With more complex vehicle designs, the frequency and number of measurements contained in telemetry data streams has dramatically increased. One way of improving the use of bandwidth is to change the sample rate, quantity, or type of measurements dynamically.

A telemetry front end must be programmable to handle different formats. In a front end that decommutates and routes measurements, a decom list is a control program, which defines the location, size, orientation, and identity of the measurements. To deal with dynamic format changes, a telemetry front end must be able to switch between decom lists.

A practical approach to decom list switching must address the needs of error avoidance, packet switching, and the location of switching keys in any portion of the format. Switching between formats should not be restricted to a preprogrammed sequence, but should allow multiple destinations from a particular decom list.

A practical and flexible implementation of decom list switching is detailed along with an explanation of how this implementation solves a variety of decommutation problems.

Keywords:
Format Switching
Decommutation
Decom List Switching
Packet Switching

Introduction

Three factors have created an increased interest in Decom Switching:

1. The trend toward more complex vehicles and instrument systems makes a growing tidal wave of information available on the vehicle to the test engineer. To practically
transport that information to the ground, telemetry formats continue to grow more complex, and bit rates continue to climb.

2. There is a growing trend towards using the telemetry link as one side of a communication network; tying computers in the air with computers on the ground.

3. Test missions often progress through various phases. Different test phases may focus on different parameters. Each phase may require a different format to efficiently support it.

Format and Decom list switching have been supported by Aydin Monitor’s Model 1126B Frame Synchroniser / Decommutator. The switch was triggered on an exact match and only one destination decom list or format was allowed. The switch could be immediate or at the end of the minor frame.

Format switching can involve changing everything from the frame synchronization pattern and bit rate to changing the mix of minor frame and subframe words. However, rapid switching of frame sync patterns and bit rates usually requires a resynchronization time, where data is lost for a frame or two. Changing the mix of parameters in the stream can be done without loosing sync or data, this change involves only the way the stream is decommutated. This class of format switching is called Decom Switching.

**What is a Decom List?**

To support formats with different bit orientations, word lengths, or different numbers of subcommutated word slots, the decommutator needs to be programmable. The program that specifies how to decom the data stream is called a Decommutation List or Decom List. Even changing how one word slot is identified requires some kind of change to the decom list.

**Concerns of Switching**

A practical decom list switching approach must be reliable, flexible and able to serve a diversity of switching needs.

To be reliable, an approach to decom switching should be able to work in the presence of errors; not switching to a wrong decom list, and properly switching to the correct decom list.

To be flexible, the time that the switch becomes effective should be programmable, and have some logical relationship to the format. It should be able to serve the needs of packet
switching systems. The implementation should be able to handle switching keys located in any portion of the format. Practical decom list switching should allow multiple cards or subsystems to switch together, and should allow multiple destinations from a single decom list.

**System Context**

This approach to decom list switching has been implemented on Aydin Monitor Systems’s FSC011 and FSC012 frame syncronizer / decommutator modules. They are designed to operate in a Series 2000 Distributed Telemetry Preprocessor System (S2K). The S2K system is a Data Flow Architecture using 16 bit ID Tokens (Tags) and 32 bit data words. The design of the FSC011/12 may require more than one card per stream for some formats such as Recycle and subsubframe ID. See Figure 1 for a typical one chassis configuration.

The FSC011/12 is a form of RISC processor optimized to very flexibly perform serial to parallel conversions, and supply both the data and ID Tags to the S2K Mercury Bus (HgBus). See Figure 2. At the end of the decom list, and under certain initialization conditions, the RISC processor finds the first decom instruction using the contents of the start address register. For an immediate decom switch, the RISC processor is interrupted, and performs a jump to the address in the Temporary Register (TR).

**Outline of Approach**

The Decom List specifies certain time slots in the format as containing decom switching information, the words filling these slots are called decom switch Key Words. The least significant 11 bits of the decommutated data words are used to address a 2K x 16 bit Switch RAM supplying new addresses. The least significant bit of the resulting Switch RAM Data Word indicates whether to do a switch or not. Depending on the timing mode, the Start Address Register (SAR), or a Temporary Register (TR) is loaded with the new addressing information from the Switch RAM. Decom Data words less than 11 bits are padded with zeros in the most significant bits. See Figure 3.

**Timing Of Switches**

When a decom switch is detected, a new address is made available with a strobe. In each timing mode, the address and strobe are used in slightly different ways to change the time when the switch effects the decommutation of data. Four different timing modes may be selected:

Immediate mode (IMM) does not change the value of the Start Address Register, but the new address is loaded into the temporary register (TR). At the same time the RISC
processor is forced to execute a Jump (TR) instruction. The decom list becomes effective with the third word following the decom switch key word. Since the Start Address Register (SAR) is unaltered, the decom list continues to begin at the instruction pointed to by the SAR. For Immediate switching, Key Words in the last three words of the minor frame are not effective and are not recommended. Immediate mode provides support for packet switching applications. See Figure 4.

Minor Frame mode (MF) loads the new address directly into the SAR. When the RISC processor examines the SAR at the end of the current minor frame, the new address is used to find the first decom instruction. The RISC processor will continue to execute from the new decom list until another decom switch is detected. See Figure 4.

Next Minor Frame mode (NMF) loads the new address into the Temporary Register, but waits until just after the current minor frame ends before copying the new address into the Start Address Register. NMF mode provides an extra minor frame of delay before a switch becomes effective.

SubFrame mode (SF) loads the new address into the TR, but waits until just before the RISC processor reads the SAR during the last frame to copy the new address into the SAR. The new decom list is effective with the first minor frame of the format. See Figure 4.

Note that these timings are with respect to each individual card, for instance, a subsubframe card cannot change lists at the minor frame rate, but only at the subframe rate and slower. (Immediate mode excepted.)

If a switch is detected but is not yet effective, additional decom switch detections will update the registers, and the address supplied by the most recent decom switch detection is the one that will be used. (Immediate mode excepted.) See Figure 5.

Masters and Slaves

A decom switch Key Word may be located at any level of the format; minor frame, ID subframe, Recycle subframe, ID subsubframe, or Asynchronously embedded frame. If a format requires two or more FSC011 or FSC012’s to properly decom it, then both cards may need to switch together. In that case both cards need to see the decom switch key word, and only one card makes the decision. A decom switch I/O bus with the 11 decom data bits and a decom switch signal are available on the P2 connector. An FSC011 or FSC012 may be programmed to make the decom switch decision (Master), or monitor the bus for a decom switch decision (slave). In addition, they may be programmed to ignore
the bus, and make their own independent decision. A dependent card may be a Decom Switch Master. An external source may also be set up as the decom switch master.

**Error Correction and Detection**

Error correction and detection both require an intelligent choice of code words and a certain amount of redundancy. For a word of N bits in length, there are $2^N$ different patterns. To set up a code, some of these patterns are designated to be valid words (code words). The remainder of the patterns are invalid words (non-code words). The code words convey useful information, the non-code words do not convey useful information.

The Hamming distance between two bit patterns is the number of bits which differ between the two patterns. It is also the number of bits set when the two patterns are exclusive OR’d together. The Hamming distance of a code is the minimum Hamming distance between any two patterns of the code. To get the best random error detection and correction performance the code needs to have the maximum Hamming distance possible, and still have a code word for each destination decom list.

The number of patterns distance M away from the code word of length N bits is given by the combinatorial function $C(N, M)$. These are the patterns reached by M bit errors. $C(N, M)$ and their sums are evaluated for several values of N and M.

<table>
<thead>
<tr>
<th>C(N, M)</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C(11, 0) = 1$</td>
<td>$\text{sum} = 1$</td>
</tr>
<tr>
<td>$C(11, 1) = 11$</td>
<td>$\text{sum} = 12$</td>
</tr>
<tr>
<td>$C(11, 2) = 55$</td>
<td>$\text{sum} = 67$</td>
</tr>
<tr>
<td>$C(11, 3) = 165$</td>
<td>$\text{sum} = 232$</td>
</tr>
<tr>
<td>$C(11, 4) = 330$</td>
<td>$\text{sum} = 562$</td>
</tr>
<tr>
<td>$C(11, 5) = 462$</td>
<td>$\text{sum} = 1024$</td>
</tr>
</tbody>
</table>

$2^8 = 256 = 93 + 93 + 70$

To implement three bit error correction with four bit detection on an eight bit code word, only two decom lists may be supported; List [A], [B]. All 93 memory locations of the Switch RAM with an address near or equal to [A]’s code word would be programmed with [A]’s Start Address and the 93 locations for [B]’s code word, with [B]’s Start Address. The other 70 locations are half way between the two codes and should be marked as ‘do not switch’ to the control circuitry.

Another method of improving the switching reliability is to make use of the subframe time feature to give time for multiple switch detections, Choose a good code and dedicate a
number of positions in the format to hold decom switch information. If any of them have no errors, the switch will be done correctly at the end of the subframe.

Applications

1. Three identical telemetry streams from three overlapping zones of coverage track a flight. They are skewed by less than one major frame of data. The task is to select the best stream from the three maintaining major frames intact and without loosing any data. Each FSC has two decom lists; first, one with ID’s that route the data to the output stream, and second, one that routes telemetered time words, and status to the DSP002 where the decision on when to switch input streams in made. All the FSC’s are programmed to be slaves, and the DSP002 drives the decom switch bus interconnecting them with a switching key word, and the switch command pulse. To maintain full major frames of data, the FSC’s are programmed to switch at subframe time.

2. An engine test facility runs the engines though three phases. The first phase is startup, the second is dynamic speed, the third is fixed speed (cruise). Each phase has different concerns. As the test progresses, when the front end is commanded to change modes, the mode word in the telemetry stream changes, as does the measurement mix. The FSC simply switches to a new start address at the end of the minor frame in which the mode changes.

3. A time division multiplex channel off of a satellite carries information packets for 14 different sites. Only the packets for this site are to be delivered. In this case, the FSC is programmed for immediate switching and variable fill data. If the maximum time between packets is exceeded the FSC can warn of a link problem.

Conclusion

This practical approach to decom list switching addresses the needs of error avoidance, packet switching, and the location of switching keys in any portion of the format. Switching between formats is not restricted to a preprogrammed sequence, but allows multiple destinations from a particular decom list.

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Probability and Statistics for Engineers and Scientists 2nd Ed., Walpole and Myers, Macmillan 1978
DECOM SWITCH CIRCUITRY

FIGURE 3

<table>
<thead>
<tr>
<th>FS</th>
<th>SF COUNT</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>D5</th>
<th>D6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SW!</td>
<td>IMM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MF</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>NMF</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>SF</td>
<td>1</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FS - FRAME SYNC PATTERN

SW! - KEY WORD FOR DECOM SWITCH

IMM - IMMEDIATE MODE EFFECTIVE HERE TO END OF MF
(SF 1 WORDS D4,D5,D6 ONLY)

MF - MINOR FRAME MODE - SWITCH EFFECTIVE HERE

NMF - NEXT MINOR FRAME MODE - SWITCH EFFECTIVE HERE

SF - SUBFRAME MODE - SWITCH EFFECTIVE HERE

Figure 4
### SWITCH TIME MODES

<table>
<thead>
<tr>
<th>SF</th>
<th>COUNT</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>D5</th>
<th>D6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>SW1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SW2</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NMF</td>
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<td></td>
<td></td>
<td></td>
<td>SW3</td>
<td></td>
<td>SW4</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>SW5</td>
<td></td>
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<td>SW6</td>
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<tr>
<td>SF</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FS** - Frame Sync Pattern

**SWx** - Key Word for Decom Switch

**MF** - Minor Frame Mode - if SW1, SW2 valid - SW2 Address is used

**NMF** - Next Minor Frame Mode - if SW1, SW2 valid - SW2 Address used

**SF** - Subframe Mode - if any valid - most recent valid key's address is used

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Figure 5