Technical Article

Gamechanger Audio Bigsby Pitch-Shifting Pedal with State-of-the-Art Audio Digital Signal Processing

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Abstract

Gamechanger Audio took on the challenge to create a unique real-time pitch-bending algorithm—so realistic that guitar players could solely focus on delivering the best musical experience. Implementing such an extremely computationally demanding algorithm requires real-time digital signal processing capabilities with fast access memories that could guarantee low latency and deterministic behavior.

This article elaborates on the system requirements, implementation details, and design challenges of the Bigsby® Pedal and how the comprehensive feature set of Analog Devices' ADSP-21569 SHARC+® audio processors addressed these.

Bringing the Bigsby Tremolo Into the Modern Electric Guitar Setup

Gamechanger Audio makes audio effects units and instruments, with a special focus on developing new, unusual technological solutions that push music creation forward. Breakthrough product designs aim to give musicians previously unheard sounds and new ways of interacting with their instruments.

With a strong reputation as an esteemed innovator in the industry, this company has garnered widespread recognition through collaborations with renowned modular synthesizer manufacturer "Erica Synths," acclaimed musicians like Jack White, and the legendary Fender Musical Instruments Corporation (Bigsby).

The Bigsby Pedal (Figure 1) is a polyphonic pitch-shifting effects unit for musical instruments, designed to replicate the feel and classic sound of the Bigsby Tremolo system. The Bigsby Tremolo, designed by engineer Paul Bigsby in 1951, was the first mechanical string bending mechanism—a spring-loaded hand-operated lever that allowed guitarists to gently increase or decrease their instrument's string tension—thus pioneering a whole new category of new playing techniques for electric guitars.

Since then, a variety of different mechanical vibrato systems have been used on electric guitars—including the Stratocaster's "whammy bar" (used by musicians such as Jimi Hendrix and Jeff Beck), Eddie Van Halen's "Floyd Rose" system, and many other basic string-bending mechanisms.

The Bigsby Pedal's real-time pitch bending algorithm produces realistic sounds with a variety of sound sources. It can also be used with bass guitars, acoustic instruments, such as banjos, mandolins, and violins, as well as with vocals, synthesizers, wind instruments, etc.

Figure 1. Gamechanger Audio Bigsby Pedal.

Enabling Creativity Without Physical Limitations

Although a crucial part of the electric guitar sound, mechanical vibratos can be cumbersome mechanisms that reduce the guitar's sustain, decrease the guitar's tuning stability, and increase the risk of string breakage during performance.

Therefore, the aim is to develop a digital solution that offers all types of classic string-bending and vibrato sounds without experiencing any tuning issues or mechanical faults.

To achieve this goal, implementing an exceptionally accurate real-time pitch-bending algorithm is required, so that guitar players can fully focus on the performance, without losing the tonal characteristics of the instrument and the playing dynamics. Such a mathematically demanding algorithm requires extremely high computing capabilities and fast memory access to produce high quality sound and feel with minimal latency.

As depicted in Figure 2, ADI's ADSP-21569 SHARC+ digital signal processor (DSP) is an ideal solution due to its architecture, high performance floating-point core, audio-centric peripheral set, and large on-chip static random access memory (SRAM), which removes the need for external memory. Additionally, it offers state-of-the-art dedicated hardware functions and ever-increasingly important security features.

ADSP-215xx Family of DSPs Based on 1 GHz SHARC+ Core

The ADSP-2156x series (ADSP-21562/ADSP-21563/ADSP-21565/ADSP-21566/ADSP-21567/ADSP-21569) of DSPs are designed to provide immersive audio and sound experiences in automotive and consumer/pro-audio applications. The ADSP-215xx processor family is based on the SHARC+ single-instruction multiple-data (SIMD) core operating at up to 1 GHz clock frequency.

The 32-bit/40-bit/64-bit floating-point processor is optimized for high performance audio/floating-point applications with large on-chip SRAM, multiple internal buses that eliminate input/output (I/O) bottlenecks, a feature-rich audio peripheral set, and a wide variety of control and connectivity options, as depicted in the block diagram in Figure 3.

Maximizing System Performance Through Hardware Functions

To keep the feel and sound of an analog tremolo system, there can be no digital artifacts or synthetic-sounding tones with minimal latency. The end goal is to be able to perform real-time polyphonic pitch-shifting with excellent timbral preservation and seamless transitions between pitch-shift coefficients to emulate characteristics of early vibrato systems. As string tension is released, different gauged strings will drop in pitch by different amounts, thus resulting in a slightly out-of-tune sounding chord.

The SHARC+ DSP architecture enables the user to perform complex calculations necessary for real-time polyphonic pitch-shifting. The 1 GHz core frequency and the 640 kB of on-chip Level 1 (L1) and 1024 kB of on-chip Level 2 (L2) SRAM ensure great computational power and extremely efficient data access. The optimized finite impulse response (FIR) and infinite impulse response (IIR) hardware accelerators on the ADSP-2156x processors are tidily coupled with the SHARC+ core with the help of a dedicated fabric and run at core speed. This tied integration allows the FIR/IIR accelerator ports to directly access the processor's L1 memory with reduced latency, as these accesses do not go through the main system fabric. The built-in circular buffers for fast Fourier transform (FFT) functions of the SHARC+ core are extremely fast and efficient and allow the user to do multiresolution analysis and keep latency to a minimum.

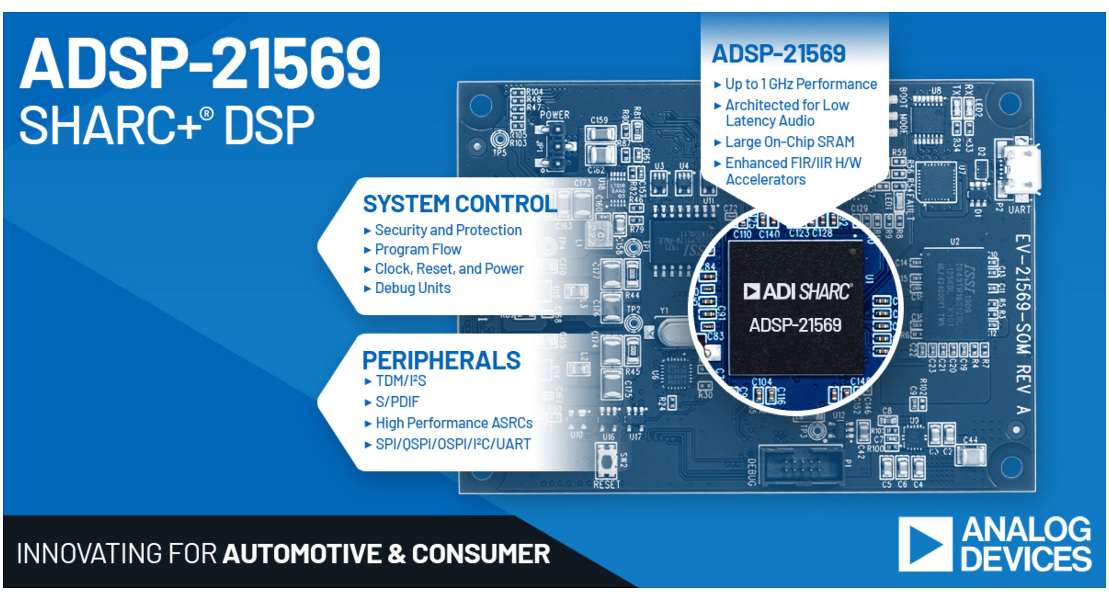

Figure 2. ADSP-2156x SHARC+ DSP series.

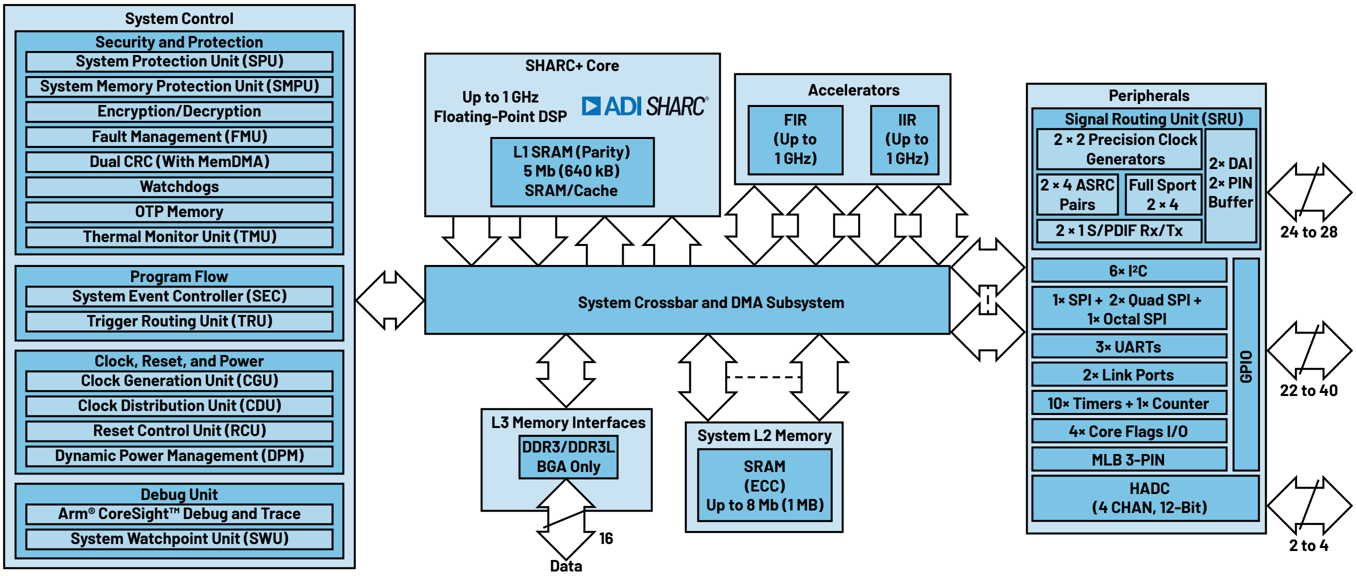

Figure 3. The ADSP-21569 full-featured model processor block diagram.

Full Audio Connectivity and Security

The ADSP-2156x DSP also features an advanced and innovative digital audio interface, which includes eight serial ports (SPORT) with support for time-division multiplexing (TDM) and inter-IC sound (I²S), as well as musical instrument digital interface (MIDI®) communication, making the pedal fully controllable and programmable via a digital audio workbench (DAW) or through a variety of standard MIDI controllers (Figure 4).

Figure 4. Bigsby Pedal audio interfaces.

Additionally, this audio-centric processor also supports two Sony/Philips digital interfaces (S/PDIF), eight asynchronous sample rate converter (ASRC) pairs, four precision clock generators (PCGs), and 24 audio buffers, all of which when combined enable high efficient audio communication links.

Furthermore, the ADSP-2156x series offers a cryptographic engine with support for standards-based hardware-accelerated encryption, decryption, authentication, true random number generation, and secure boot for intellectual property (IP) protection. IP security is an ever-increasing concern in today's consumer and pro-audio markets, and ADI enables Gamechanger Audio to protect its unique and innovative algorithmic solution.

Flexible Features and Intuitive User Interface

The Bigsby Pedal's foot-pedal format is a unique twist on the classic string bending technique. By removing the spring-loaded mechanism from the guitar's body and placing it on the floor (Figure 5), both of the player's hands are free to keep playing rhythmical, complex patterns and intricate solo licks, while a foot-controller performs all pitch bends. This creates a new kind of performance tool—something that allows guitar players and multi-instrumentalists to invent new playing techniques and create musical arrangements that would otherwise be impossible with a mechanical vibrato system or with a basic pitch-shift effects unit.

Enabled by the high performance SHARC+ core, the Bigsby Pedal can produce realistic real-time pitch shifts over a range of two octaves, adjustable with depth knobs. The tone and detune parameters of the pitch-shifted signal can also be adjusted—the detune parameter particularly is a painstakingly accurate recreation of the "out-of-tune" effects, characteristic of early vibrato systems. The rate knob lets users automate the Bigsby Pedal's pitch-bending algorithm, to produce vibrato and chorus effects of various speeds. All of these would not be possible without the floating-point capabilities of the SHARC+ core, along with its low latency and large on-chip memory offerings.

Figure 5. Bigsby pedal final product.

Bigsby Pedal—The Final Product

When Gamechanger Audio first presented the Bigsby Pedal to the guitar community, one of the most common comments was: This is so brilliant, but so obvious. Why didn't anyone think of this years ago?

The simple answer is that the Bigsby Pedal would be unimaginable if the pitch-shifting algorithm did not produce exceptional results. Any digital artifacts or synthetic-sounding tones would simply defeat the purpose of the whole product. The final algorithm is extremely complex and requires an incredible amount of computing power—thanks to ADI's SHARC+ family of high end scalable audio DSPs and its optimized architecture specifically tuned for real-time audio signal processing, builders like Gamechanger Audio can dream big and make a pedal like the Bigsby become a reality.

References

Bigsby Pedal. Gamechanger Audio, 2024.

Fender Musical Instruments Corporation, 2024.

ADSP-2156x SHARC Product Family. Analog Devices, Inc., 2024.

About the Authors

Maikel Kokaly-Bannourah earned a B.Eng. Hons. in electrical and electronics engineering from the University of Hertfordshire (UK) and an MBA Degree from the MBA Business School in Las Palmas (Spain), joining Analog Devices in the year 2000. Maikel is currently a principal field applications engineer with over 20 years of experience in audio processing and connectivity solutions, with a particularly strong focus on ADI SHARC DSPs. He has been deeply involved in ADI's audio processors, DSPs, and CODECs, as well as $A^2B^{®}$ transceivers and HDMI technology, supporting a wide variety of consumer applications, such as hearables and wearables, professional audio, unified communications, and musical instruments connectivity.

Martin Swahn has a M.Sc. degree in electrical engineering from Royal Institute of Technology (KTH) in Stockholm, Sweden. Martin has 20 years experience working in the semiconductor industry and joined Analog Devices in 2015 where he has held multiple different positions, both technical and commercial. Currently, Martin is supporting a wide range of customers as principal account manager in Sweden.