MUX—What It Is!

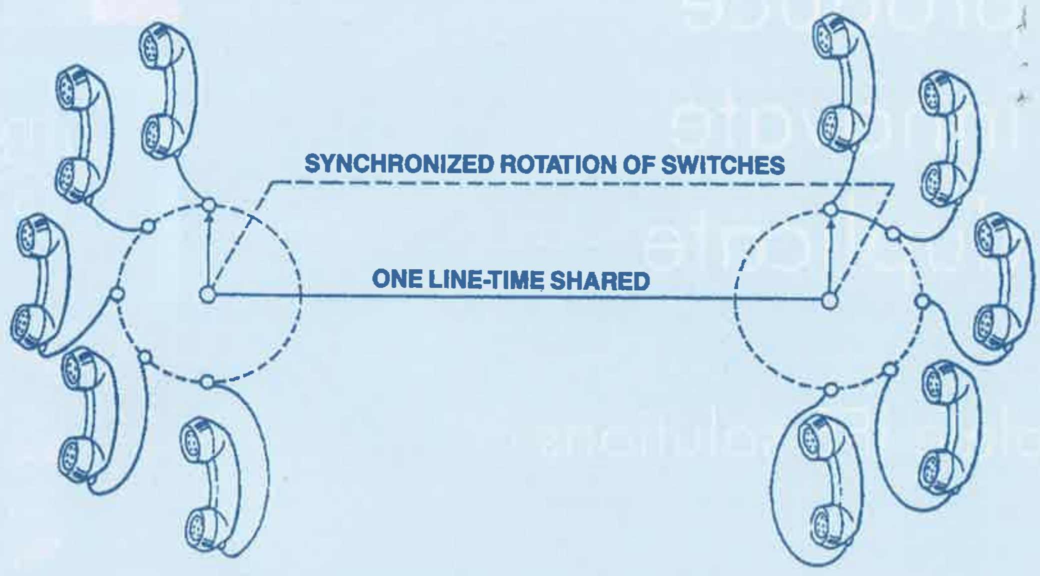
... A Multiplex Primer

Editor's Note: The word "MUX" is used frequently in WAEA forums, and it's not uncommon to see eyebrows raise or foreheads furrow at the use of this strange, unfamiliar word. MUX is the acronym for multiplex. It is also a key ingredient in the audio and video entertainment systems on many of the world's commercial aircraft. Without "MUX," IFE would require many additional miles of wires. Rory Briski has authored an article on this subject directed to readers with a non-technical background.

It began in the mid 1960's. For the first time, airline passengers were able to select and listen to their own individually selectable audio programs, and the world of passenger entertainment hasn't been the same since. The B707 and DC-8 were two of several types of aircraft that hosted this revolutionary innovation.

A primary piece of equipment in use at that time was the CAM-1 Tape Reproducer developed by Transcom. This unit used large tape cartridges to house the audio tapes. The cartridges were unique in that the tape was not spun upon a reel but was folded back upon itself repeatedly. This made the tape look like a very long snake coiled back and forth within the shell of the tape cartridge.

The audio signals were fed into a distribution system manufactured by EECO Inc. This system consisted of an audio amplifier, many junction boxes, and, of course, a PCU (Passenger Control Unit) at each seat. The audio amplifier took the inputs from the CAM-1, amplified them and sent them to the



Simplified Multiplexing Using Telephones
Figure 1

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passengers via the junction boxes. Each audio channel required two wires to be routed to the junction boxes. If six channels were made available, twelve wires were required to be fed throughout the aircraft. If ten channels were available, twenty wires had to be fed throughout the aircraft. The junction boxes in turn split the wires again to feed each PCU within its respective seat group.

The PCU contained a volume control knob and a channel select knob. Two small speakers within the PCU provided the audio. The sound from these speakers was transferred to the passengers' ears by the twin tubes on pneumatic headsets.

This method of audio distribution was a fine application of the technology that was available at that point in IFE history. The frequency response was good, the reliability was fair, and the passengers were happy to have the ability to select their audio programs.

However, as the novelty of inflight audio passed, passengers demanded more. The design of the hard-wired system caused many cross-talk problems. That occurs when listening to one audio channel, but another audio channel can be heard in the background. Also, as more and more passengers listened to the same audio channel, the signal level was reduced to the point that it was inaudible in the rear of the aircraft. The many thousands of tie points within the system also caused a degradation in the audio signal. If an airline wanted to change its programming from stereo to mono, or mono to stereo, then major wiring changes had to be made to the aircraft. While the system operated as expected and had an overall positive reaction from the passengers, it wasn't without its problems.

MUX or Multiplex systems have been in common use since the mid 1940's. The first widespread commercial use was in telephone systems to increase the number of calls that could be placed on one telephone line. The MUX system is easiest to describe in its most basic form by referring to their early use by the Bell Telephone company. As shown in the accompanying drawing (Figure 1 on page 29), a multiplex system can be visualized as several telephones connected to only one line through two switches, one at each end of a single pair of wires. As a switch is turned on, each telephone is sequentially connected to its corresponding telephone on the other end of the line.

A more formal definition would be that multiplexing is a technique used to time-share a common carrier being fed several different audio or data inputs. Each time the switch engages a given telephone line it is said to be "sampling" the audio on that line. Sampling refers to cutting out a small slice of the audio signal. This "slice" is labeled for later identification and sent down the line to the receiver to be demultiplexed and then directed to the appropriate telephone.

In 1970, Pan Am became the first user of a multiplexed audio distribution system in the airline industry. This system was installed on a B747 and was manufactured by Telephonics Corp. It did not fare as well as the hard-wire system in use on the narrow-body aircraft. The MTBF (Mean Time Between Failures) of the MUX system was a mere five flight hours compared to 85 flight hours of the EECO system. The units that make up a wide body MUX system and their interrelationships are shown in Figure 2 on page 32.

One of the driving factors for MUX on these wide-body aircraft was the ability to multiplex control signals for the reading and call lights. Due to the twin-aisle design and the high ceilings of these aircraft, it was impossible for passengers to control these functions from their seats. If the controls were put into the overhead to accomplish these tasks (as on a B707), the weight penalty would have been about 1,555 pounds. A MUX system accomplishing the same purpose would weigh only 580 pounds. Because weight is gold to an airline, MUX had at least one clear advantage over hard-wire. These same concepts were used on the DC-10 in 1973 with American and United being the first customers of that aircraft and on the L-1011 in 1975 with TWA, Eastern, and Delta kicking it off.

As technology progressed, some of the old cordwood circuit designs gave way to Hybrid integrated circuits which were a major factor—raising the Telephonics MUX system MTBF to an unheard of 100 hours.

Telephonics was not the only player with a MUX system. Hughes Aircraft Corp. also offered its version of a competitive system. The Hughes system had a distinct advantage over Telephonics in that the technology had progressed to the point of eliminating the cordwood molecules altogether and replacing them with all solid state electronics. The MTBF's were again raised ... to an incredible 300 hours.

Telephonics and Hughes used a technique called PCM (Pulse C Modulation) in their multiplex system. This technique is basically a conversion of the analog audio signal into a digital word. The digital word is typically a 10 to 13 digit code that represents all of the characteristics of the sampled sliced audio. This code is then transmitted throughout the system in place of the analog audio and then decoded and reconstructed at the receiver. Figure 3 on page 32 (top left) shows a typical PCM waveform. The decoded signal is shown in Figure 3 (bottom left). Every 1/30,000 of a second each audio input is sampled and a slice is cut out and fed into the multiplex stream. The demultiplexed audio signal does resemble the input signal somewhat, but it is not a true reproduction.

Matsushita Avionics Systems (MAS) entered into the MUX arena in 1980 with the introduction of its systems on the B767 aircraft. MAS developed a different type of sampling based on the Delta Modulation technique (having nothing to do with the airline by the same name). This type allows for the sampling to be done about 10 times more often than PCM (about 300,000

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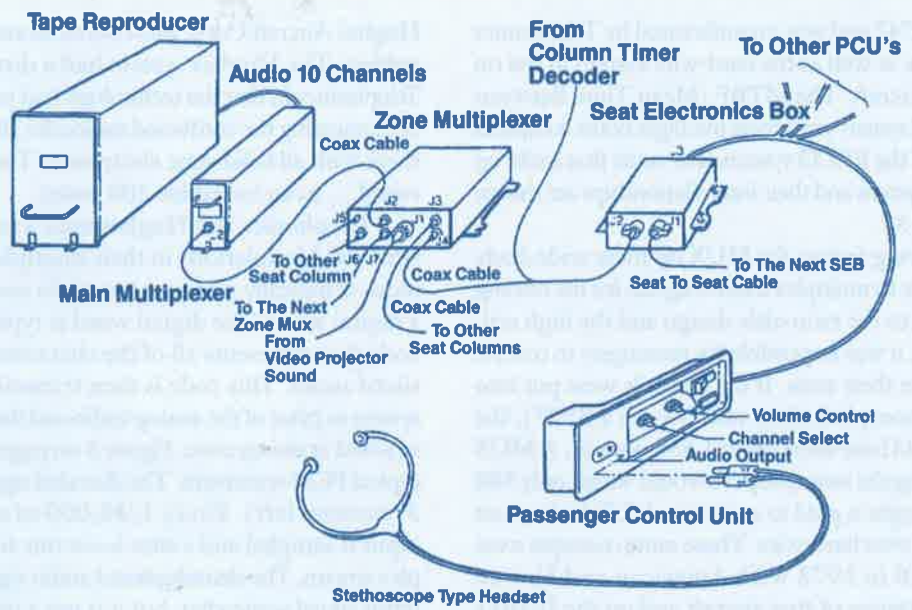
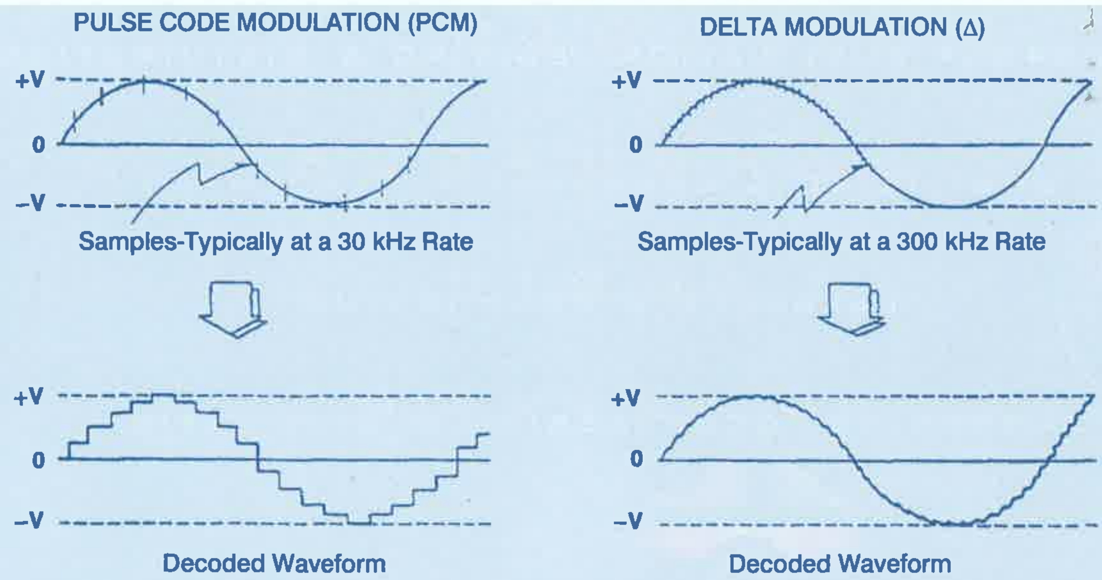


PES System Simplified Diagram
Figure 2

times per second). Figure 3 shows a comparison of Delta modulation versus PCM.

Adaptive Delta modulation samples only the change in the previous digital word (slice of audio), it doesn't copy the current signal. This allows for a greater sampling rate and therefore a truer reproduction of the input signal.

The multiplex system is represented in Figure 4 on page 34. The multiplexed audio signals from each channel is fed down the wires one after another in a continuous flow - first a slice of channel one, then a slice of channel two, then channel three, etc. etc. This stream carries along with it a series of clock pulses that tell the receiver (Seat Electronics Box) what channel is where. Suppose a passenger selected channel six at the PCU. The PCU would transfer a signal to the Seat Electronics Box (SEB) to send it the audio program on channel six. The SEB would then monitor the Multiplexed data stream and listen for the clock pulses that said channel six was coming down the line. The SEC would then send the audio slice of channel six up to the PCU. This would happen 300,000 times per second, so fast that the human ear was incapable of discerning the separate slices.



Comparison of Delta Modulation Versus Pulse Code Modulation
Figure 3

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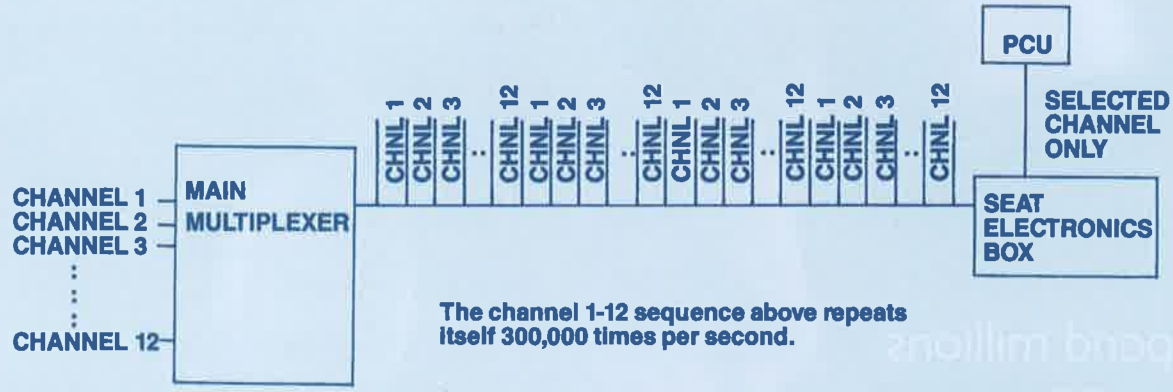

Narrow Body Aircraft Simplified MUX System
Figure 4

To bring it all together, the audio was first input into the system by the Entertainment Tape Reproducer. This typically supplied 12 channels of audio to the Main Multiplexer on 24 wires, 2 wires per audio channel. Since the Main Multiplexer was typically located within one or two feet of the Tape Reproducer, this posed no problem. The Main Multiplexer took these 12 audio inputs and multiplexed them onto a single pair of wires or onto a coax cable.

In a typical narrow-body aircraft application the Main Multiplexer has four outputs. Each output is fed to a different part of the aircraft and sent to the SEB's to be demultiplexed and then directed up to the PCU to be heard by the passenger.

Wide-body aircraft have a slightly different scheme. Located within each zone of the main cabin is another box called a Zone Multiplexer or Sub-Multiplexer. This box is used to add the move audio for that zone onto the multiplex stream along with the Tape Reproducer audio. This allows each zone in the aircraft to have a different movie playing, with the audio for each movie appearing on the same PCU channel in each zone. For example, if all movie audio is to be on channel one and two, then a passenger in zone one would have their soundtrack fed to them by their Zone Mux or Sub-Mux on channel one and two, and a passenger in zone four would have a different sound track fed to them by their Zone Mux or Sub-Mux on their channel one and two.

To trace the path more fully, the Zone Mux/Sub-Mux sends its multiplex stream to the SEB's within its zone. There is one SEB per seat group. A seat group consists of one, two, three or four seats. There is one PCU per seat. The SEB is the demultiplexer and actually does the work of removing the audio channel selected by the passenger from the multiplex stream.

On wide-body aircraft the reading and attendant call lights are also controlled by this same process. When a passenger presses the reading light button on his or her PCU, a signal is sent to the Seat Electronics Box that the light should be turned on.

The SEB (Seat Electronics Box) then waits until its turn in the multiplex stream to say if it wants anything done. When its turn comes, it says turn on the light for seat "B." This is then decoded by other electronic devices, and the light is turned on. This process causes the slight delay when turning on and off the reading light.

The control of the PSS (Passenger Service System) functions described above are accomplished by a single pair of wires using a similar multiplexing scheme as for the audio.

Troubleshooting this type of system used to be a very time consuming and complicated procedure. With the ability to design and manufacture microprocessors and LSI microchips, a system that can basically troubleshoot itself was developed. On a narrow body aircraft a BITE (built-in test equipment) test takes about 300 milli-seconds to run. That is about 1/3 of a second.

This system will test all audio channels at all volume levels on all Digital Passenger Control Units within the aircraft. The trouble spots are then indicated and, in some cases, what the fault actually is. To activate this test a single switch is turned on.

With the data lines that are available in a wide-body aircraft multiplex system an even more comprehensive test can be run. The person conducting the test will know at a glance that the Seat Box in seat 31ABC is bad or that the cable assembly in the overhead between seats 12ABC and 13ABC has an open wire in its data #1 line. A bad PCU will be spot lighted by its reading light.

Although the ability to troubleshoot the systems has become more sophisticated, the actual need to do so has significantly been reduced. For example the MTBF of a typical Seat Electronics Box flying on a B747 is 310,000 flight hours, with an overall system MTBF in the 1,500 hour range.

So then, "What is MUX?" Is it a sophisticated, high fidelity, stereo music distribution network? Is it a high-speed data communications system? Is it an extremely efficient troubleshooting tool? Is it all of the above? Or more importantly, what will MUX become in the future? But then, that's another story.