



PERFORMANCE, COST, AND FREQUENCY ATTRIBUTES GIVE SILICON TV TUNERS THE EDGE AS THEY PLAY KICK THE CAN WITH THEIR PREDECESSORS.

BY PAUL RAKO • TECHNICAL EDITOR

SILICON TV TUNERS: THE GAME IS ON

Silicon-tuner ICs have for nearly a decade found use in set-top boxes for satellite and cable. Now, thanks to their high performance, simplicity, broad frequency coverage, compactness, and universality, they are making inroads into phones, set-top boxes, service gateways, automobiles, PCs, and even TVs. What's more, they use no SAW (surface-acoustic-wave) filters and few supporting components, making them more reliable and less costly than their can-tuner predecessors. Once TV manufacturers gain expertise in RF (radio-frequency)-PCB (printed-circuit-board) layout, you can expect silicon tuners to obsolete their predecessors, can tuners (**Figure 1**).

The venerable can tuner, so-called because TV manufacturers pack the mixer-oscillator/PLL (phase-locked loop) and associated components into a large metal can, also contains the demodulator chips that convert the RF signal from the tuner into a baseband analog-TV signal or a digital stream for HD (high-definition) formats (**Figure 2**). The shielded metal can containing the circuitry prevents interference from the external TV signal and prevents internal clocks and high frequencies from polluting signals in the TV. Although large and unwieldy, can tuners have the advantage of a huge manufacturing base that keeps cost low. However, they require designers to use different

SAW-filter frequencies for various regions and TV-modulation standards. They also require dedicated factories and work forces to manually align their air-wound coils. In contrast, some manufacturers use silicon tuners directly on the motherboard rather than putting them into a can. Because of their size, silicon-tuner circuits are also less susceptible to interference and may eliminate the need for shielding around the chips.

William Chu, director of RF products at Maxim Integrated Products, notes that reducing the cost of a can tuner has reached fundamental limits and that silicon tuners can provide frequency to as much as 1 GHz. The TV market repre-

sents the last frontier for these tuners. IC companies developed these chips by exploiting the fact that cable-TV channels all have similar signal strength, making it easier to tune into a station than tuning broadcast-TV signals with widely different strengths. This task also depends on the distance from the transmitter and the transmitter's power level. Satellite and cable signals with digital modulation are also easier to tune. The engineers who created the digital-modulation standards ensured that the signals were easier to tune and demodulate than those of an analog TV.

THE WOES OF ANALOG TV

An analog station has more energy at its boundaries (**Figure 3**). At the lower part of its bandwidth, synchronization-carrier energy locks the picture rasters at the left side of the screen. The audio-subcarrier bandwidth is on the right side of the screen. This scheme prevents analog TV from undergoing the "cliff effect" (**Reference 1**). Instead of losing the whole picture and sound in a weak-signal area, an analog station instead has "snow," speckles of noise throughout the picture. The higher synchronization and audio-signal energy mean that you can still watch the video and hear the audio.

Cresta Technology Corp. Ex. 2004

Silicon Laboratories Inc. v. Cresta Technology Corp.
IPR2014-00809

Cresta Ex 2005-1
Silicon v Cresta
IPR2015-00626

Although energy distribution in an analog signal is good for your reception, it makes it harder to keep adjacent channels from interfering with each other in a tuner. The greater power at the edges of the band easily bleeds into the channel next to it. The combination of widely different signal strength, often on adjacent channels, and the energy spectrum in an analog TV's RF signal poses a great challenge to silicon-tuner designers.

Before you discount the importance of analog reception, remember that most of the world still uses analog. In the United States, for example, analog transmission is still legal for low-power stations and legacy stations that cannot afford to convert to digital modulation. In addition, the United States' northern and southern neighbors, Canada and Mexico, still broadcast analog TV. US consumers expect their TVs to be able to receive stations from these countries. Many other countries' conversion to digital modu-

AT A GLANCE

Thanks to their high performance, simplicity, broad frequency coverage, compactness, and universality, you can expect silicon tuners to one day replace the venerable can tuner.

Silicon tuners work with analog and digital demodulator chips.

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Tuning broadcast TV is a demanding task.

Manufacturers make tuners in CMOS (complementary metal-oxide-semiconductor) and SiGe (silicon-germanium) processes.

lation won't take place for years. The problems of digital-TV reception may well slow the adoption of digital TVs in

countries that have not yet converted. Furthermore, many cable-TV systems still broadcast the local channels as analog signals, and a cable-ready TV must be able to receive these signals. "Taking analog reception out of a TV is fraught with peril," says Brian Mathews, vice president of marketing at silicon-RF-tuner manufacturer Xceive. "No TV manufacturer would consider it." So, although the law no longer dictates that a TV must receive analog, manufacturers will provide it for at least the next 10 years.

Another benefit of TV-tuner ICs that work with analog signals is that, if the chip can handle the broad signal variations of an analog transmission, it can also work in rural China, where cable-TV systems' grossly overmodulated and undermodulated signals lack proper leveling. Silicon-tuner ICs also can handle future changes. The standards body for the ATSC (Advanced Television Systems Committee) can change specifications or improve the modulation so that it works for mobile TVs, and the analog tuner chip still works. The same manufacturers of analog chips also design programmable demodulator chips, so you can update firmware to provide for future changes. Silicon tuners also make practical white-space transmission of signals in bands without TV channels (see sidebar "TV tuners and white space" in the Web version of this article at www.edn.com/100923df). Because the silicon tuners have better blocking of adjacent channels, a 5W data transmitter near your house does not interfere with the microvolt signals that happen to enter the adjacent channel.



Figure 1 This NXP silicon-tuner evaluation board has provisions for shielding a metal can around the chip, but some applications may not require the can.



Figure 2 TV tuners are migrating from can-tuner modules (left) toward integrated silicon tuners (center) to devices that designers can integrate directly on the motherboard (right) (courtesy Silicon Laboratories).

TV-TUNER SPECIFICS

A TV tuner must downconvert a 54- to 862-MHz RF signal to an IF (intermediate frequency), typically of 38 or 45 MHz; amplify the signal to a standard level using AGC (automatic-gain-control) circuits; and attenuate or reject all the signals that are out of the band of the channel you are tuning. A stronger signal may be immediately next to the signal of interest, making these tasks challenging. When the tuner encounters UHF (ultrahigh-frequency) signals as large as 700 MHz, the filtering function must have a high Q (quality) factor. Like quartz crystals, SAW filters have high Q factors, so they can pass one narrow frequency, and the response quickly rolls off, or attenuates. To achieve the same performance as that of SAW filters, some silicon-tuner manufacturers upconvert the lower-band signals to high frequency, filter them with high-Q silicon circuits, and then downconvert the filtered signal to IF. This double conversion works well, but it consumes more power than do other methods. Other companies use novel circuits and proprietary architectures to get their chips to work better than a can tuner.

Silicon tuners also have better noise performance than can tuners. "The problem with active filters is that high-Q circuits always have more noise," says Philip Karantzalis, a filter-application engineer at Linear Technology. As a result, tuner manufacturers must use clever designs to get high Q and low noise. IC-process improvements, such as spiral inductors, also help TV-tuner manufacturers get high-Q filtering into a chip without the benefits of SAW filters. IC-design tools and process improvements now allow IC designers to use bond wires and spiral metallization as inductors and to make on-chip high-Q circuits, leading to the recent vast improvement in the performance of PLL chips, silicon oscillators, and TV-tuner chips.

A TV front end has two important functions. The tuner function downconverts and amplifies the desired channel. The demodulator function creates the baseband analog or digital signal from the RF IF that comes from the tuner. The analog signal is a classic composite-video signal, and the digital channels usually demodulate to an MPEG (Moving Picture Experts Group)-2 digital bit stream (**Figure 4**). The demodulated signals

then go to an SOC (system on chip) that creates the LCD's pixel-drive signals and handles analog- and digital-audio signals. Melissa Chee, director of marketing at Fresco Microchip, notes that silicon-tuner manufacturers bring an overall system knowledge of how the silicon tuners and silicon demodulators work together. IC designers divide these blocks—but not

in a standard way. For example, Maxim, Entropic, and other companies make tuner ICs with no demodulator, Silicon Labs and Xceive include analog demodulation, and Fresco makes demodulator chips that work with tuner ICs (**Figure 5**). In yet another approach, some chip sets require an external tracking filter but integrate the tuner and both demodula-

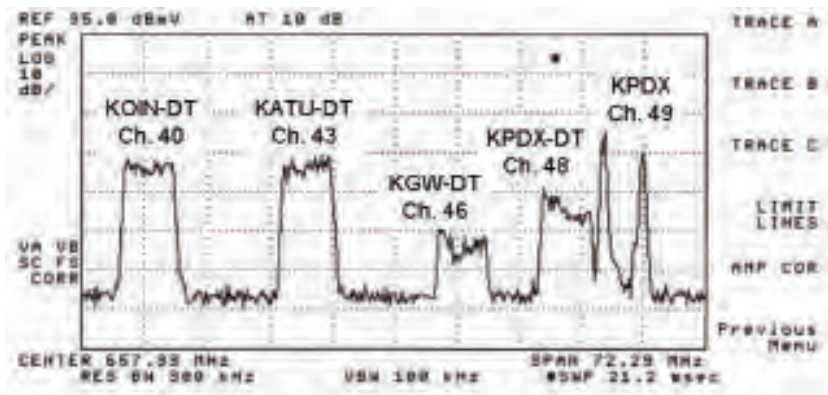


Figure 3 In this frequency-spectrum plot, channels 40 and 43 are strong digital signals. Channels 46 and 48 are weak digital stations that are either far away, low-power, or both. Channel 49 is an analog channel with significant energy at the edges of the band (courtesy Marvell).

tors into one IC. TV manufacturers evaluate each of the systems with combinations of various vendors using proprietary test screens. TV vendors, meanwhile, jealously guard their test patterns because they don't want their competitors to know how they design the TV for certain scenes and action. Be prepared for TV manufacturers to put you "through the wringer on analog performance," says Xceive's Mathews.

Vendors take an interesting approach in the processes they use to create silicon TV tuners. For example, Xceive and Maxim use a BiCMOS (bipolar-complementary-metal-oxide-semiconductor) SiGe (silicon-germanium) process because it yields higher performance and intrinsically better noise performance, especially at higher frequencies (**Reference 2**). Silicon Labs and Marvell, however, offer tuner ICs using a conventional CMOS process (**Figure 6**). Neither company reveals the specifics of the process, but a CMOS process is typically less expensive per square millimeter than a BiCMOS process. The drawback is that a CMOS IC requires many parallel tran-

sistor circuits to produce increased linearity. Using bigger transistor structures, biased at higher currents, yields better noise figures. TV manufacturers don't care about the process as long as the parts meet performance and cost goals. Vendors of parts using SiGe processes may announce CMOS parts, but they must determine the die-cost-versus-die-size trade-offs that recommend one process over another (**Reference 3**).

Sensitivity and selectivity are the fundamental specifications of tuners. Sensitivity indicates how faint an input signal can be for the receiver to successfully receive it. A sensitive tuner chip requires a low noise factor in the RF front end (**Figure 7**). The selectivity spec of a radio is a figure of merit relating to how well a tuner chip can receive one channel without disturbance from a nearby channel or intentional interferer, such as an FM-radio station. TV engineers often express selectivity as near-channel blocking. Because these signals can have larger amplitude, it makes broadcast-TV tuning a demanding engineering task.

Linearity is another important specification in silicon-tuner chips. Because analog, digital HD, and cable QAM (quadrature-amplitude modulation) all depend on accurate representation of the signal's envelope, the chip must linearly amplify the RF signal. Linearity is also essential for handling another problem: A tuner circuit must receive weak signals even though stronger signals from nearby transmitters are close to the channel you select. According to Eric Garlepp, senior product manager at Silicon Labs, linearity in a TV-tuner

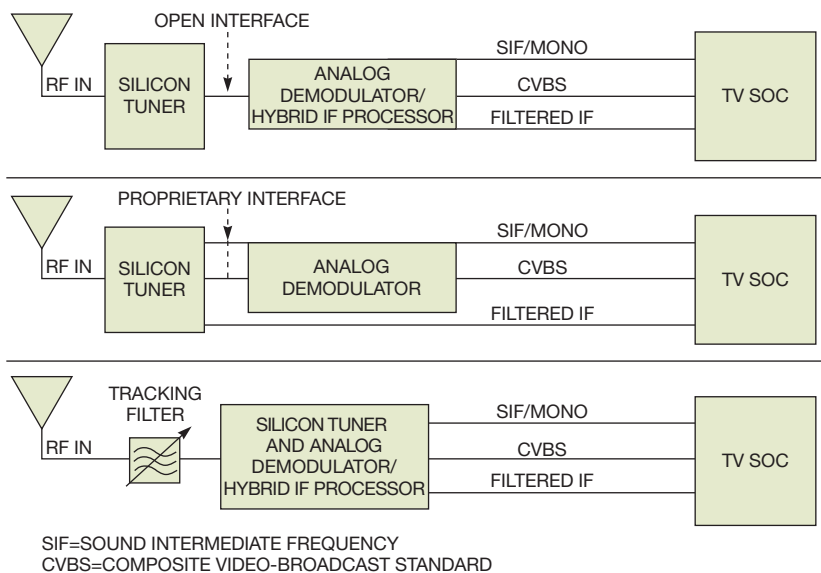


Figure 4 Silicon demodulators can work with pure tuner chips, such as those from Entropic and Maxim (top). NXP makes chip sets that use a separate analog demodulator (center). Silicon Labs and Xceive incorporate the analog demodulation into their tuner chip (bottom), although they typically do not need a tracking filter. Silicon Labs' product does require a balun (balanced-unbalanced) transformer in front of the chip, whereas Xceive's does not. All of the schemes send SIF, CVBS, and the signal IF to the TV SOC (courtesy Fresco Microchip).

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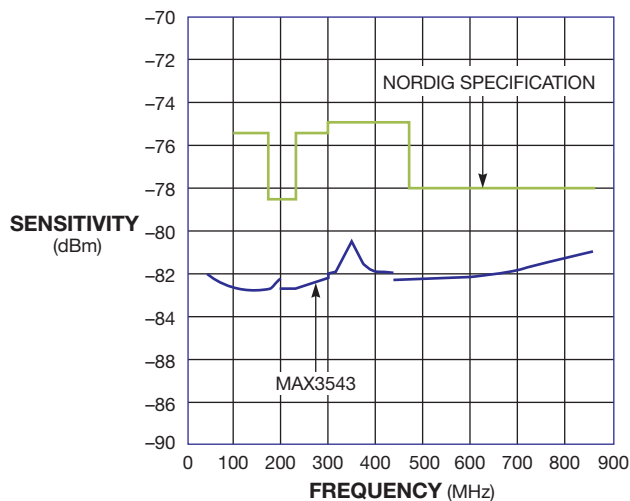


Figure 5 The SiGe process in this tuner IC allows it to achieve sensitivity performance far beyond the NorDig digital standard (courtesy Maxim Integrated Products).

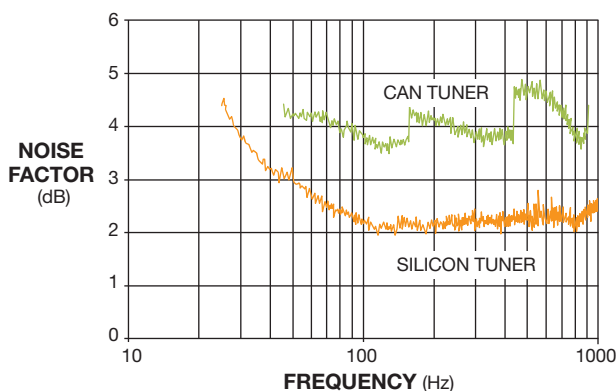


Figure 6 CMOS tuner ICs can produce lower noise than can or SiGe tuners. The upturn in the lower plot at low frequencies is the inherent flicker noise typical of all amplifiers. It is not relevant below 54 MHz, the lowest TV-channel frequency (courtesy Marvell).

chip involves two aspects: inherent broadband linearity to cope with large signals across the bandwidth and linearity after filtering out the 6-MHz band, which is important for accurate signal reproduction and picture quality. It becomes more difficult to achieve adequate performance as the received frequencies approach 700 MHz. At frequencies as low as 54 MHz, however, citizens-band-radio transmitters provide a large signal. You must prevent this signal from mixing into the TV band because that band includes nonlinear RF circuitry. Silicon Labs' CMOS tuner IC achieves the linearity and SNR (signal-to-noise ratio) for TV reception. Other important specs for silicon-tuner chips include image rejection, power, size, color fidelity, second- and third-intercept points, RF and IF AGC loops, voltage noise, and power.

As you can see, silicon tuners for TVs have one of the most difficult tasks of any mixed-signal IC. They must work at frequencies as low as 54 MHz without external coils or inductors, as high as 862 MHz for broadcast TV, and as high as 1 GHz for cable systems. They must handle both analog- and digital-modulation schemes and schemes that depend on regional variations. In addition to the broadcast-TV-modulation standards, silicon ICs must also handle cable-modu-

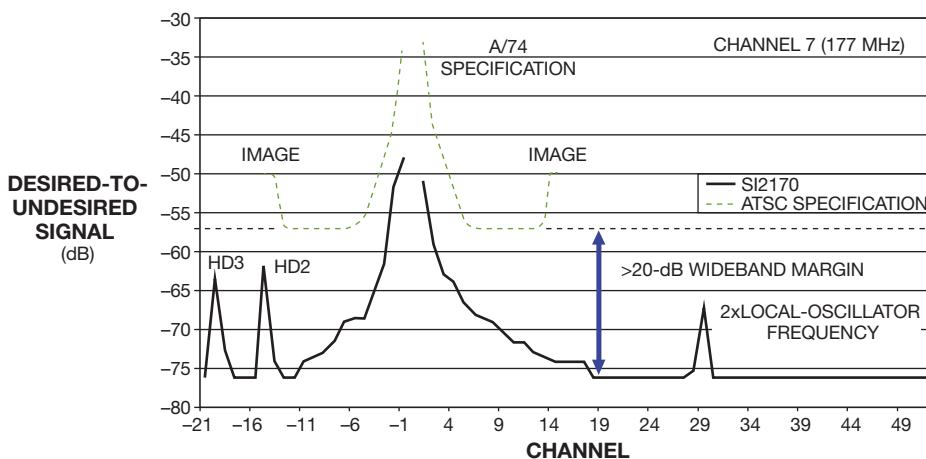


Figure 7 Selectivity, or near-channel blocking, is a critical spec for terrestrial TV. Clever IC design allows this silicon-tuner manufacturer to far exceed the ATSC-A/74 requirement (courtesy Silicon Labs).

lation standards, such as 256QAM (256-point QAM). The input signals to a tuner IC also can have signals of only -80 dBm next to signals of -20 dBm—even higher in locations near transmitter towers. To meet consumers' expectations, silicon tuners and demodulators deliver performance exceeding that of can tuners, and they fit into the small spaces of modern slim-LCD TVs.

"Any sufficiently advanced technology is indistinguishable from magic," said the late Arthur C Clarke, a British science-fiction author, inventor, and futurist, in 1961. The high performance and low cost of silicon TV-tuner ICs will soon be performing magic in a large proportion of the 500 million tuner systems people buy every year. **EDN**

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You can reach
Technical Editor
Paul Rako at
1-408-745-1994
and paul.rako@cancom.com.

