INTERFACE SPEEDS DATA TRANSFER AND RECOVERS LOST DATA

Recovery mode—a method of recovering data lost because of head positioning errors—is embedded in a disk drive interface that allows data transfers to occur three times faster than existing standards.

by Don Nanneman

Compact high performance Winchester disk drives continue to add capacity in response to the storage needs of powerful microcomputer systems. Drives have taken advantage of all the techniques at their disposal to increase track densities and thus gain more capacity per recording surface. However, the next round of storage expansion will depend on increases in linear bit density, which will result in a higher data transfer rate. Although media will support large increases in bit-packing densities, the interfaces that are available will not support the resultant data transfer rates.

These problems are taken into account by the ST412 HP (high performance) interface, which specifies a maximum data transfer rate of 15 Mbits/s—three times that of current standard interfaces. The impact a new interface has on system and controller designs is minimized by retaining all features of the existing ST506/412 interface, a recognized standard for 5¼-in. disk drives. Signal functions and definitions remain essentially the same as those defined in the ST506/412 interface specification. There are major enhancements that system integrators should be aware of, however. Among the most important of these is the provision of a method for recovering misread data.

Using the ST412 HP's recovery mode, a drive can reposition its read/write heads during read operations on command from the controller. To allow increased storage capacity by putting more bits in each track, the interface's data read/write channels accommodate data transfer rates as high as 15 Mbits/s, compared to 5 Mbits/s in the ST506/412 interface. Access time improvement results from increasing the stepping rate.

The enhanced interface permits the minimum time between step pulses to range as low as 1 μs, as compared to 5 μ in the ST506/412 version. Potential capacity is improved by doubling the maximum number of head selects.

Probably the most significant aspect of the ST412 HP interface to system designers and users is the availability of recovery mode. Previously, Winchester subsystems that encountered difficulty reading a block of data from the disk had only one alternative to try and recover the data. Data had to be reconstructed using the error correction codes (ECCs) previously recorded on the disk. However, if the problem was caused by faulty positioning of the read and write head over the data track, the drive was not

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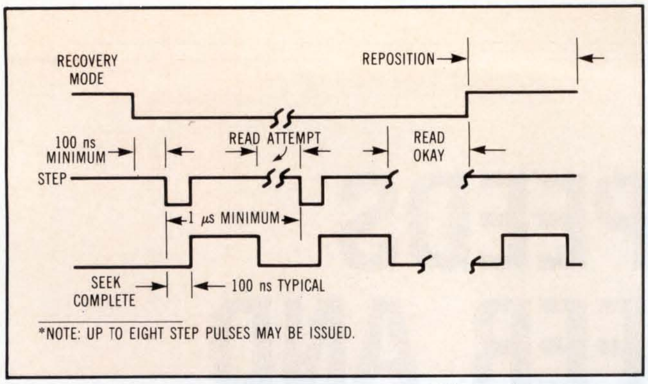

Fig 1 When in recovery mode, a controller pulses the step line to tell a drive to perform another recovery operation. The drive responds with a seek complete signal to indicate when the controller can attempt to read data. After the controller turns off recovery mode, the drive moves the read/write heads back to their nominal positions, eliminating any offset produced by micropositioning.

able to read the ECC information any better than it could read the data itself. The final result would be lost data.

Although Winchester disk drives are highly reliable, in rare instances they can misplace data. The culprit in most cases is offtrack head positioning, a problem compensated for by recovery mode. The problem arises in the first place because of mechanical variations. Factors such as temperature or humidity can cause the disk's positioning system to place the head slightly to one side of a recorded track. This position prevents the head from reading the strongest signal of the recorded data. If the head is far enough off the track, the signal is too weak for the controller to read reliably.

Positioning accuracy becomes increasingly important as small Winchesters move into ever higher recording densities. These higher track densities leave a much lower margin for positioning error. Provision of recovery mode by the ST412 HP will benefit high performance systems as they grow in capacity.

Recovery mode at work

To understand recovery mode operation, consider what happens when a positioning error occurs in a drive that uses a voice-coil actuator. Remember that recovery mode can be implemented in different ways, depending on a specific drive's capabilities. The implementations discussed here are only examples of how a drive might handle recovery.

After positioning the disk's read/write heads, the computer system's controller normally reads data from the disk and calculates ECCs. The calculated codes will match those recorded on the disk when the data was written, if the data was read accurately. However, in this case, offtrack heads prevented accurate reading and the two sets of codes do not match. In response to the error, the controller first commands another read. This second attempt has a good chance of working, especially if the error resulted from a slightly noisy signal. In fact, a controller will generally initiate up to eight rereads. However, because the error results from faulty positioning, each read results in a read error. Therefore, the controller instructs the drive to enter recovery mode.

To enter recovery mode, the controller sets the recovery mode line true and generates a step pulse (Fig 1). When the drive receives this pulse, it sets the seek complete line false and starts recovery procedures. First, the drive backs the heads up two tracks and repositions them over the original track from a positive direction. This operation can correct a faulty position by overcoming any hysteresis in the actuator mechanism. As soon as the heads settle, the drive sets seek complete true, informing the controller that it can read data again. Note that the system remains in recovery mode.

If the controller's attempt to read data is unsuccessful, it issues another step pulse. Because recovery mode is still active, the drive will perform the second recovery operation. After setting seek complete line false, the drive this time moves the heads two tracks forward and repositions them from a negative direction. Seek complete returns true, and the controller again tries to read data. An unsuccessful attempt to read data correctly this time causes the controller to issue another step pulse. The drive will now microposition the heads offtrack in an attempt to find a stronger signal. In this example, the drive moves the heads backward one-tenth of a track from the nominal track position. If data cannot be

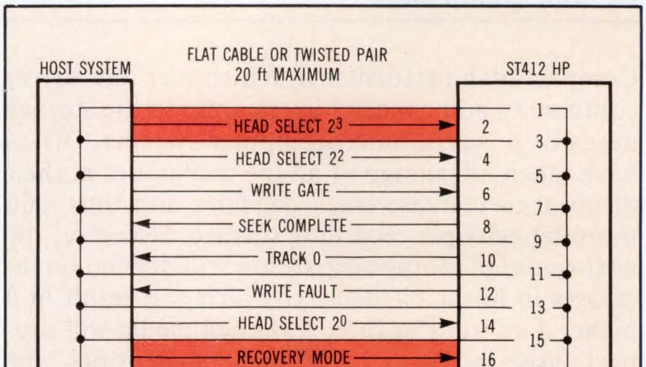

Fig 2 The control signal connector in the ST412 HP employs two lines that were reserved on the ST506/412 interface: recovery mode and an additional head select. These changes represent the only pinout differences between the two interfaces.

read at this location, the drive will move the heads another one-tenth track backward. Failure to read data on this attempt causes the drive to move one-tenth track away from the nominal position in a positive direction and then, if necessary, by another one-tenth track increment.

The controller can issue as many as eight step pulses while in recovery mode. Whenever one of the drive's recovery methods results in a successful read, the controller returns the recovery mode line false, and the drive returns the heads to their nominal position. If all attempts to read the data while in recovery mode fail, the controller can then resort to reconstructing the data using the ECC information. Since positioning correction methods (ie, recovery mode) were not successful, it can be assumed that the read problem may be media related. However, the system should attempt all available mechanical means of recovering data, such as recovery mode, before trying to use ECC.

If ECC is used before mechanical repositioning methods are exhausted, the controller may, in fact, alter correct data and send it to the host. ECC effectiveness relates directly to the clarity of the information given for correction.

Stepper-actuated drives use similar methods

Recovery mode is beneficial not only for high performance drives using voice-coil actuators, but it can also be used with drives employing stepper motor positioning systems. Although most steppers cannot fully implement micropositioning—part of their function is stepping one whole track with each movement—they can handle other recovery mode procedures. In the same read-error situation described for the voice-coil example, the controller for a stepper-based drive would still attempt several standard reads after the first read failed to work. If this approach fails to produce good data, the controller enters recovery mode as before and issues a step pulse to the drive.

At this point, the recovery method followed by the stepper-based drive differs from that of the voice-coil device. In this case, the drive responds to the first step pulse by initiating a recalibrate procedure, which returns the read/write heads to track 0 position. Then, the heads are sent to the problem track in order to allow the controller to attempt another read operation. If this read fails, the drive and controller can continue through the recovery operations. First, they can back off two tracks and reposition the heads from a positive direction. If this fails to recover the data, they can then move forward two tracks and reposition from a negative direction. As with the voice-coil drive, these movements attempt to overcome any hysteresis in the actuator mechanism.

These are some of the functions that a drive equipped with standard stepper motors can use to recover data mechanically. It is interesting to note that some of today's controllers already employ these techniques. Because no microstepping is required, the methods work equally well on any drive. To support higher track densities, some stepper motors now provide incremental track stepping (ie, one-quarter or one-half track steps). A possible contributor to offtrack errors in drives equipped with incremental steppers, in fact, is missing one of those increments in a series. This could leave the heads one-quarter track off—a fault that recalibration should correct. With incremental steppers, the drive could step the heads one-quarter track forwards and backwards from the problem track in recovery mode.

Recovery mode is one of two ST412 HP features that define two additional pinouts to the ST506/412 version. The other involves the head select lines, which determine the maximum number of read/write heads that a drive can use. Because high performance Winchesters can benefit from more than eight heads—the maximum number allowed by the ST506/412 interface—the ST412 HP increases the number of head select lines from three to four. Addition of this line doubles the allowable number of heads, making 16 heads available. When these additional heads are used, a high performance drive can access data faster and increase capacity. The control signal connector carries both head select and recovery mode lines (see Fig 2).

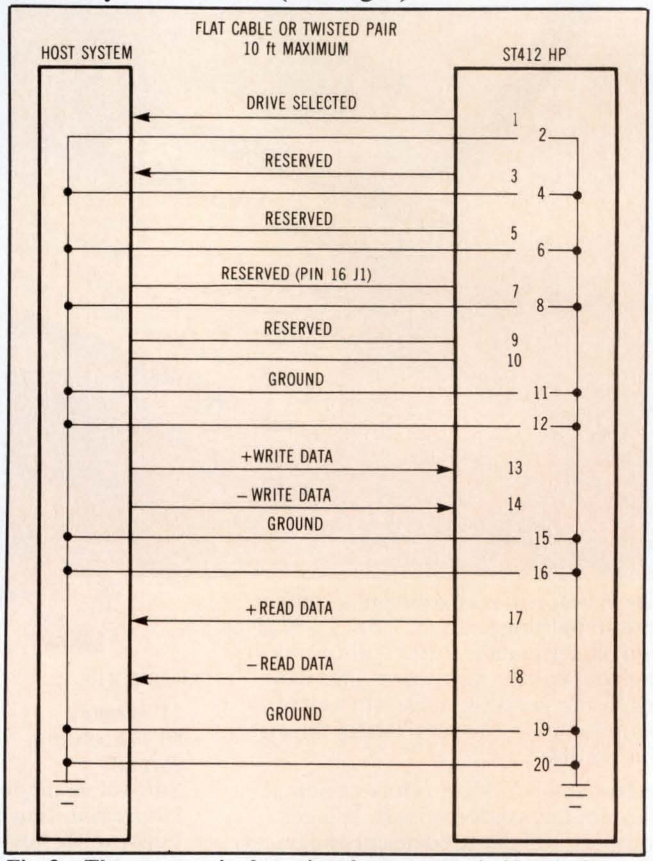

Fig 3 The ST412 HP's data signal connector is identical to that used in the ST506/412 version. The ST412 HP's maximum data transfer rate is higher, but that change does not affect the pinouts. However, the maximum cable lengths were reduced from 20 to 10 ft.

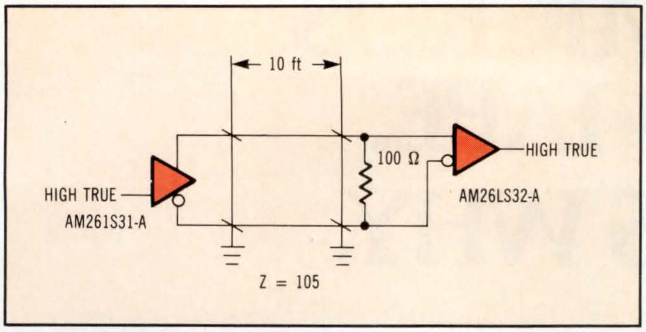

Fig 4 The data line driver/receiver combination used in the ST412 HP constitutes an EIA RS-422 driver/receiver pair, which employs flat ribbon cable or twisted-pair wiring. A proposed "Dash A" version specifies additional high performance parameters.

Another important change in the ST412 HP interface increases the maximum data transfer rate between the drive and its controller to 15 Mbits/s. The connector that carries read/write data and related signals, however, remains unchanged (see Fig 3). Although the maximum data rate has been increased, Winchester subsystems using the ST412 HP can transfer data at lower rates. In fact, the first drive manufactured by Seagate for use with the enhanced interface (the ST8100) transfers data at a 10-Mbit/s rate. This rate satisfies the needs of most second-generation small Winchesters.

While increasing the data rate does speed up the drive's data I/O, there is a more important benefit. Storage capacity is increased because bits can be recorded at a higher density in each track. Since the drive must read data as it passes under a read/write head and send it on to the controller at that same rate, higher bit density results in a higher data transfer rate. The converse is true for write operations.

Since Seagate introduced the first 5¼-in. Winchester drive (the ST506), improved technology has provided the means to record data at much higher bit densities. To maintain compatibility with existing interfaces, however, drives had to maintain the same bit density in order to use the same data rate. Thus, a valuable method of improving storage capacity was unavailable. Drives instead raised storage capacity through the use of alternatives such as increased track density and data-encoding schemes, which did not affect the data rate. By providing a higher data transfer rate, the ST412 HP clears the way for the use of higher bit densities to attain increased storage capacity, while maintaining compatibility with the standard interface.

Data transfer with the ST412 HP uses two pairs of balanced signals: write data and read data. For the write data differential pair, a flux reversal on the disk track results when the +write data line goes more positive than the −write data line, if write gate is active. For the read data pair, a flux reversal on the track of the selected head causes the +read data line to go more positive than the −read data line. The drive/receiver combination used for transfers both to and from the drive is depicted in Fig 4.

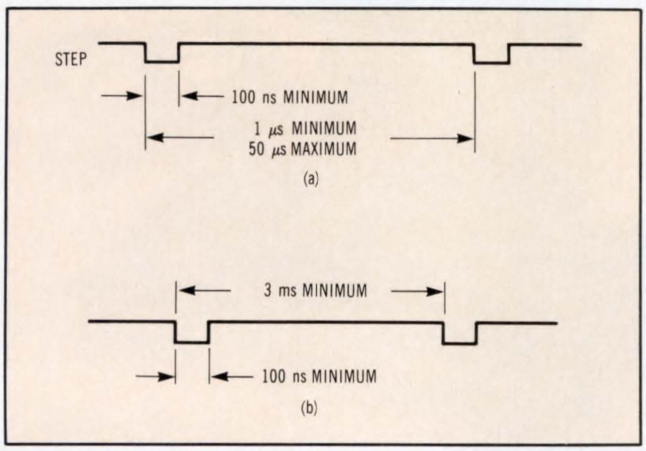

Fig 5 One of the two types of seeks permitted by the ST412 HP is a buffered version that lets the controller send a step pulse every microsecond (a). The second type of ST412 HP seek is a slow seek (b). Here the read/write heads move at the rate of the incoming step pulses—a minimum of every 3 ms.

Step pulse rate allows faster accesses

Another difference between the ST506/412 interface and the ST412 HP is the maximum rate at which a drive can accept step pulses. As with the data transfer rate change, the increase in the step rate does not alter the interface pinouts. In fact, the increase in step rate does not physically alter anything in the interface; it is a specification change only.

Here again, the change is necessary because of improvements in Winchester technology. Drives can now step faster, thanks to improved actuator technology. A buffered seek technique saves time on seeks when the heads must move several tracks at once. Rather than sending one step pulse and waiting for the heads to move before sending another pulse, buffered seek allows the controller to send a burst of pulses. This lets the heads traverse the distance to the selected track without settling at each track along the way.

A 5-μs minimum time between step pulses on a buffered seek and 3 ms on a slow seek is specified by the ST506/412. The ST412 HP specifies a 1 μs minimum on buffered seek operations to allow very fast access [Fig 5(a)]. The interface also reduces timing on slow seeks from 3 ms to 50 μs [Fig 5(b)]. The slow seek specification allows the heads to move at the rate of the incoming step pulses.

This change in the maximum seek pulse rate does not change the seek procedure from that specified by the ST506/412 interface. The seek procedure (see timing diagram in Fig 6) begins when the controller deactivates the write gate line and activates the appropriate drive select line with the drive in the ready condition and seek complete true (indicated by the ready and seek complete lines, respectively). Next, the controller selects the appropriate direction for the heads to move using the direction in line. A low on the direction in line causes a seek inward toward the drive's spindle; a high initiates a move outward toward track 0.

Then, the controller pulses the step line, causing the head to move one track either in or out on each pulse, depending on the state of the direction in line. On buffered seeks, the drive stores the pulses until it receives the last one (defined by a delay of 50 μs). It then executes the seek as one continuous movement.

When the controller begins sending step pulses, seek complete goes false. When this line returns true, the controller can select the required read/write head by placing that head's binary address on the head select lines. Now the controller can read data. If a write operation is needed instead, the controller must first ensure that no write fault conditions exist. It can then activate the write gate line and place data on the write data line.

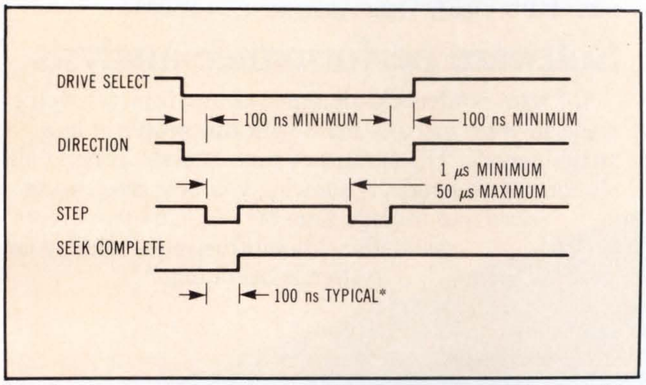

Fig 6 An ST412 HP seek operation proceeds exactly as with the ST506/412 interface. Note that the seek complete signal goes low 100 ns after the step pulse's leading edge.

Write fault is used by the drive to indicate a condition that could cause data to be improperly written if left uncorrected. The line monitors five conditions: a head receives write current without write gate active or there is no write current with both write gate and drive select active; multiple heads are selected or no heads are selected; dc voltages are grossly out of tolerance; write gate is active with no seek complete; and write gate (a last condition that results from the addition of recovery mode to the ST412 HP interface) is active while the drive is in recovery mode. A low on the write fault line indicates that the drive has inhibited further writing until the fault condition is corrected. The controller cannot reset write fault, it only monitors the line for the signal's appearance. The controller should edge-detect this signal.

The physical interface

The most important aspect of the ST412 HP's physical interface is that it is identical to that of the ST506/412 interface. The two connectors that are involved carry the control signals (J1) and the data signals (J2). J1 can be multiplexed in a daisy chain configuration. This connector mates with an edge

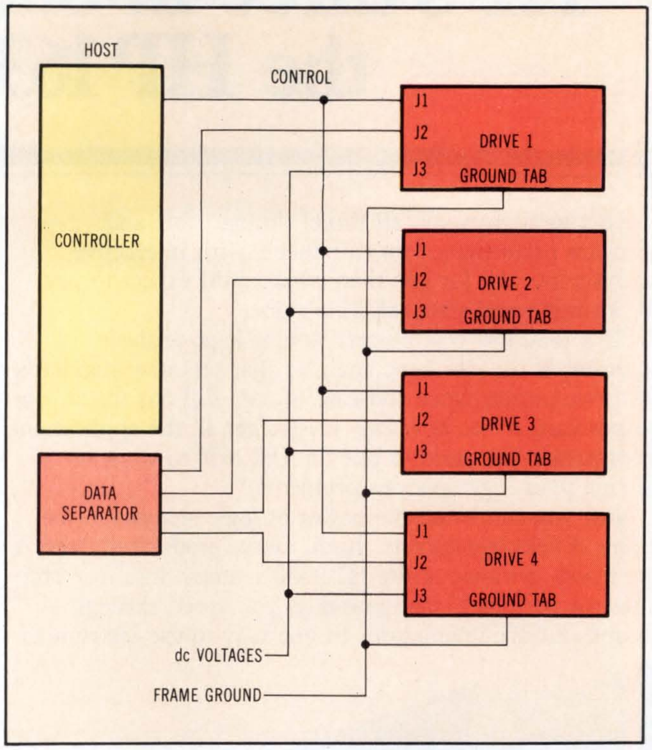

Fig 7 A typical connection for a four-drive Winchester subsystem shows the daisy chained control lines and radial data lines. Note that the data separator is part of the controller.

connector on the drive's PC board. Recommended connectors for J1 include AMP ribbon connector 88373-3 or Molex 15-35-1341. J2 is configured in a radial fashion. An edge connector on the drive's PC board also mates with J2. Recommended connectors are AMP ribbon connector 88373-6 or Molex 15-35-1201.

A typical connection for a four-drive Winchester subsystem (Fig 7) routes power inputs to the drives via connectors designated as J3. Note that the control lines between the controller and the drives are in a common connection, while the data lines connect radially between each drive and the data separator. The data separator is isolated here to emphasize both the radial arrangement and the signal separator requirement in multidrive configurations.

Whether a Winchester subsystem employs four drives or only one, the ST412 HP interface enables system designers to take advantage of very high capacity drives while maintaining standard interface compatibility. Thus, it offers versatility, opportunity for greater storage capacities, and an ST506/412-like interface that permits straightforward controller enhancements for standard designs.

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