

## 16.3: Silicon TV Tuners Will Replace Can Tuners as Transistors Replaced the Vacuum Tube

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**Abstract:** *While the evolution of television receivers has accelerated on many fronts in the last decade, fully-integrated silicon tuners design has lagged this evolutionary wave. The silicon TV tuner is now perfected and will rapidly replace tradition Can tuners, just as transistors replaced vacuum tubes during the mid-1960s.*

**Keywords:** television; tuner; Can tuner; silicon tuner; integrated tuner; TV tuner; Xceive.

### Introduction

The past decade delivered an unprecedented and multi-front evolution of television broadcasts and receivers. These advances include stereo audio, HDTV, flat-screen technology using LCD and plasma displays, and television receivers integrated into personal computers.

The ultimate goal for television receivers is a fully integrated solid-state TV with a flat-screen LCD or plasma display. While significant progress has been made toward this goal, tuners have lagged the evolutionary development.

This lag however is in the process of changing. Demand for smaller and lower-power TVs, flat-screen miniaturization, and even government standards are driving the development of silicon tuners to the razor's edge. In fact, the FCC has set standards requiring all new televisions to incorporate digital tuners within the next two years.

### Tuner History

The traditional tuner design for decades has been the "Can" tuner...appropriately named as they are housed in metal enclosures to minimize RF interference and crosstalk.

*Can Tuners:* Despite this long history of use, Can tuners have some major deficiencies. First, the requisite use of tunable and fixed coils has virtually dictated discrete transistor designs for the tuner. This results in poor temperature characteristics and a physically large, power-hungry module – some as large as 2" x 4".

Perhaps the primary deficit with Can tuners is that each must be tuned individually as part of the manufacturing process. Not only is this a time-consuming step, but the tolerance of the passive components results in a relatively broad acceptance standard for Can tuner quality control.

Still, the Can tuner has ubiquitous presence in televisions from small CRT-based TVs all the way up to the very large, flat screen models.

*Silicon Tuners:* The silicon tuner is poised to unseat the Can tuner in virtually all applications, in the same vein as transistors replaced vacuum tubes. Silicon tuners have the potential to offer a number of advantages compared to Can tuners.

First, highly-integrated silicon tuners are much easier to manufacture, and no tuning is required. This reduces the overall cost of the tuner. Second, the tuner can be made extremely small compared to the Can tuner because of the high level of integration.

Another important advantage of silicon tuners is that a single tuner can receive television signals using *any* of the several worldwide transmission standards. This means that an international manufacturer need only stock a single, meets-all-standards tuner, instead of one or multiple Can tuners for each disparate standard.

Other advantage of silicon tuners over Can tuners include:

- Integrated analog *and* digital tuners
- Multiple tuners in the same package for picture-in-picture and other applications
- Greater reliability
- Superior thermal stability
- Tighter quality control standards
- Quicker channel lock: ~5 ms vs. ~150 ms.

These advantages, coupled with recent IC design rules and techniques have enabled practical silicon tuners. New IC techniques being used include enhanced BiCMOS process, Silicon-Germanium (SiGe) transistors, and 0.18  $\mu$  design rules. This design evolution, when added with government dictates, will result in a rapid and universal transition to silicon tuners.

### Overcoming Physical and Integration Problems

The fact that silicon tuners have lagged virtually all other television developments clearly identifies this technology as having difficult challenges to realize a producible tuner. And indeed, a number of difficult hurdles had to be crossed before a practical, manufacturable silicon tuner could be produced at a reasonable cost.

*Necessity for tuners:* An obvious question at this point might be 'why are tuners even necessary? Why not do it all digitally?' Ideally, the tuner would be produced with a simple (in concept...extremely complex in design) Analog-

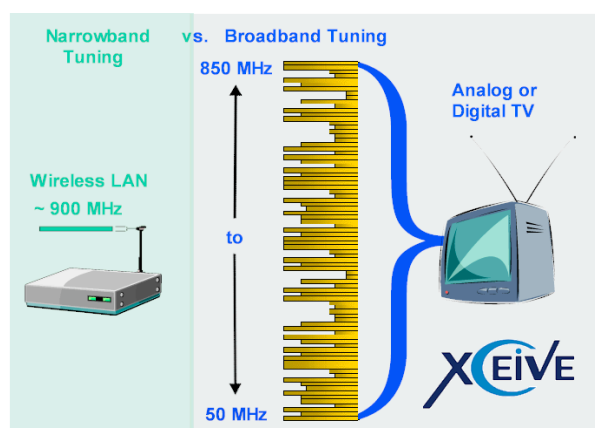
to-Digital (A/D) converter. The analog television signal would be directly converted to a digital data stream without tuned circuits, including input and output filtering.

Even a cursory look at television bandwidths reveals the magnitude of the A/D problem to be overcome. The Nyquist Theorem requires nearly *two billion* samples per second using an A/D converter to sample the analog input signal across the entire 860 MHz television bandwidth, and with enough bits of resolution to reproduce an HDTV-quality picture. A/D converters with that sampling rate and resolution currently cost in excess of \$1,000 each [1].

This extreme sampling speed and resolution is necessary because of the very large bandwidth associated with broadcast TV. However, if a tuner is used, this broadband input can be tuned to a single, baseband signal that is significantly simpler to process with A/D devices.

**Broadband Requirement:** The tuner simply pushes the difficulty of handling this very large bandwidth from the A/D converter to the tuner; and problems dealing with the large bandwidth still had to be solved.

Most receiver designs cover a relatively small frequency range. A couple examples include 802.11b wireless LANs and cellular phones. The tuner in a cellular phone tunes about 500 kHz of bandwidth. A television receiver, by comparison, must tune about 860 MHz...three orders of magnitude more bandwidth.



**Figure 1. Narrowband vs. Broadband Tuning**

The extreme difference in bandwidths results in many proven narrowband design techniques not transferring to

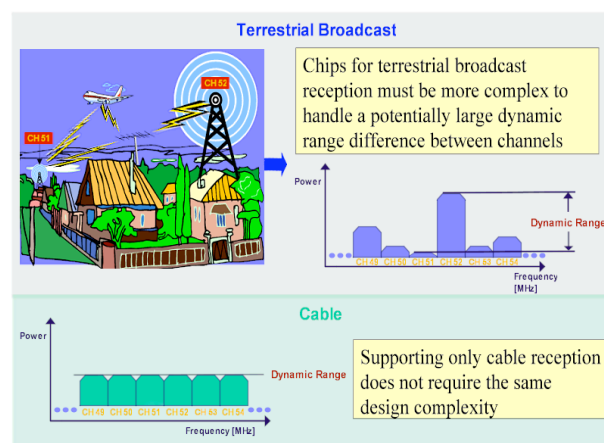
television's wideband requirements. Figure 1 illustrates the magnitude difference in the two receiver applications.

New techniques have replaced traditional analog designs to facilitate broadband capability with new silicon tuners.

**Dynamic Range:** An even bigger obstacle was designing highly integrated circuitry to accommodate the enormous dynamic range required for broadcast television signals. Signals reaching the receiver are affected by the variable and arbitrary distance from the transmitter. It's not unusual to have signal strength variations of several-thousand-fold.

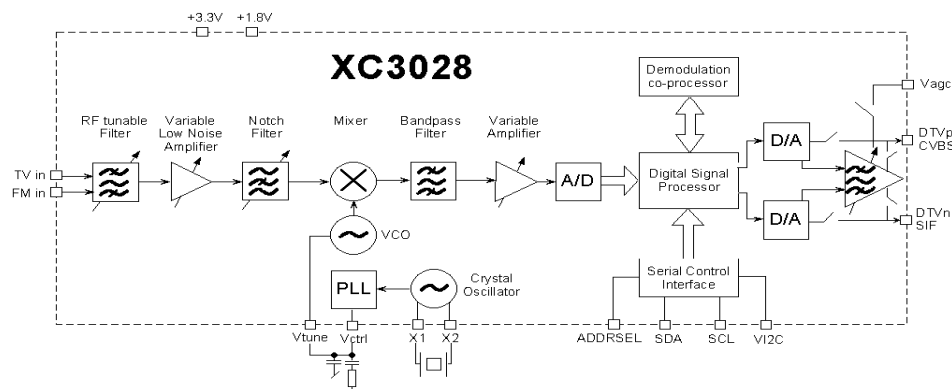
Other factors affecting the received signal integrity include environmental influences on signal propagation and multipath due to reflections.

Cable signals are of relatively uniform signal strength and integrity, which allowed some early silicon tuner designs to work in that environment. However, only very recently have silicon tuners achieved the dynamic range required to reliably reproduce a quality television picture and audio (see Figure 2). Silicon tuners, such as Xceive's XC2028 and XC3028 have a dynamic range of 80 dB, more than enough to handle the challenge of broadcast signal quality.



**Figure 2. Broadcast Signals vs. Cable Signals**

**Sensitivity:** The large dynamic range also demands that the receiver be extremely sensitive to receive very weak signals – yet not prone to front-end overload caused by very strong signals. New active filter designs have produced the sensitivity required, but immune to overload induced by strong, local signals. This results in a superior sensitivity of  $-83$  dBm or better.



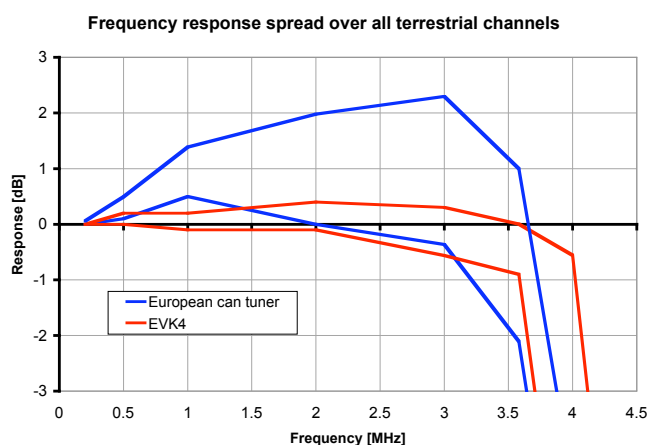
**Figure 3. Block Diagram of Xceive XC3028 Analog and Digital Silicon Tuner**

### Silicon Tuner Solutions

Several manufacturers have full or partial silicon tuner solutions. Leading the way is Xceive Corporation, who became the first company to produce a one-design-fits-all-TV-standards analog tuner ICs. The XC2028 is a complete analog RF-to-baseband tuner, and the XC3028 is a complete analog and digital RF-to-baseband tuner.

*Silicon Tuner Design:* Both Xceive chips are based on a systematic, iterative design approach to optimize highly integrated functions in traditional and non-traditional ways. The basic block diagram of the silicon tuner is shown in Figure 3. This design is significantly more complex than a Can tuner, incorporating substantial digital processing circuitry in addition to the RF signal conditioning and tuning front end. The XC3028 integrates in a single IC:

- Wideband tunable filters
- Image rejection filter
- Programmable channel filter
- Wideband Voltage Controlled Oscillator (VCO).



**Figure 4. Superior tolerance of silicon vs. Can tuners**

*Performance:* Not only are silicon tuners a significant improvement over Can tuners in many areas, they also have a much tighter QC acceptance tolerance due to eliminating high-tolerance passive components. Figure 4 shows the frequency response of two individual Xceive silicon tuners vs. two high-quality Can tuners. Note how little variation exists in the Xceive tuners.

To further illustrate this, several Can tuners were tested and their response plotted. These appear in Figure 5 on the following page. Note that 1 to 2 dB of variation across the frequency range is normal. In addition, each tuner has a slightly different transfer characteristic, resulting in slight variations in the picture quality of the completed television receiver.

Xceive extensively analyzed the sources of non-linear signal degradation to further enhance dynamic range over the full television bandwidth. Each non-linear degradation was cancelled with an inverse-acting non-linear source.

Another advancement is that no external Low Noise Amplifier (LNA) is required with Xceive tuners. Other solutions may require external LNAs to achieve the -83 dBm sensitivity of the Xceive design (ATSC signal).

*Fabrication:* A final factor in physically being able to integrate the full tuner function was the fabrication of the IC itself. The fabrication took advantage of improvements in the BiCMOS process as well as benefiting from small, 0.18  $\mu$  architecture. Both factors contribute to both speed and low power consumption.

Perhaps even more important in the fabrication process is the use of SiGe transistors. These active devices are faster, more power efficient, and importantly have improved noise characteristics compared to traditional silicon transistors.

Incorporation of this leading edge technology significantly impacts the ability to incorporate the Xceive tuner in a package smaller than a dime.

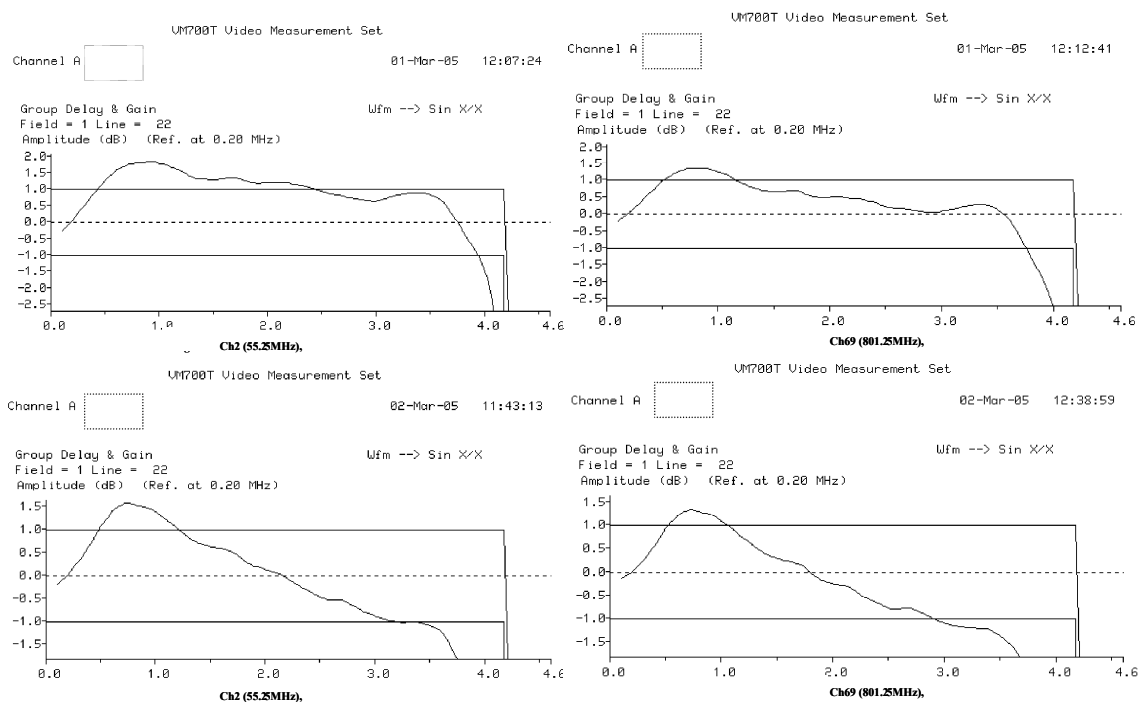


Figure 5: Transfer Characteristics of Several Can Tuners

## Applications

There are many obvious applications for silicon tuners – they will clearly replace Can tuners in virtually every consumer television set within just a few years. Beyond that, however, the reduction in size and power requirements open a new and diverse universe of applications.

*Tuners for PCs:* The demand for television receivers integrated with PCs already exists. New silicon tuners will make them significantly more practical. For example, Compro has designed a USB 2.0 compatible TV receiver based on the Xceive XC3028. This tiny device (VideoMate U880) is about the same size as a USB Flash drive.

*Multiple Tuners:* Another existing market that will get a major boost from silicon tuners is Picture-In-Picture. Because of the low-power design and strong adjacent-channel interference rejection, multiple silicon tuners can easily be incorporated into a single design, allowing instant access to several broadcasts.

*Cellular Phone and PDA:* The size of silicon tuners, with their stingy use of battery power, allow for the first time to have television reception in a cell phone or PDA.

## Conclusion

The entire television broadcast industry has been in the midst of sweeping changes over the last 10-15 years. One of the last components to experience this sweeping evolution is the tuner.

Only recently have tuner designs caught the innovation wave. Newly designed silicon tuner chips, integrating the full tuner function, are now available and have performance, packaging, and power advantages over the traditional Can tuners.

Xceive Corporation was the first to introduce a single tuner chip from RF-to-baseband that can universally work with any worldwide television broadcast standard. They have both analog, and analog plus digital tuner chips available.

## References

1. Atmel Corporation, "10-bit A/D converter soars to 2.2-GHz," Planet Analog, <http://www.planetanalog.com/printableArticle.jhtml?articleID=164301312>.