



techFusion

Data Recovery/ Computer Forensics Engineers





Overview :

Recovery of Physically Over-Written Data

TechFusion

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Introduction

When there has been a hard drive failure, or failure of similar storage media, the data typically is *logically* misplaced. A normal data recovery process deals with the restoration of such misplaced and lost data.

However, when the data has been physically erased or over-written, whether by accident or intentionally, it is regarded as destroyed. The regular means of data recovery, being the techniques normally employed in the industry for such purposes, are no longer capable of restoring or locating the data.

TechFusion has developed and refined techniques and processes for recovering data that is thus regarded as destroyed. In this presentation we explain how we recover such data and present an overview of TechFusion's TF-SH405 process for the recovery of physically erased or over-written data.





The Underlying Basis of TechFusion's Recovery of Physically Over-Written Data

When a magnetic head comes to a spot on a track to write new data over existing data, after having come to rest once, or after variations or slight changes in temperature or supply voltage, it is offset just slightly, radially or tangentially in the polar coordinate system, from its prior position. It is thus not aligned with the old position and the old data that it wrote. Thus in an erasure or over-writing process data is never fully erased or over-written, because tiny remnants of it are left behind.

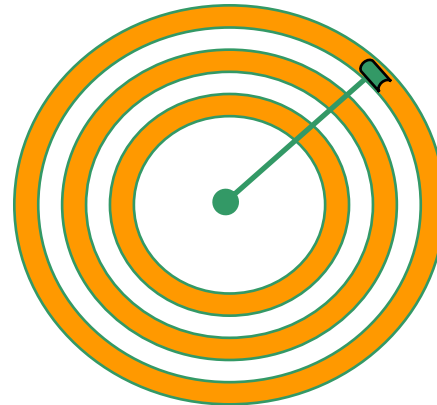


Figure 3. Magnetic Head Traversing Tracks on Disk Drive





Spin-Stand Block Diagram : Electronics, embedded software, technician interface (UI):

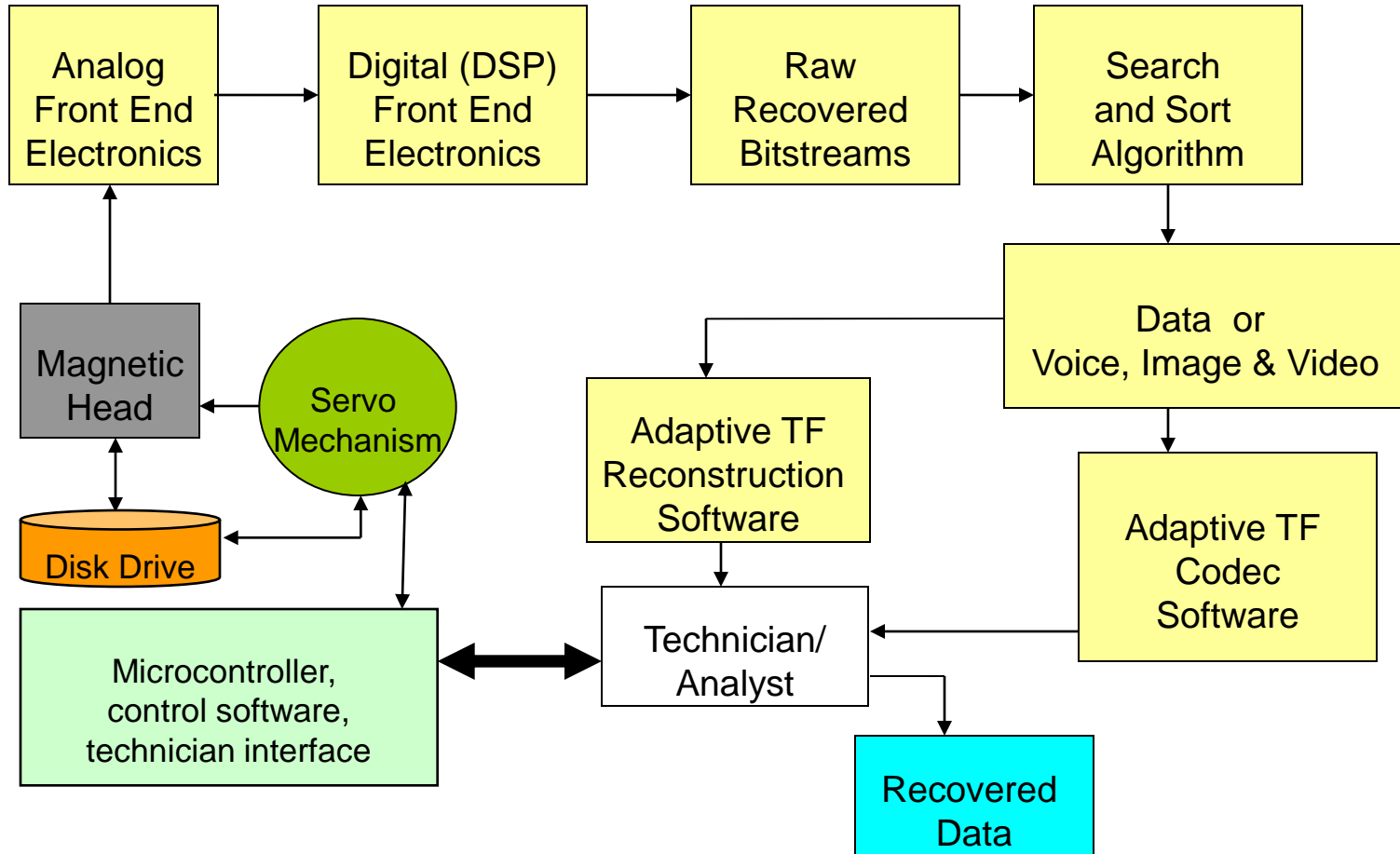


Figure 2. Spin-Stand System Block Diagram





The following slides illustrate and explain our TF-SH405 recovery process in its sequential steps.





The disk drive from which data is to be recovered is removed and placed in the TF-SH405 spin-stand. The spin-stand has our highly accurate servo positioning system, a magnetic head of high sensitivity and sophisticated electronics, as compared to a commercial disk drive.

The hardware and software of the TF-SH405 spin stand are not commercially viable in a mass-produced disk drive. They include diagnostic tools for automated recovery as well as for enabling our technician-analysts, where need be, via our Interface Software to intervene, probe, recover and reconstitute data from sectors and tracks on a disk drive as required.

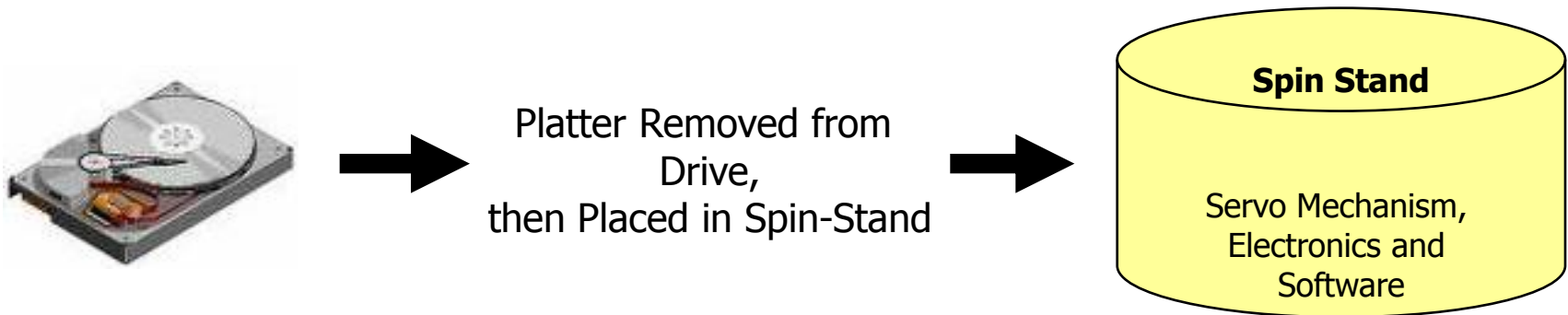


Figure 1. Spin-Stand





When data on a disk drive is physically over-written, whether for the purpose of deletion or the recording of new data, the process still leaves behind an old layer of data, which during subsequent read operations produces a weaker signal in the magnetic head than the new data. The new data is juxtaposed over the old data, as shown in the diagrammatic representation below. Arrows indicate the direction of magnetization. As the magnetic head traverses the hard disk, change in direction of magnetization denotes a 1 or 0 :

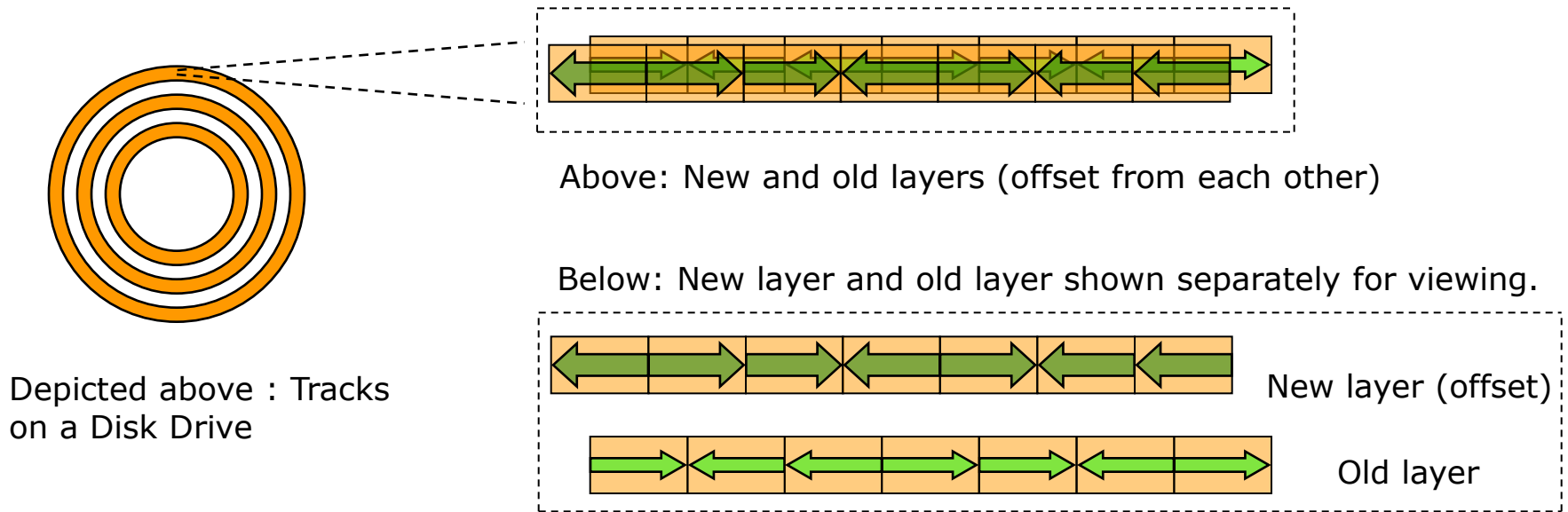


Figure 4. New and Old Layers of Data on a Disk Drive

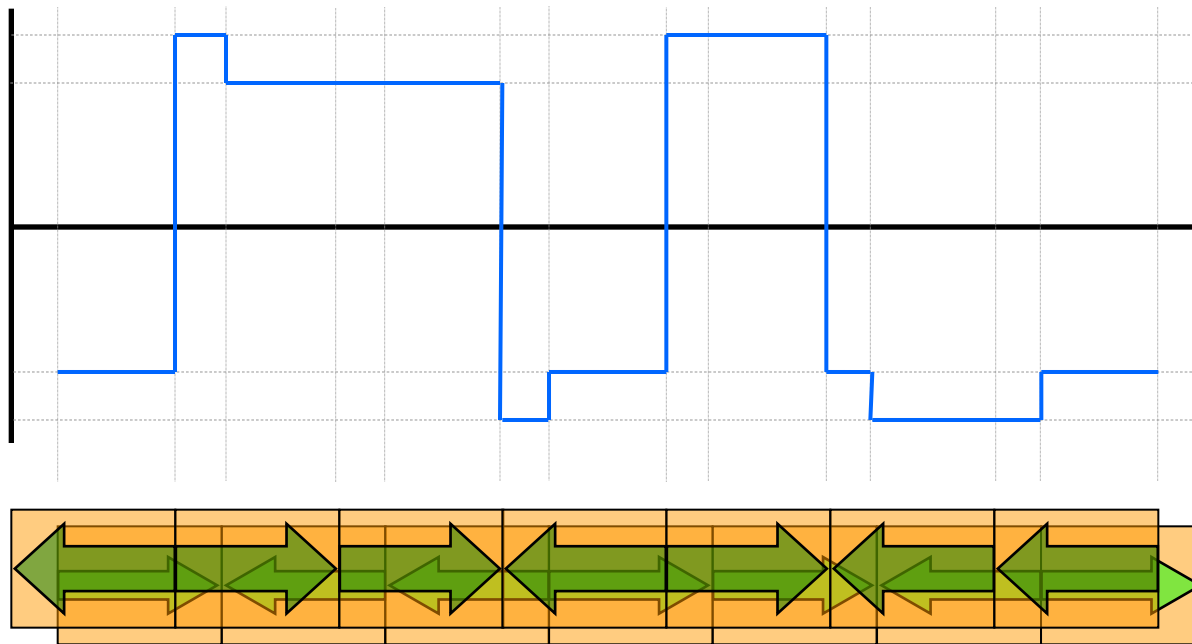




Since the old data is not completely written over, both the new and the old data layers produce a signal in the magnetic head when the head traverses the track.

I (current produced in magnetic head, with resultant SNR)

Figure 5. Current induced by data in Magnetic head



d (distance traversed by head along track on hard disk)

New Data

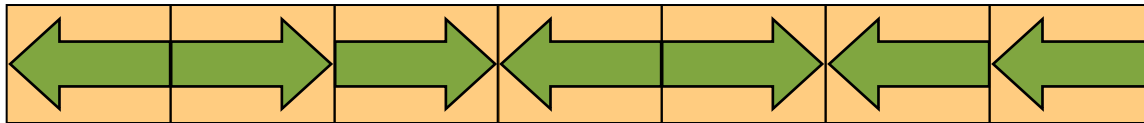
Under-Layer

Both layers produce a signal in the magnetic head. The old, under-layer of data produces a signal with less strength, and hence gives lower signal to noise ratio (SNR) upon a read operation than the new layer.





In a regular recovery process, using standard electronics and software, it is just the new (most recent and logically misplaced) data that is readable and recoverable:



In TechFusion's physical recovery process such as the TF-SH405 the old, over-written data as well as the new data is readable:

New Layer

Under-Layer

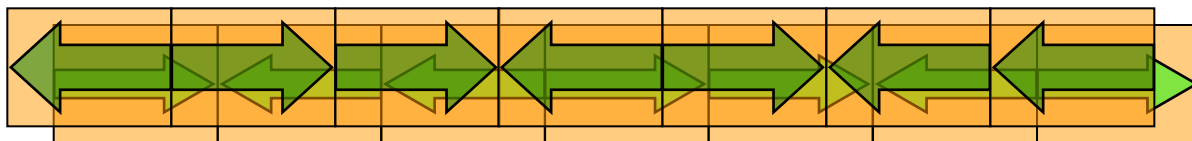


Figure 6. New and Old Data





The signal produced by the magnetic head is received and conditioned by the spin stand's front-end electronics and made suitable for further processing. The raw signal is in the form of a change of inductance in the read head, which results in a change of current. This signal is then converted to voltage, which form it needs to be in, in order to be properly processed. A trans-impedance amplifier next converts the signal which comes in current from the read head to voltage.

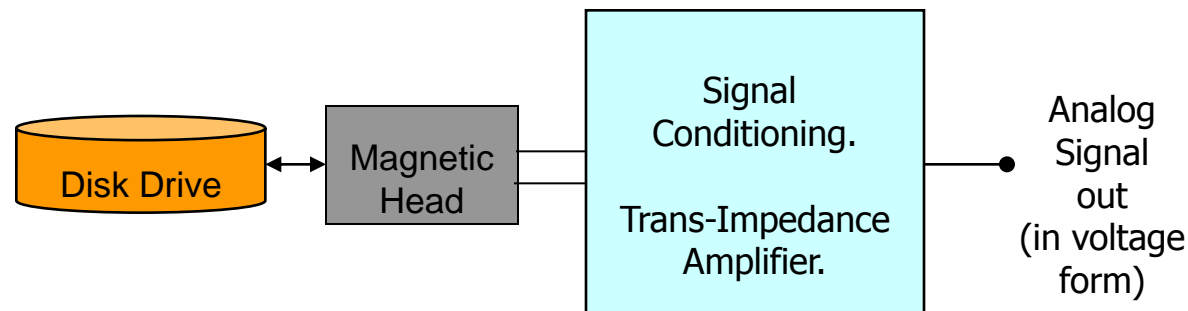


Figure 7. Signal Path





The trans-impedance amplifier receives the signal in form of a current from the magnetic head. The signal from the magnetic head is fed into the op amp, which has its non-inverting input grounded. The value of the feedback resistor is set appropriately so that the output peak-to-peak voltage is within the input range of the next stage ADC, being the range 0.5-1.0 Volt p-p. The inverting input is forced to be virtual ground by the op amp, thus the output voltage follows the input current by the factor $-R$.

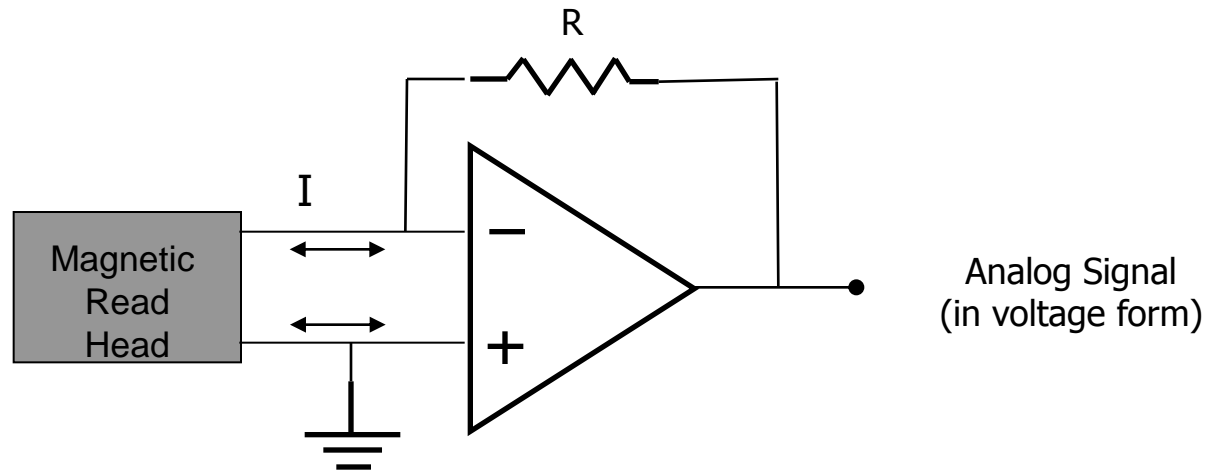


Figure 8. Transimpedance Amplifier Performing Current to Voltage Conversion of the Read Signal





Next the analog signal, now in voltage form is converted to digital, to enable the processing of said signal and extraction of the raw data, using the ADC (analog to digital converter). The ADC is set to sample (measure) the voltage level of the signal at regular, very brief, predetermined, intervals. This time interval is much shorter than the duration of magnetic flux transition indicative of a 0 or 1, and the ADC is set to over-sample for each such change.

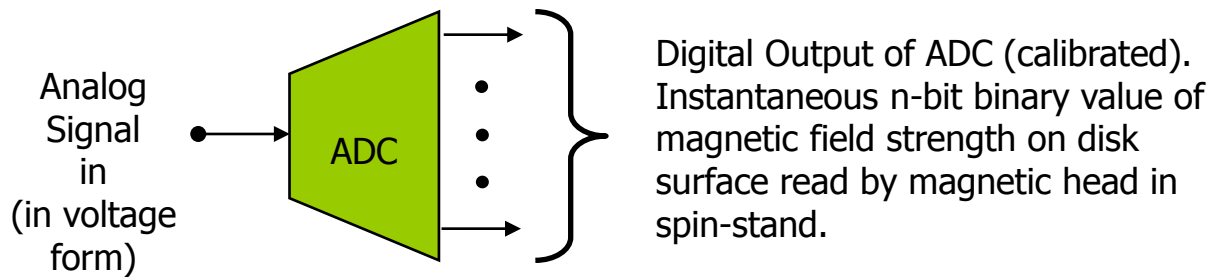


Figure 9. Conversion of Signal Read from Magnetic Head into Digital Form





The binary value that is output by the ADC represents the magnitude of the signal from the magnetic head, indicating magnetic field strength on the surface of the disk.

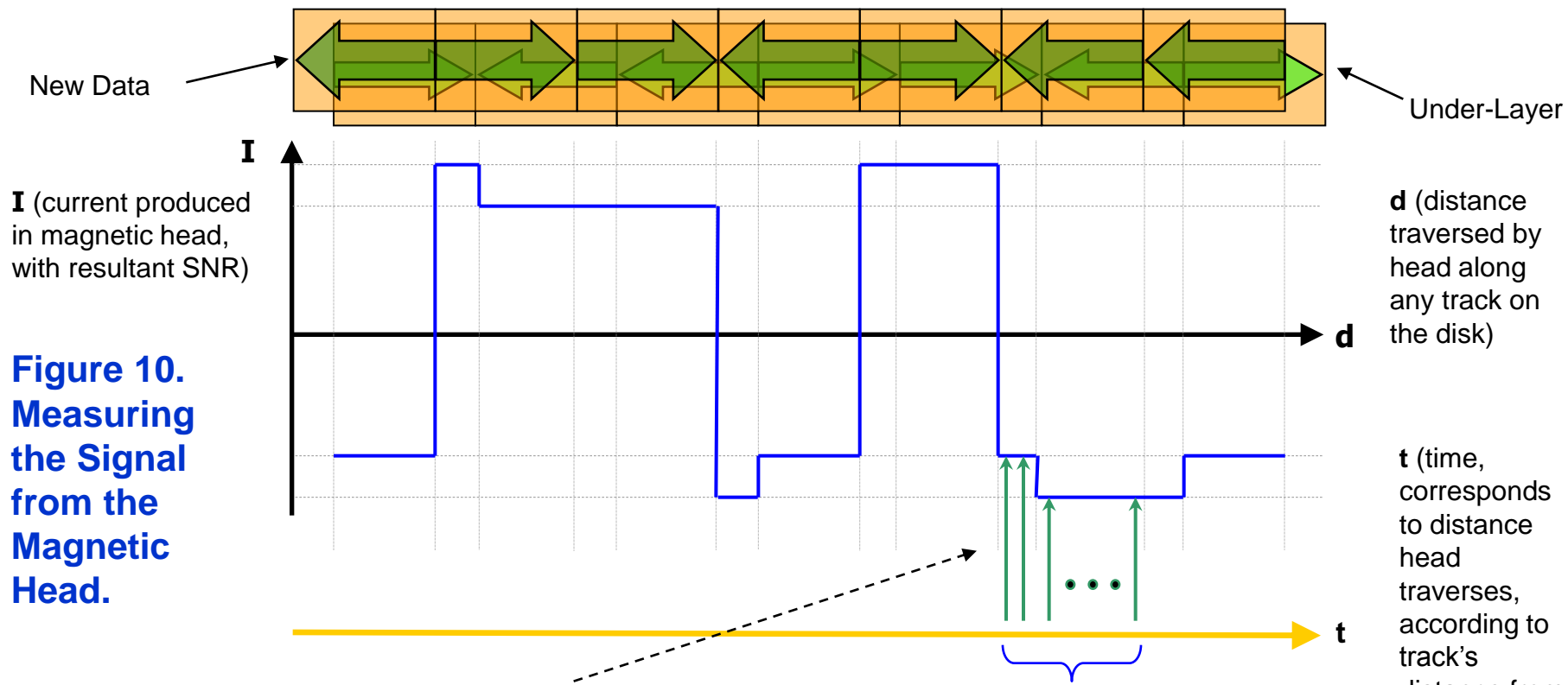


Figure 10.
Measuring
the Signal
from the
Magnetic
Head.

Arrows represent instantaneous measurements (A/D samples). For clarity measurements are shown here over one bit period only..

Multiple measurements made during one bit period on any track yield finer resolution and aid in the discernment of old and new layers.





The signal produced by the magnetic head as it traverses the disk is typically noisy, as may be seen in the example oscilloscope trace shown. To avoid variation in the value of the signal while it is being measured, it is sampled with an aperture in time in picoseconds, and a variance in time, from sample to sample, of less than a picosecond. In the case below, although noise is present, the effect of the old and new layers are visibly discernible to aid the eye (as well as the electronics) in rendering a 'hard decision' (one or zero) . Where the noise encountered is greater or reaches the sensitivity levels of the electronics, the spin-stand employs soft-decision and other DSP techniques for greater SNR.

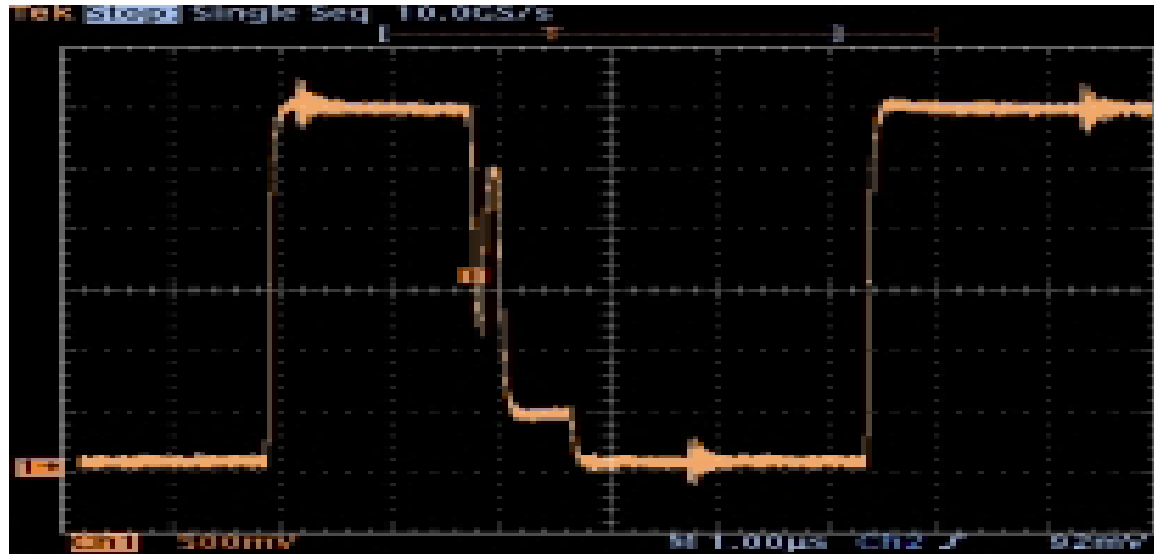


Figure 11. Typical Oscilloscope Trace of Data





The logical states of 1 and 0 denoting the raw data are deciphered from the digitized waveform by setting respective threshold levels for 1s and 0s and having configured the arithmetic logic unit (ALU) to compare the values of signal amplitude measured and digitized by the ADC with these thresholds, for hard decisions. The number of levels we are seeking to decipher determine the number of ALUs required. In the case at hand it is four, but for clarity one is shown in diagrammatic form. The ALU is used as a digital comparator.

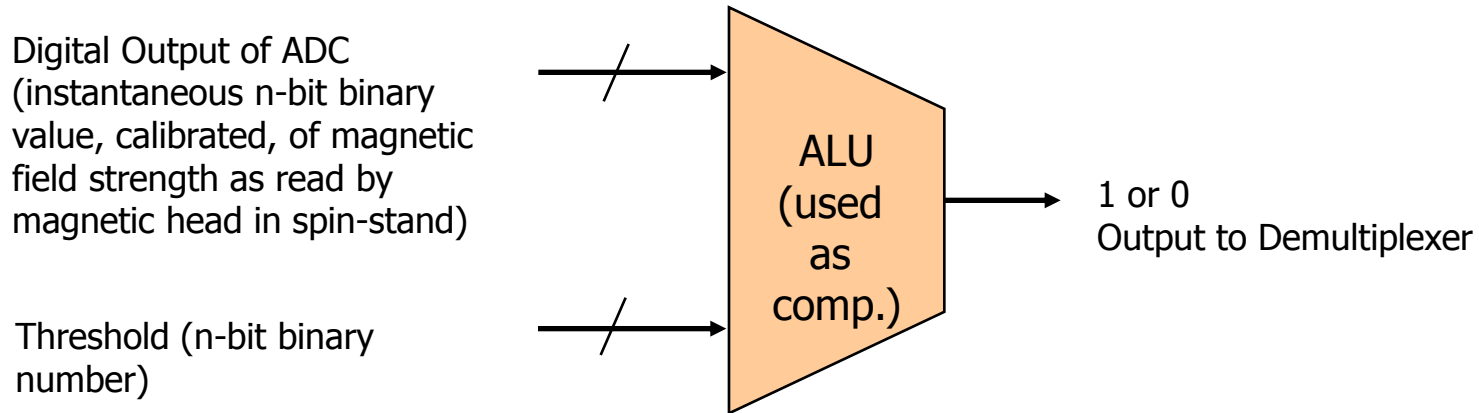


Figure 12. Comparator Used as Digital Discriminator





The comparator (ALU) output indicates levels which correspond to transitions in levels of inductance in the read head. It is separated into appropriate streams, based on the regularity found and on the speed of the particular track it is read from. The microcontroller and electronics know where the head is at any time, for it starts from a known position and is thereafter directed by them. The speed of the track is calculated using the RPM and the circumference of the track, $2\pi r$. Based on the speed of the track and the changes in state (1s and 0s) encountered as the head traverses the track, the bit period is computed. Once the bit period has been determined, the new layer and under-layer of data in the data stream output by the ALU are separated by a demultiplexer timed by a clock derived from the bit period.

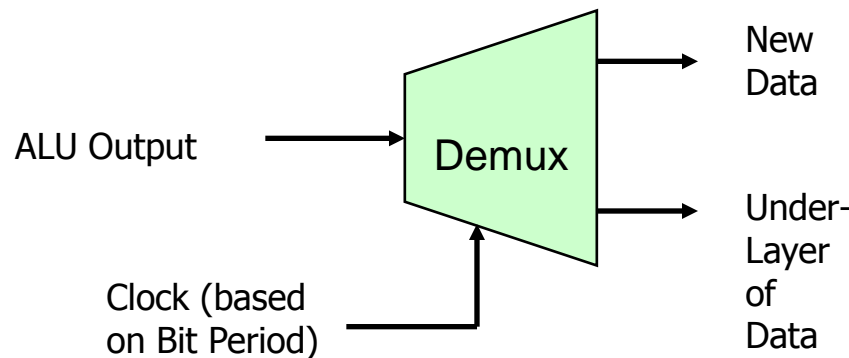


Figure 13. Demultiplexer – Separating Old and New Data





When the data streams corresponding to the new layer and under-layer are recovered, this represents the data *as was recorded on the disk*. It now needs to be fed through the stages which the original drive would go through to read the data if it were not corrupted. User data in disk drives is routinely encoded for a variety of reasons, including timing and clock recovery, DC balance (avoidance of a long string of ones or zeroes), in a number of stages prior to being recorded on the disk, starting with line codes. The data derived from the disk is decoded using the same algorithms. Similar line codes, for the same reasons, are employed in communications and telecommunications. For the disk the standard algorithm used is Run-Length Limited (RLL),. When the starting position of the data is known, the first bit is known, and the bit stream recovered is fed into a decoder to recover the user's data. Decoding the data at any point except a known starting point depends on what data has preceded it. As the starting point, the boundary value, may not be known in many cases, the bit stream is fed to several decoders simultaneously, with the input to each offset by one bit from the input provided to the last stage. One of the decoders in the series recovers it and is depicted below.

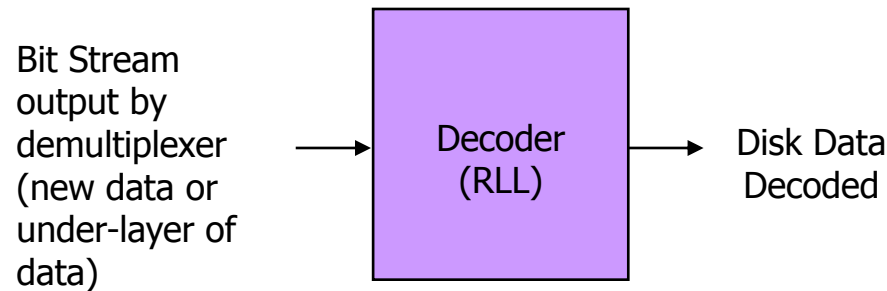


Figure 14. Decode Stage, Run-Length Limited





After the line code, the data may have been further coded prior to recording by a Forward Error Correction (FEC) scheme in order to impart association to the disparate bits, utilizing appropriate algorithms. By virtue of this new association, if a bit or number of bits become corrupted, recovery is facilitated by the decoding algorithm using the intact bits. FEC performs at the mathematical level and, when implemented, electronic level what spell check performs at levels closer to human language. Lexicon and context in human language and composition is what the FEC algorithm imparts to the disparate bits by associating them. Upon read, FEC detects and corrects errors for the data was previously encoded using the same code, just as spell check detects and, optionally, corrects errors in the textual data for it was previously encoded as human language. Often the FEC codec consists of a convolutional code following the line code concatenated with a Reed-Solomon block code. The data is iteratively line-decoded, then passed through the Viterbi convolutional decoder, followed by the Reed-Solomon decoder. In other hard drives space-time encoding schemes may be used and it is decoded using corresponding algorithms.

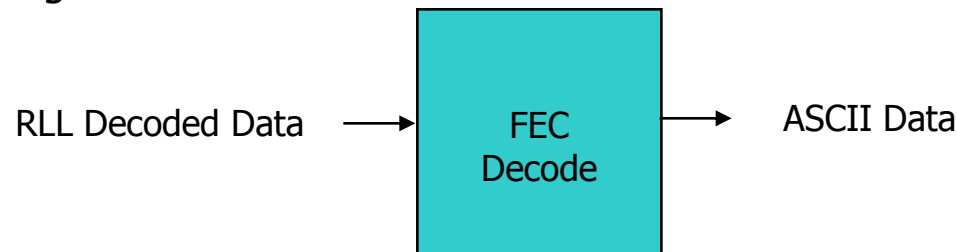


Figure 15. Decoding of Forward Error Correction





The data obtained after the decoding process is in the form of a long string of 1s and 0s. For the recovery of textual data, the string of 1s and 0s thus obtained is put through an ASCII decoder, a 7-bit decoding of alphanumerics and, as necessary, symbol decoders, to recover the textual data. Since the data fed to the ASCII decoder may not be temporally aligned to the start bit of the 7-bit code but likely would start somewhere in the middle of a code, the data is fed simultaneously to several such decoders (in the case of ASCII seven), with the input to each of the seven stages being offset by one bit compared to the input to the previous stage. Of these, one of the streams will produce intelligible textual data.

At this stage textual errors in the data that has been thus recovered can be detected using more mundane techniques such as spell-check. The technician-analyst puts the process through iterations where synchronization may be disrupted, which may occur. Spell-check provides further cues to the technician-analyst to adjust settings for more efficient recovery. The recovered data is then reviewed and where necessary further reconstituted by the technician-analyst.

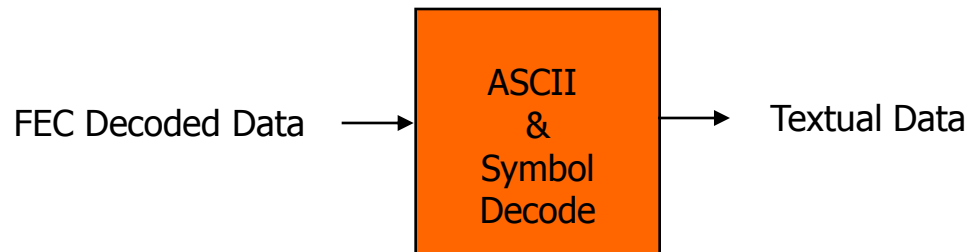


Figure 15. ASCII and Symbol Decode





Summary

In the foregoing an overview of TechFusion's TF-SH405 process of recovering data that has been physically erased or over-written has been presented. The presentation is not intended to disclose all details of TechFusion's commercial recovery processes : There are certain aspects of the technology that we will retain as proprietary, and areas such as the read head where advancements in our process are not disclosed in this document. The TF-SH405 process is not intended to be applied to PMR technology.

Following a recording media crash, typically textual data files and associated meta data (headers descriptive thereof) are the most sought after files for recovery. Thus the recovery of data is given more coverage and attention in this presentation. We use much the same process in the recovery of voice, audio and video, with some minor differences. Notably the differences are that the codecs for voice recovery are not, for the most part, ASCII, but G.7xx and others, for audio the codecs are MP3 etc., for images the codecs are JPEG etc. and for video MPEG etc.

This process of recovering physically over-written or physically erased data is much more involved than that of regular data recovery; it entails much more sophisticated equipment and our technician-analysts performing it undergo special training and possess a different level of expertise than required for regular data recovery. The process also takes more time and, as would be manifest, entails considerably higher cost than regular data recovery.





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