# A Room-Sized Computer in Your Digital Music Player

By ReadWorks

It was the morning of December 7, 1941, and problems were mounting for General George Marshall. American Army code breakers had intercepted and deciphered conversations between Japanese leaders in which they announced they had given up on diplomacy with the United States. War now seemed imminent. As U.S. Army Chief of Staff, it was Marshall's role to warn every U.S. Navy post in the Pacific, including the Hawaiian base at Pearl Harbor, that they should take immediate steps to prepare for an attack.

Ever since the 1920s the United States had relied on the coded A-3 Scrambler system, operated by the American Telephone and Telegraph Company in New York, for its most secure military communications.

Marshall didn't trust the Scrambler, and his instincts were right. Years later it was discovered that the Germans had already cracked the code for the Scrambler, and were able to listen in on all conversations between American military leaders and their units using a listening station built in a former youth hostel on the Dutch coast.

To avoid having his critical message fall into Japanese hands, Marshall decided against using the Scrambler and instead sent his orders to Hawaii via telegraph code, a safer but slower system. That morning the Japanese launched a surprise air attack on the U.S. Naval base at Pearl Harbor. They sank or severely damaged 21 ships and boats and killed 2,402 people.

Marshall's orders to prepare the base's defenses did not arrive until after the last Japanese plane disappeared over the Western horizon.

The disaster at Pearl Harbor confirmed what Marshall and other military leaders already knew: they needed a secure system for communication with their troops, one that could not be cracked by enemy forces. They turned to a company called Bell Labs, which in the 1920s had developed the Vocoder, an early voice encoding machine which took analog recordings, capturing the sounds as they were naturally emitted. The Vocoder recorded people's voices and divided them by frequency into different pieces. It sent those pieces separately via radio waves to a machine on the other end, which received the different pieces and spliced them together to recreate the original sound.

The analog Vocoder became the basis of a newer, digitized version. With digital signals, the flow of sound is divided into segments, and each note is assigned its own unique binary value. Early methods of digital recording and playback had fewer values, which meant that when they were replayed, the recording sounded like a series of short segments with gaps in between. Advances in computing power allowed for more values to be added to the equation, so that conversations and other sounds could be replayed continuously and without gaps.

The new, digital version of the Vocoder was called various names, including Project X and SIGSALY. It also was called the Green Hornet. That's because the different signals were

sent by cable along with a buzzing noise made to sound like random background static, further disguising the transmission. Once the signals were received and spliced back together to recreate the entire conversation, the buzzing sound remained. People thought the resulting noise sounded similar to the theme song from *The Green Hornet* radio show, which was popular at the time.

Like the Vocoder, SIGSALY broke human speech down into multiple parts. Unlike Vocoder, however, SIGSALY was a digital system. Bell Labs engineers took digital samples of analog sounds recorded at uniform intervals and converted those sounds into numeric code. Each sample was quantized to the nearest value within a series of digital steps, much as you might round 99 cents up to a dollar.

This process is called *pulse-code modulation*, and today it remains the method used by computers, MP3 players, and compact discs to translate sounds into digital form for later recreation into analog sound. The quality of that sound has to do with two properties: the sampling rate, which means the number of times per second a sample is taken; and the bit depth, which measures the number of possible values sounds can be divided into, along the audible continuum of frequencies (the more possible values, the closer each individual sound will be to the original).

By March 1943, the first SIGSALY machine was built by Western Electric and shipped to Washington, D.C., where it was installed in the Pentagon. (Rumor has it the first machine was originally planned to be installed in the basement of the White House, but President Roosevelt decided against it because he knew of British Prime Minister Winston Churchill's fondness for long, late-night phone calls.) The system was so large and generated so much heat that it required its own separate air conditioning system. Four months later, a twin system was installed in the basement of Selfridges Department Store in London, connected by cable to Churchill's war cabinet room a mile away. The two systems were connected by a cable under the Atlantic.

Though cumbersome and expensive to operate, the SIGSALY system appears to have worked well during the war. More than 3,000 high-level conversations happened over SIGSALY, covering troop movements, equipment drops and strategy, and no record has ever been found of the German or Japanese militaries deciphering its coded messages. The system became the first transmission of speech using pulse-code modulation, and the first effective use of bandwidth compression to recreate speech. SIGSALY's room-sized terminals were eventually set up in 10 places including Hawaii, Paris, Algiers and Guam. In addition, a mobile system was built to operate on a Navy ship that would accompany General MacArthur's campaign across the Pacific Ocean, which military strategists had envisioned as the only way to beat Japan until the atomic bomb was dropped on Hiroshima in 1945. After the war ended, SIGSALY was used to coordinate the return of troops and the repositioning of units across Europe at the start of the Cold War. SIGSALY was taken out of service in 1946.

While pulse-code modulation continued to be used in coded military communications for decades, it wasn't until 1972 that the technique was used in music to manufacture digital master copies of phonograph records. The first commercial music release using pulse-code modulation didn't come until a decade later, when Billy Joel's album, *52nd Street* was issued on compact disc. CDs sales, however, started to dwindle by the early 2000s when consumers began switching over to digital music files, the most common format of which is probably the MP3. MP3s possess a similar sound quality of a CD, and are recorded using the same method of digital sampling. The primary difference between them is their physical form, or lack thereof—CD's have one, whereas MP3s exist only as computer files. Because they have no physical presence, MP3s can be saved and played on a variety of devices, reducing the risk of physical damage to disks and greatly reducing the cost, weight, and space required to maintain a music collection. Because the data in MP3 files is compressed to save memory space on most devices, however, the sound quality and range is generally lower than music played during a live performance or recorded onto records and CDs.

While some audiophiles claim that digital recording and playback of music can never fully recreate the full sound of music the way that a fully analog phonograph record can, improvements in processing speed, sampling rates, and bit depth mean that today, a digital recording is almost indistinguishable from an analog one.

Name: _____ Date: _____

**1**. According to the text, what did the disaster at Pearl Harbor show that the U.S. military leaders needed?

**A** a way to prepare military bases' defenses more quickly
**B** a way to improve the speed of the telegraph code
**C** a secure system for recording and playing music
**D** a secure system for communication with their troops

**2**. In this text, the author describes a sequence of technological developments. In what order were these technologies created?

**A** the Vocoder, SIGSALY, CDs, MP3 music files
**B** SIGSALY, the Vocoder, CDs, MP3 music files
**C** CDs, MP3 music files, the Vocoder, SIGSALY
**D** MP3 music files, SIGSALY, CDs, the Vocoder

**3**. The method used by SIGSALY to encode messages was more effective than the method used by the Scrambler to encode messages. What evidence from the text best supports this conclusion?

**A** The Germans were able to crack the code for the Scrambler, while no record has ever been found of the German or Japanese militaries decoding SIGSALY's messages.
**B** Marshall didn't trust the Scrambler for his secure military communications, so he decided to send his message to Hawaii via telegraph code.
**C** More than 3,000 high-level conversations happened over SIGSALY, covering troop movements, equipment drops, and military strategy.
**D** The SIGSALY system saw the first transmission of speech using pulse-code modulation and the first effective use of bandwidth compression to recreate speech.

**4**. Which machine had the most direct impact on the way music is recorded and played?

**A** the Scrambler
**B** the Vocoder
**C** SIGSALY
**D** the telegraph

**5**. What is the main idea of the text?

**A** Thousands of people were killed at Pearl Harbor due to the failure of the U.S. military's secure communications system.
**B** A voice encoding system made for military use was the basis for some of today's digital music systems.
**C** SIGSALY was the first digital voice encoding system, and it used a process called pulse-code modulation to encode human speech.
**D** While CDs and MP3s both used pulse-code modulation to record and play music, they have very different physical forms.

**6**. Read these sentences about the Vocoder, a voice encoding machine.

"The disaster at Pearl Harbor confirmed what Marshall and other military leaders already knew: they needed a secure system for communication with their troops, one that could not be cracked by enemy forces. They turned to a company called Bell Labs, which in the 1920s had developed the Vocoder, an early voice encoding machine which took analog recordings, capturing the sounds as they were naturally emitted. The Vocoder recorded people's voices and divided them by frequency into different pieces. It sent those pieces separately via radio waves to a machine on the other end, which received the different pieces and spliced them together to recreate the original sound."

Based on these sentences, what does "encoding" mean?

**A** adjusting the volume of a message so that it can be heard more clearly
**B** recording a message so that it is perfectly preserved and understandable
**C** changing a message in some way so that it cannot be understood
**D** deleting a message so that no one can access it aside from the recipient

**7.** Choose the answer that best completes the sentence.

The Vocoder was an analog voice encoding machine, _____ SIGSALY was a digital system.

**A** even though
**B** therefore
**C** while
**D** during

**8**. SIGSALY used a process called pulse-code modulation to translate human speech into digital form. What are two technologies that use this method today?

**9**. How did the digital voice encoder SIGSALY make today's MP3 players possible? Support your answer with evidence from the text.

**10**. How can technology from the past impact technology today and in the future? Support your answer with evidence from the text.