Featuring

CMOS Silicon Tuners for Large-Screen TV Sets

- SAW filter no longer required due to the adoption of a low IF system
- Low-noise/Low-distortion RF amplifier circuit
- Built-in tracking filter improves interference rejection performance
- Low phase noise PLL circuit achieves high reception sensitivity
- Reduction of the spurious radiation that could degrade picture quality during analog broadcast reception
- Low power

As the trend towards even thinner home TV sets progresses, the need for further miniaturization in the tuner module, one of the largest functional components in a TV set, is increasing.
At the same time, the number of functions provided by TV sets continues to increase, with multi-screen display and recording capabilities, such as hard disk and Blu-ray disc drives, now being common. As a result, the number of models that include multiple tuners is increasing, thus making the need for further miniaturization in tuner modules even stronger.
The high-functionality silicon tuner IC, which can replace the CAN tuner (see photograph 1), which is implemented with many discrete components such as coils and variable capacitance diodes (varactor diodes), is now seen as the desired solution for implementing miniature tuner modules. Although silicon tuner ICs are now used in cellular phones for One Seg small screen TV broadcast reception to achieve the required ultraminiaturization, when it comes to use in TV sets, creating a silicon tuner IC that can provide the performance required to achieve high picture quality and the performance to satisfy the requirements of the many TV broadcast standards used around the world is an exceedingly difficult technological problem.
Sony has now created, using a CMOS process, a silicon tuner with superlative sensitivity and picture quality performance for use in large-screen flat panel TVs. This device makes it possible to design a miniature tuner in an area 1/10 or less that of existing Sony tuners.
This CMOS silicon tuner achieves sensitivity and picture quality performance equivalent to or better than those in current high-performance tuners used in large-screen TV sets. Sony's TV tuner module and IC design experts held many discussions to overcome the challenges posed by this difficult technology development and succeeded in developing the industry's first silicon tuner that can receive both analog and digital broadcasts. Sony has also announced the "BRAVIA" series of LCD TVs that use this IC.

*: "BRAVIA" is a registered trademark of Sony Corporation.

What is a Tuner?

A tuner is one of the basic building blocks that makes up a TV set, and at least one is included in every TV set.
TV sets, as one realizes from the origin of the abbreviation (television), receive broadcast signals sent from distant broadcasting stations, extract the video and audio signals from the broadcast signal waveform, and then display

Photograph 1 Example of an Existing Tuner Module

The marked section corresponds to the silicon tuner Sony has developed.

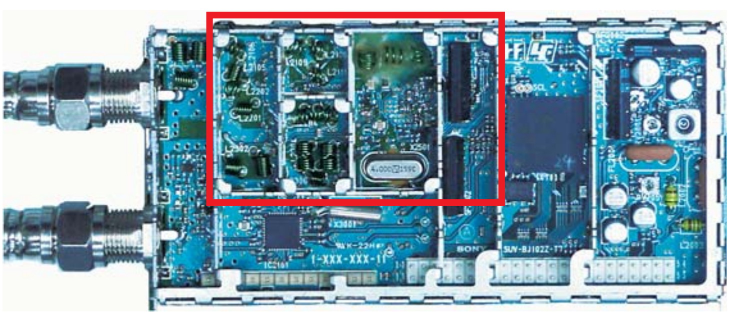
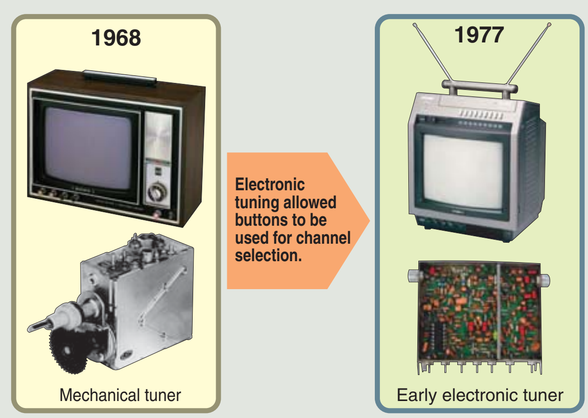


Figure 1 From Mechanical Tuners to Electronic Tuners



The use of electronic tuning in color TVs was accelerated by the development of digital tuning control ICs, the varactor diode, and MNOS nonvolatile memory.

the video on an LCD screen while outputting the audio from speakers.

The role of the tuner is to "tune" (i.e. select) the channel that the user wants to watch from the many broadcast waveforms that reach the TV set after being collected by the home antenna.

Functionally, a tuner could be called a "variable frequency filter". The range of frequencies received, however, is extremely wide: from 50 MHz to 800 MHz, and the tuner must extract an arbitrary 6 MHz band from this range. Furthermore, the suppression of adjacent channels must be at least 50 dB. Another problem is that the TV set receives signals from stations both near and far with power levels ranging from 1 μV to a few volts, and must amplify these signals without distortion.

To make the frequency variable in this manner, at the start of TV broadcasting, tuners were constructed by switching a coil contact or using a variable capacitor. (See figure 1.) At that time, the channel selector was a dial that was turned, and was also called a mechanical (or rotary) tuner.

The varactor diode had been developed by the latter half of the 1970s and electronic tuning became practical. This made possible the current form of the TV in which the channel is selected by pressing buttons or using a remote control.

In the 30 years since then, although there have been some advances in tuner modules, such as certain sections being implemented as ICs, there has been no change in the basic form.

In this article, we introduce the points that allowed the extremely technologically difficult tuner function to be implemented using solid state devices and what problems had to be resolved to achieve that.

Implementing the Functions Required in a Terrestrial TV Tuner in a Single Chip

As we mentioned previously, tuners use the superheterodyne method, in which the frequency is converted and then passed through a fixed filter to amplify the weak signal that comes from the antenna, control the gain, and implement a variable frequency filter.

Sony has now integrated the circuits required to form a superheterodyne receiver on a single chip: an RF amplifier, an RF filter, a frequency conversion mixer, a frequency conversion local oscillator, a frequency control PLL, an IF (intermediate frequency) filter, and an IF amplifier. (See figures 2 and 3.)

Features of this Tuner

■ SAW (Surface Acoustic Wave) Filter no Longer Required due to the Adoption of a Low IF System

To select only the desired channel, TV tuners required a highly selectivity SAW filter in the tuner output block. Although SAW filters have superlative selectivity, their large package has been an impediment to tuner miniaturization. Furthermore, since the signal loss in the SAW filter is large, the power consumption in the driver amplifier required to drive the SAW filter is proportionately large.

A low IF technique is adopted in the Sony CMOS silicon tuner to make it possible to implement the channel selection filter on the chip itself. Although it was difficult to integrate this filter on the chip with the intermediate frequencies used previously (57 MHz in Japan), if a low IF is used, a high selectivity low loss active filter can be implemented relatively easily. Also, in the demodulator IC block in the following stage as well, this approach has the advantage that it is easier to get good performance from the A/D converter if the frequency is lower.

Figure 2 Block Diagram

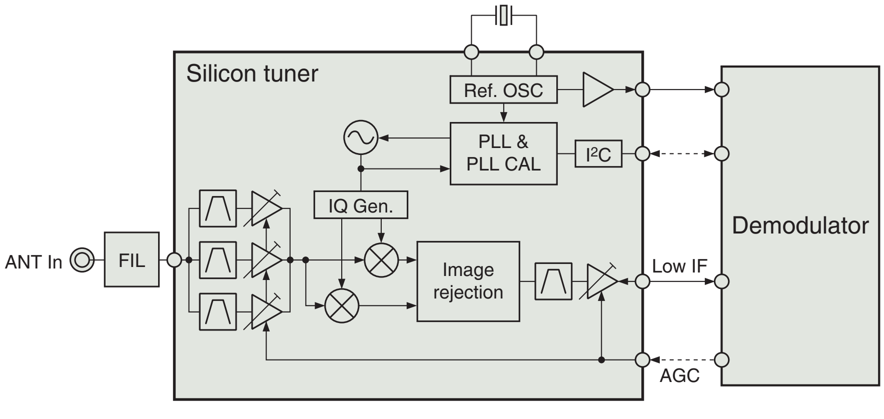
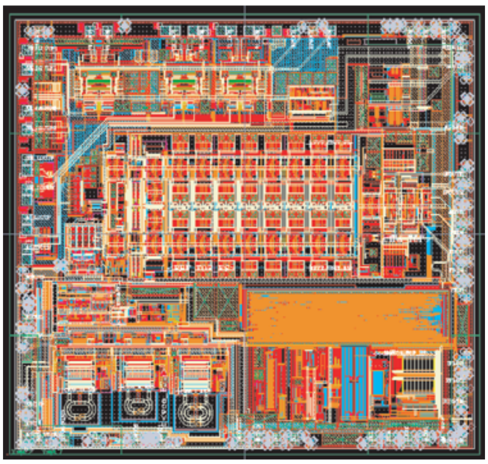


Figure 3 Chip Layout



The low IF technique is said to have just one aspect, its image rejection characteristics, in which it is inferior to other methods. While it is common to reject images with a filter located in the previous mixer stage in earlier IF systems, it is extremely difficult to reject images using an actual filter, since the image interference corresponds to the channel next to the desired channel. In Sony's CMOS silicon tuner, an image canceling circuit is used for image rejection. The image interference rejection performance is determined by the relative precision of the IC internal signal. (See figure 4.) The signal relative precision requirement, calculated from the image rejection performance, required in a TV tuner is 0.03%. This is a value that is about two orders of magnitude higher than the precision that can be achieved with normal IC processes. To achieve these rigorous specifications, Sony optimized the circuit structure and design specifications, and strove for thorough symmetry down to the finest parts of the layout, and achieved fully adequate image rejection characteristics.

■ Built-in Tracking Filter to Improve Interference Rejection Performance

In existing TV tuner modules, it was necessary to have tracking filters that use air core inductors and varactor diodes at the previous and following stages of the input amplifier to exclude interfering signals from other broadcast waveforms and other sources. There are, however, sample-to-sample variations in the characteristics of air core inductors and to achieve optimal characteristics at all times, it was necessary to adjust the winding spacing of those coils each time by hand. Therefore high skill levels were required of the staff performing those adjustments in the mass production process. In this CMOS silicon tuner, however, surface mounting chip inductors with comparatively low sample-to-sample variations and IC internal variable capacitors are used in the tracking filter. Although it is still necessary to correct for the sample-to-sample variations in the filter characteristics as it was with air coil tuners, this adjustment is performed by switching the IC internal variable capacitors using control data. Therefore it is possible to automate this process with software and other tools, and stable tuner characteristics can be acquired without depending on the skill and experience of the employees.

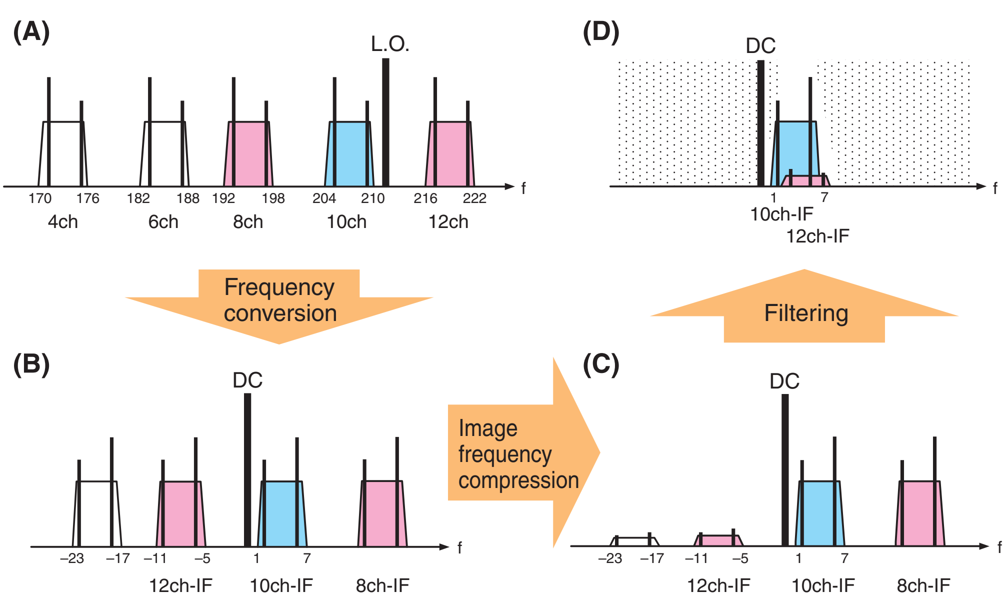
■ Low Noise/Low Distortion RF Amplifier Circuit

In the CMOS silicon tuner, an extremely high ability to withstand interference is required in the input block RF amplifier to make it possible to eliminate the air core filter, which has superlative selectivity characteristics. Sony took full advantage of the limited supply voltage and incorporated a wealth of distortion characteristics improving ideas in this CMOS silicon tuner. As a result, this device achieves the same ability to withstand interference as existing coil tuners, despite using a 2.5 V supply voltage. This tuner can produce clear video even in a poor signal environment in which the tuner is surrounded by multiple broadcast towers.

■ Low Phase Noise PLL Circuit Achieves High Reception Sensitivity

Extremely high signal purity (low phase noise) is required in the local oscillator used in TV tuners to achieve high quality video. In existing TV tuners, such characteristics are achieved by providing a resonant circuit with an extremely high Q that, like the tracking filter, uses an air core inductor and a varactor diode. In this CMOS silicon tuner, Sony adopted an ultrahigh frequency oscillator and a high-speed divider

Figure 4 CMOS Silicon Tuner IF Signal Processing



1. The local oscillator frequency is set as shown in figure 4(A) to match the desired channel (in this case, channel 10 in Japan).
2. The signal is passed through a mixer circuit and frequency converted to the intermediate frequency. Figure 4(B) shows the resulting frequency relationship.
3. If used in this manner, the channel 12 IF in complex region will be aliased and overlap with the channel 10 IF.
   To resolve this, image frequency components are suppressed by an image canceller as shown in figure 4(C).
4. Just the desired channel (the channel 10 IF) is extracted by the IF filter. As shown in figure 4(D), although the channel 12 IF is overlaps this signal, it has been suppressed to a level that can be ignored as an interference signal.

circuit to implement a local oscillator with superlative phase noise characteristics while eliminate in special components such as the air core inductor. By combining a PLL circuit capable of dividing by fractional parts, called a fractional PLL, with this local oscillator, Sony achieved both the high resolution of the 31.25 kHz step size required in TV tuners and low phase noise. Although conventional fractional PLL circuits emit spurious radiation characteristic of fractional circuit operation, Sony diffused this spurious radiation by combining a $\Delta\Sigma$ modulator in this CMOS silicon tuner so that the signal quality is not degraded.

Reduction of Spurious Radiation that could Degrade Picture Quality During Analog Broadcast Reception

One characteristics that is critical for analog broadcast reception and is particularly difficult to design for is spurious radiation. The local oscillator and crystal oscillator that are included in the tuner circuit always incorporate a high-frequency component, and if that component leaks into the tuner input or output, it can degrade the picture quality of a specific broadcast channel.

Sony positioned this issue as one of the most critical for the CMOS silicon tuner from the start of this development effort, and proceeded with development while focusing on the spurious radiation problem. To determine the amount of spurious radiation appearing in a signal, in addition to the amount of spurious signal generated by the source and the degree of sensitivity of the circuits that are affected by that signal, it is also necessary to know the amount of propagation over the transmission paths that connects these components. Estimating this propagation level is, however, one of the most difficult points when designing for low spurious levels ("spurious design"). Sony constructed a spurious design environment that uses a noise analysis tool for CMOS silicon tuner design, and designs chips with an even higher level of precision. (See figure 5.) Sony achieved a spurious level that is more than satisfactory as a TV tuner specification by, based on the results acquired from that tool, inserting effective filters in the power supply, adding guard bands, and other measures.

Future Developments

As we have discussed in this article, Sony has succeeded in replacing the TV tuner, which used air core inductors and varactor diodes as its main components and has remained largely unchanged for the last 30 years, with a semiconductor technology based silicon tuner. It is commonly thought that using the BiCMOS process, which has superlative frequency characteristics, would present lower technological hurdles and make it easier to achieve success in this development. However, implementing a silicon tuner in the same CMOS used for the signal-processing ICs, would itself be a large step forward, both for reducing costs in the future and achieving a "one-chip TV", which is a dream of IC designers.

In the future, Sony will continue to make improvements to the CMOS silicon tuner introduced here, for example reducing power consumption (see figure 6) even further. In particular, Sony will develop and apply these technologies to create environmentally friendly TVs that do not consume larger amounts of resources.

Figure 5 Spurious Reduction Design Using a Noise Analysis Tool

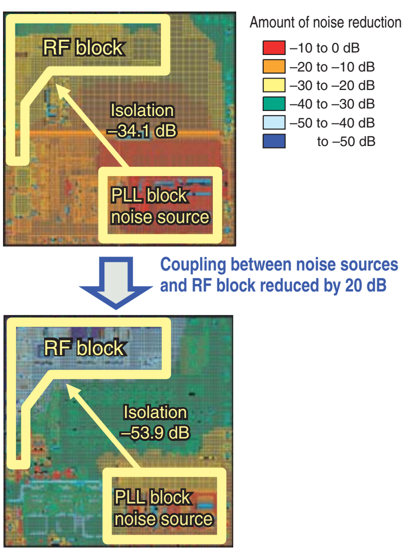
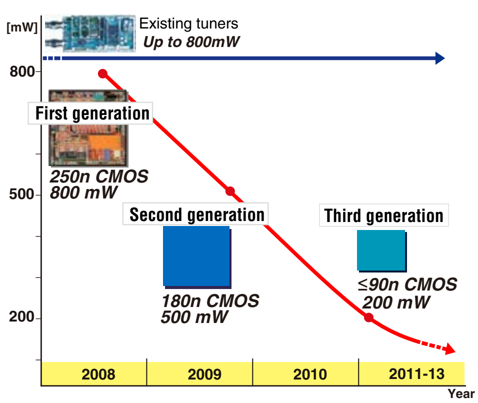


Figure 6 Trends in CMOS Silicon Tuner Power Consumption



Photograph 2 Sample CMOS Silicon Tuner Based Tuner Module