A SAW RESONATOR STABILIZED OSCILLATOR FOR A CATV SET-TOP CONVERTER

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Abstract

A SAW resonator stabilized oscillator for a CATV set-top converter has been designed and is in high volume production. The SAW oscillator, operating at one of four frequencies near 680 MHz with a long-term stability of ± 10 kHz, is the 2nd LO in a dual conversion, 54-channel converter. The oscillator uses a 0°, two-port SAW resonator in conjunction with a dual-gate MOS Field Effect Transistor. Tuning to exact frequency is accomplished by compression or expansion of two air wound inductors. This oscillator has significant performance advantages over conventional L-C oscillators, and significant cost advantages over crystal multiplier, frequency synthesizer, and AFC designs.

Introduction

The addition of sync-suppression scrambling to an existing design CATV converter (Figures 1 and 2) imposed higher frequency stability requirements which could not be practically met by the existing circuitry. A high-stability, retrofit 2nd LO was required in order to meet performance and reliability goals.

The primary design considerations for this oscillator were:

1. Low cost.
2. Small size(1"X1.5" circuit board).
3. High stability(± 50 kHz due to all causes).
4. Quick and easy tuning.
5. Output level approximately 0 dBm.
6. Operation at one of four discrete frequencies: 674.0 MHz, 675.25 MHz, 680.0 MHz and 681.25 MHz.

A number of approaches were considered. Among them were temperature-compensated L-C oscillators, AFC feedback, and crystal multipliers. None of these were comparable to the SAW resonator stabilized oscillator when cost, size and performance were considered. The disadvantages of the SAW oscillator are: 1) that four SAW devices must be stocked (instead of full coverage by a coarse frequency adjustment, as with AFC) and consequently, four types of converters must be manufactured and stocked; and, 2) at the time, UHF SAW resonators suffered credibility problems, having never been used in high-volume production previously. It is believed that disadvantage #2 has been eliminated.

SAW Resonators

SAW resonators (Figure 3) are similar to SAW filters in that they consist of a pair of interdigital transducers on a piezo-electric substrate separated by some distance. What differentiates them is the series of reflectors that are spaced one-half wavelength apart, giving rise to a sharp resonant peak in the amplitude response and the rapid change in phase as a function in frequency that makes the device useful in stabilizing oscillators.

One-Port vs Two-Port

By proper connection of bonding wires, a one-port SAW resonator can be created which exhibits a series resonance at a single frequency much like a quartz crystal. Circuits using this type SAW device were rejected as impractical due to tuning difficulty. The circuits using two-port devices were an early favorite.

SAW Resonator Specifications

The specifications that were developed for the two-port SAW resonator are listed below.

1. Center Frequency: 673.8 MHz, 675.05 MHz, 679.8 MHz, 681.05 MHz.
2. Center Frequency Accuracy: ± 150 kHz.
3. Turnover Temperature: $65^{\circ} \pm 30^{\circ}$C.
4. Frequency Drift/Aging: Less than 50 kHz drift from original center frequency from $+15^{\circ}$ to $+55^{\circ}$C for 3 years.
5. Insertion Loss (50 ohm system): Less than 14 dB.
6. Unloaded Q: Greater than 2,000.
7. Spurious Responses (50 ohm system): -10 dB Max.
8. Phase: 0°.
9. Input/Output Capacity: 1.2 ± 0.25 pF.
10. Package: 3-lead TO-5, 3rd lead case ground.
11. Power Degradation Threshold: All specifications met after application of +15 dBm matched power to one port (other port shorted to common) for 5 minutes @ 25°C.
12. Phase slope: Phase slope shall be steeper than -2°/100 kHz from 675.15 to 675.30 MHz.

There are 4 specifications that this device does not have in common with quartz crystal specs:

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1. Phase Shift can be 0° or 180° at resonance, depending on bonding.
2. Turnover Temperature is the temperature at which the highest resonant frequency is reached in the parabolic temperature vs frequency curve. This curve is characteristic of ST-cut quartz resonators.
3. Power Degradation Threshold is the power level at which the acoustic excitation becomes high enough in amplitude that metal migration begins to take place in the interdigital electrode fingers . The externally observable effects of this are an increase in loss, the appearance of secondary resonant peaks, and the appearance of flats and bumps in the normally S-shapped phase slope. In an oscillator, this will result in a steady downward drift in frequency.
4. Phase slope is specified because spurious propagation modes can exist in SAW resonators, giving rise to phase slope changes. If the phase slope becomes zero or goes positive, a forbidden region is created in which an oscillator cannot operate. Instead, it will hop from one frequency to another (about 50 kHz in this case) when tuned.

Oscillator Circuit Design

The oscillator configuration now in use (Figure 4) evolved after the trial and evaluation of several alternative designs. Determinations which were made early on were that space was available only for a very small SAW device, and that only circuits using one active device need be considered due to size and cost constraints. SAW devices were custom made to frequency and the work began.

Bipolar Transistor Circuits

Figure 5 shows the equivalent circuit of a typical SAW resonator. Loaded Q goes up as termination impedance goes down. Thus using a low impedance transistor such as a bipolar resulted in reduced tuneability. Networks which would match the transistor to the SAW device were not economically realizable.

FET Circuit

Field effect transistors typically have input and output impedances with higher real parts than bipolar transistors. Thus a simpler network is acceptable for matching SAW device terminal impedance. This keeps Q down and tuneability up. The oscillator presently in use uses a dual gate MOSFET.

The Final Circuit

The oscillator presently in production uses a dual gate silicon MOSFET (Figure 6). A resistor divider network biases both gates while a source resistor provides DC stability. The resistors were selected to optimize the RF levels in the oscillator to achieve sufficient output power but remain safely below the Power Degradation Threshold of the SAW resonator. The parasitic capacities of port 1 of the SAW resonator and gate 1 of the MOSFET are resonated by L101. The drain capacity and port two of the SAW resonator are resonated by T101, a transformer that also provides a phase shift to enable the oscillator to run at frequencies closer to the resonant peak of the SAW resonator - also the region of steepest phase slope. L101 and T101 are compressed or expanded to fine tune the oscillator in production.

The MOSFET contributes a negative frequency vs temperature characteristic to the oscillator, and thus the turnover temperature of the SAW resonator was specified at 65°C to obtain a net oscillator turnover frequency of 35°C, the normal temperature inside the converter. The center frequency of the SAW resonator is specified to be 200 kHz below desired oscillator frequency, because, due to phase shift around the loop, the oscillator cannot be tuned symmetrically about the center frequency of the SAW resonator.

Summary

The SAW resonator stabilized oscillator provides exceptional frequency stability at UHF frequencies. The oscillator that was developed combines manufacturing practicality and low cost. SAW resonator stabilized oscillators should begin to fill the gap in the spectrum of stable frequency sources that exists between quartz crystal and dielectric resonator oscillators.

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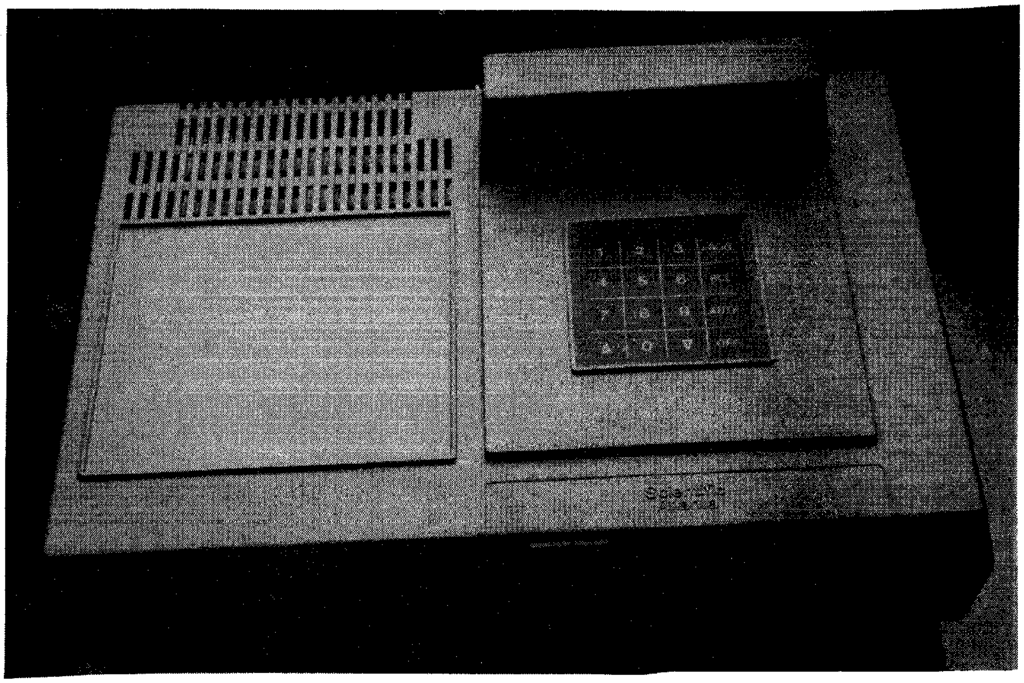

Figure 1. 54-Channel CATV Set-Top Converter

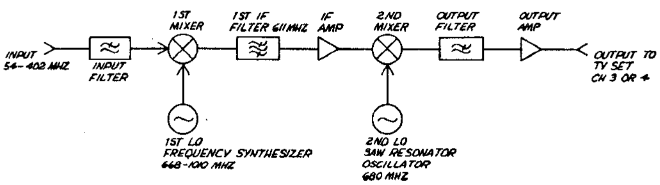

Figure 2. Set-Top Converter Block Diagram

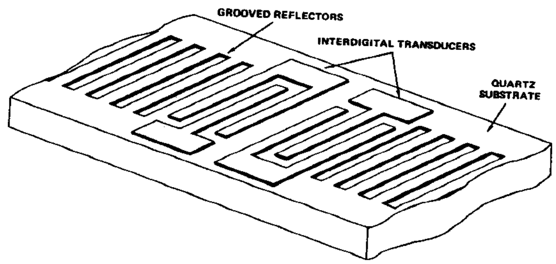

Figure 3. SAW Resonator Construction

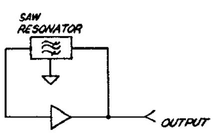

Figure 4. Oscillator Block Diagram

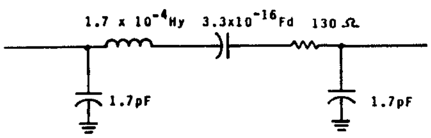

Figure 5. SAW Resonator Equivalent Circuit

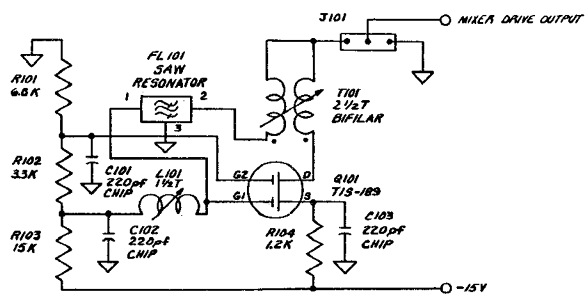

Figure 6. SAW Resonator Stabilized Oscillator Schematic Diagram

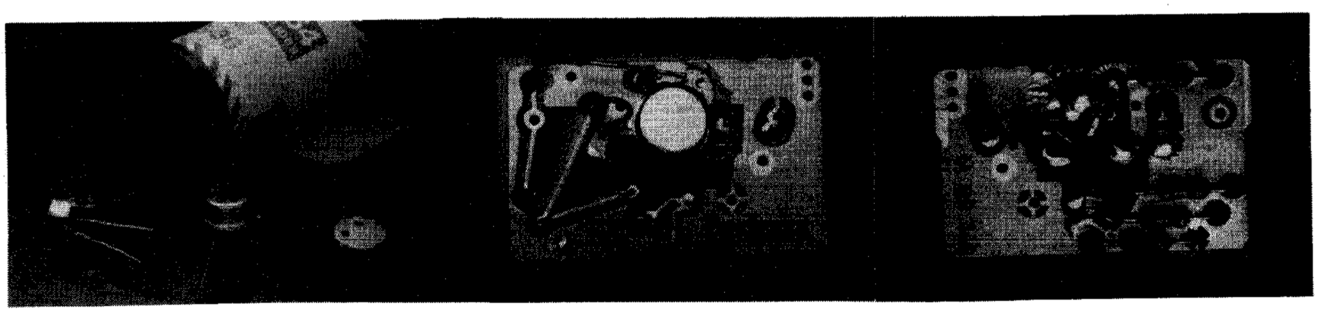

Figure 7. SAW Resonators and Stabilized Oscillator (Front and Rear Views)