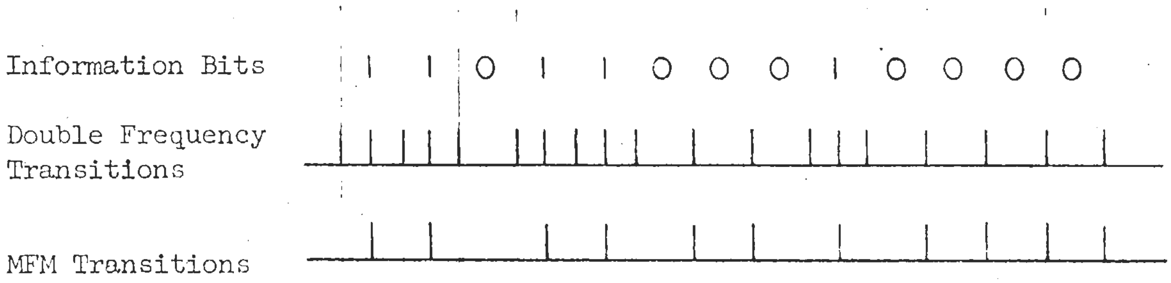
MFM modifies Rule 1 in the following manner:

MFM Rules

1. Clock bit rule: a transition occurs at boundaries between cells having successive 0 information bits.

2. Data bit rule: a transition occurs at the center of a cell if the information bit is a 1, no transition occurs at the center of the cell if the information bit is a 0.

The following timing diagrams will serve to show the similarities and also illustrate that MFM requires half the maximum transition rate of double frequency code.



As is illustrated by the timing diagram, the highest and lowest frequency involved in MFM is 1/2 the corresponding frequency for double frequency code at the same data rate. Therefore twice the data rate is available for the same transition rate.

1.2.2 M^{2}FM Code

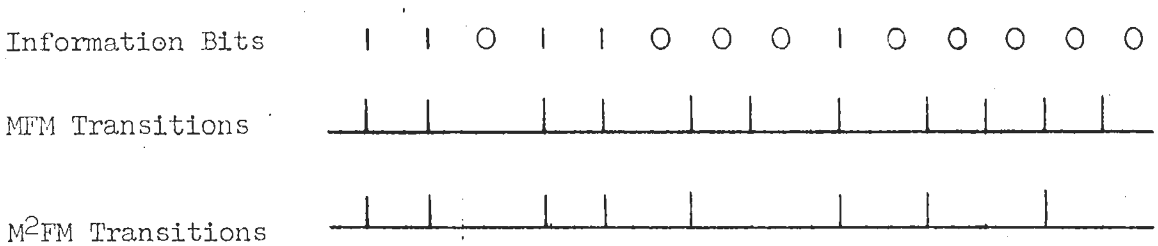
A further modification of coding Rule 1 results in M^{2}FM.

M^{2}FM Rules

1. Clock bit rule: a transition (clock bit) occurs at the boundard between two adjacent cells if no clock bit was written at the previous boundary and the boundary is between successive information bit 0's.

2. Data bit rule: a transition (data bit) occurs in the middle of a cell if the cell contains an information bit 1.

The following Timing Diagram will show the differences in MFM and M^{2}FM.



As is illustrated by the timing diagram, the highest frequency in M^2FM is the same as in MFM. However, the lowest frequency in M^2FM is 4/5 the lowest frequency in MFM. Also note that clock bits in M^2FM are not as close to other transitions as in MFM.

2.0 DISTORTIONS DUE TO MEDIA

2.1 General

High efficiency recording codes such as MFM and M^2FM were developed to overcome the limitations of distortions due to the media. Although more efficient than double frequency code, they are still limited by the same distortions.

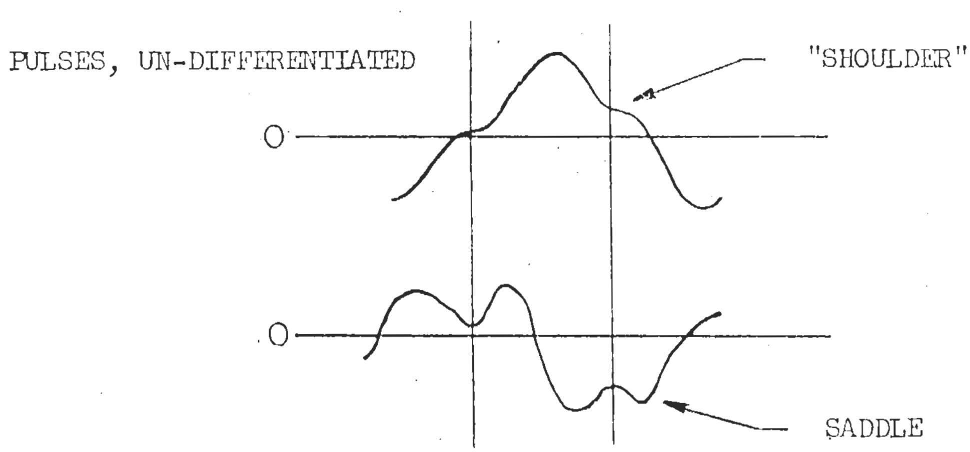
The information content in the unprocessed readback of any saturated magnetic recording system is contained in the peaks of that readback. Receiving the information requires determining if a peak did or did not occur in a given time "window". The peaks are found by electronically taking the derivatives of the readback, and finding the time when the derivative goes to zero. In the PerSci system, a 200 ns pulse is produced at each zero crossing of the derivative; this pulse is the "read data" pulse. A "data separator" circuit is then used to convert these pulses into clock pulses to define cell boundaries on the "separated clock" line and data pulses at the center of the cell when the information bit within the cell was determined to be a "1". Four distortions due to head and media interfere with this process. They are: amplitude distortion, shouldering, peak shift, and asymmetry.

2.2 Amplitude Distortion

Track 76 is recorded on a radius of 2.03 inches. Track 00 is recorded on a radius of 3.62 inches. Since the same number of bits is recorded on all tracks, the bits per inch (packing density) is 1.78 times as great on Track 76 as it is on Track 00. Amplitude of readback is dependent upon packing density and head tolerance. The output of an acceptable low amplitude head from high frequency at Track 76 may be only 10% of the amplitude from an acceptable high output head to low frequencies at Track 00. This effect defines the dynamic range over which the read circuits must work. The effect is present in any saturated magnetic disk recording system.

2.3 Shouldering

As packing density becomes lower, the pulses on the diskette take on some of the characteristics of isolated pulses. That is, the pulses begin to flatten and form "shoulders".



The derivative of these "shoulders" slips toward 0, forming "saddles". If these saddles reach 0, this is recognized as a transition and a spurious clock or data pulse is produced. In practice, this derivative never quite reaches 0, but as it gets low the system becomes susceptible to noise. The wide dynamic range discussed in the previous section precludes effective amplitude discrimination; therefore, the shouldering effect must be controlled by other means. Double frequency code and MFM code limit frequencies to a 2-to-1 spread and M^2FM limit frequencies to a 2.5-to-1 spread. Keeping the range of frequencies to 2.5-to-1 and specification of maximum resolution of the head at Track 00 eliminates errors due to this cause.

2.4 Peak Shift

As packing density becomes higher, the shoulders disappear. However, at the transition between a high frequency and lower frequency region of the readback, the peak of the last high frequency half cycle is shifted in time toward the lower frequency. This is the most important single effect limiting the amount of data that can be put on the media. This effect can shift a data pulse into the clock window, or a clock pulse into the data window. The magnitude in time of peak shifts in MFM code and double frequency code is the same; however, the decode window for MFM before considering any effects is half that of double frequency code at half the transition rate, since the practical decode window is the theoretical window with no time distortion effects minus all time distortion effects. This practical decode window gets rapidly small with increases in peak shift.

M^2FM has a greater high frequency to low frequency ratio than MFM. Therefore, peak shifts can be slightly greater. However, clock pulses in M^2FM code are never close to another pulse. Therefore there is less peak shift on clock pulses than on data pulses, and the decode window can be widened for data pulses and narrowed for clock pulses. Therein lies the advantage of M^2FM.

Practical systems using both MFM and M^2FM have been built. Write precompensation is used in these systems to reduce the effect of peak shift. Write precompensation consists of recognizing from the data that a peak shift will occur, and then writing the transition offset in a compensating time.

The amount of peak shift is controlled by specification of the heads. The ratio of amplitude of high frequency output to low frequency output from a head or a specified track of known quality is directly related to peak shift. This is known as head resolution. PerSci uses heads with a minimum resolution of 55% measured at Track 76 on an IBM 3740 diskette for double density applications. All PerSci heads also must have a maximum resolution of 90% at Track 00. This prevents overcompensation as well as keeping "shouldering" under control.

2.5 Asymmetry

The design of the head can cause an asymmetrical readback, even though no dysymmetry is caused by the read and write electronics. This effect is known as "pulse pairing" or "middle pulse jitter". It adds algebraically to peak shift, and cannot be compensated. This is controlled by specification and testing of the head.

3.0 DOUBLE DENSITY WITH PER SCI DRIVES

3.1 General

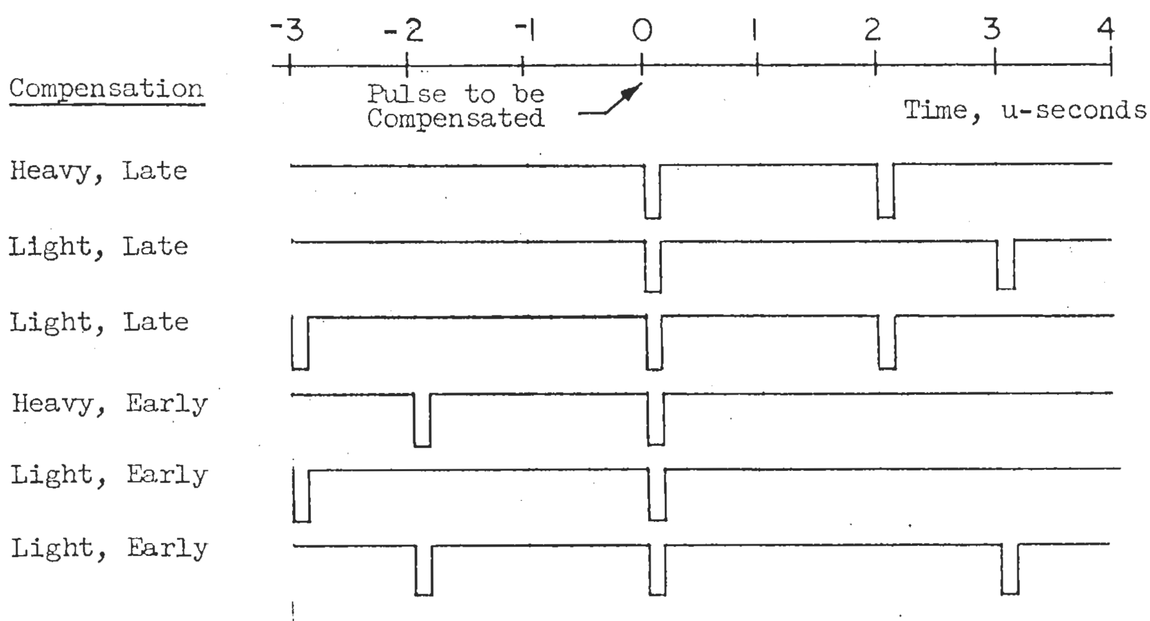
Successful double density systems have been built using both PerSci Model 70 and Model 270 diskette drives. PerSci read and write circuits are usable for both dual density and single density applications, but dual density requires tighter control on heads. A dual density data separator is offered for the PerSci drives. A jumper option will allow its use with either MFM or M^2FM.

3.2 Write Precompensation

Write precompensation is necessary for reliable operation using either M^2FM or MFM codes. It is accomplished by examining the data to be written and finding transitions from regions of high density to regions of low density, or low density to high density, and shifting the encoded write data pulse to compensate for peak shift.

M^2FM and MFM codes are similar enough to create virtually identical patterns which must be compensated. (Maximum peak shift for MFM at 500 Khz occurs when pulses 2 µsec apart are preceeded or followed by a pulse 4 µsec away. M^2FM pulses 2 µsec apart can be preceeded or followed by a pulse 5 µsec away. Peak shift in both instances is essentially the same.) Compensating the following six encoded write data patterns will work for both codes. Successful systems using both MFM and M^2FM have been built using 300 nsec heavy compensation and 100 nsec light compensation.

UNCOMPENSATED WRITE DATA PATTERNS



3.3 Format

In addition to the data stored in a sector, certain "bookkeeping" functions need to be performed. Also, provision must be made to accommodate both electrical and mechanical timing tolerances. These effects must be considered in constructing a format. PerSci dual density drives are formatted from an OEM type 33 hole diskette. PerSci drives provide sector separation and count down, providing from 32 to 2 sectors from such a diskette. (A 1-sector format is available by sectoring from the index pulse.)

A 32-sector format will be worked out as an example; other sectors basically can be obtained from the same method and information.

1. Time to Lock Phase Locked Oscillator

   Data Separator - T PLO = 50 μsec.

2. Timing Jitter in Sector Detection

   T SJ = 50 μsec.

3. Read Gate Delay - RGD = 2(TSJ) + TPLO

   RGD = 2(50 μsec) + 50 μsec.

   = 150 μsec.

4. Write Preamble - WPR = 2(TSJ) + RGD

   WPR = 2 (50) + 150

   WPR = 250 μsec.

   1 Byte = 16 μsec.

   $$\frac{250\ \mu sec}{16\ \mu sec} = 15.6 \text{ Bytes}$$

   Use 16 Bytes = 256 μsec.

5. Maximum Time for Disk to Travel from Read Write Head to Erase Head, 472 μsec. (Use this time for postamble.)

6. Sector Pulse Position Tolerance - SPP

   SPP = 5' arc = 81 μsec

7. Time Shrinking Due to Speed Variation -

   TSS = 172 μsec.

8. Time/Sector, Nominal - TS

   $$TS = \frac{166.7 \times 10^3}{32}\ \mu sec$$

   $$= 5209\ \mu sec$$

9. Time for Data - TD

$$TD = TS - (RGD + WPR + TSS + SPP)$$

$$TD = 5209 - (250 + 472 + 172 + 81)$$

$$TD = 4234 \text{ usec}$$

$$\frac{4234}{16} = 264 \text{ Bytes}$$

10. 32 Sector Format

256 BYTES	DATA
1 BYTE	ID FLAG
1 BYTE	TRACK ADDRESS
1 BYTE	SECTOR ADDRESS
2 BYTES	CRCC
19 BYTES OS	PREAMBLE
31 BYTES OS	POSTAMBLE

3.4 Data Separation

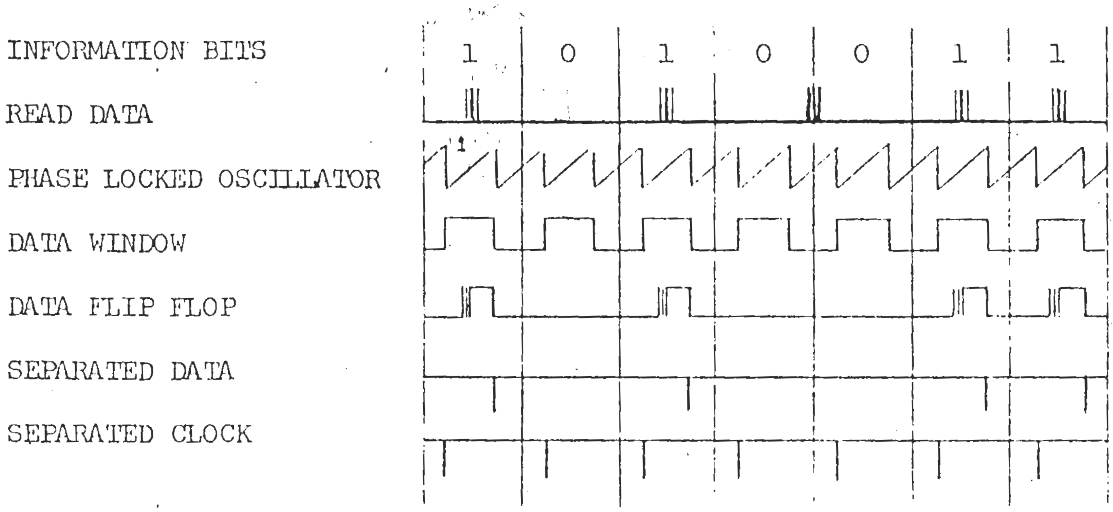
PerSci provides data separation circuits for double density as an option with the Model 70 and Model 270 diskette drives. Some users, however, prefer to put this function into their controller. The data separation function consists of generating serial data pulses on one line and a continuous train of clock pulses on another. These pulses are 200 nsec pulses from logic high to logic low on PerSci drives.

Both MFM and M^2FM codes quarantee only a certain number of total pulses per unit time. Clock pulses are not quaranteed; in fact, long periods of data without clocks commonly occur with these codes. This makes a phase locked loop type of data separator mandatory. The PerSci data separator, of course, is a phase locked loop type.

The data separator has two modes of operation; acquisition and data. The system is switched to acquisition mode by the leading edge of a sector pulse. The system is switched to data mode 140 µseconds later. Since acquisition occurs in the preamble, which is all 0's, all pulses at this time must be recognized as clock. Therefore any data pulse detected during acquisition time corrects the clock and data recognition logic. During data mode the correction logic is inhibited. Although only 50 µsec are required to lock the loop, the 140 µsec are required to insure that the preamble has been read for 50 µsec.

The difference in MFM and M^2FM separators is the 55/45 window used for M^2FM versus the 50/50 window used for MFM. A window is the time the system is looking for a data pulse or clock pulse. The data window is gated with read data to allow a flip flop set by a read data pulse to be interpreted as a data pulse. This flip flop is reset by the trailing edge of data window. A one shot is triggered when this flip flop is reset, thus generating data pulses with jitter removed. Another one shot is fired on the leading edge of the data window, thus generating the continuous train of clock pulses.

The following waveforms will illustrate MFM decoding. M^2FM is similar:



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