One chip Low power Digital- TCXO with Sub- ppm Accuracy

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Outline

• Motivation
• Basics of a DTCXO
• Conventional DTCXO
• Proposed DTCXO
  – Concept
  – Overall Configuration
  – Structure of the Capacitor Bank
  – Operation of the Controller
• Experimental Results
• Summary
Motivation

• Need for extremely accurate frequency
  – Clock for digital system
  – Reference frequency generator for communication system
• Limitation of a Crystal Oscillator
  – Problem of frequency fluctuation due to temperature variation
• Low power
  – To satisfy the demands of handheld devices
Basics of a DTCXO

- The only way to tune the oscillation frequency is by varying $C_L$.

One of the widely known oscillator structures

$$C_L = \frac{C_1 C_2}{C_1 + C_2}$$
Conventional DTCXO

- Memory + Varactor Diode
  - Varactor Diode is hard to implement into VLSI chip
Conventional DTCXO

- Memory + Capacitor Bank
  - Resolution of compensation is restricted by Memory size

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- Calculator + Capacitor Bank
  - Accuracy of compensation is doubtful

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Concept of the proposed DTCXO

- **EEPROM + Controller + Capacitor Bank**
  - Exact value of compensation capacitor is stored in EEPROM (1°C Resolution)
  - Using ALU in the controller, the compensation resolution is doubled (0.5°C Resolution)
Overall System Configuration

OSCILLATOR
- FREQ. SEL BANK
- TEMP. COMP BANK1
- TEMP. COMP BANK2
- VOL. CTRL BANK

CAPACITOR BANK

CONTROLLER
- INTERPRETER
- REGISTER
- SEQUENCER
- ADC
- PTAT SENSOR

TEMP. SENSOR

MEMORY
- ADDR. LATCH
- DATA LATCH
- OUTPUT DATA LATCH
- MEMORY CELL CORE
Overall System Configuration

• Temperature Sensor
  – 0.5°C resolution
  – -55°C ~ 120°C (Frequency variation of Crystal Oscillator mainly occurs from -40°C to 85°C)

• EEPROM
  – Compensation data (1Kbit) and Stores program code (64bit)
Capacitor Bank

Schematic of Unit cell

Temperature Compensation Bank

16 cells

UNIT CELL

UNIT CELL

UNIT CELL

UNIT CELL

UNIT CELL

UNIT CELL

UNIT CELL

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UNIT CELL

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UNIT CELL

decoder
Capacitor Bank

• Physical structure of the Capacitor Bank
  – Poly- Oxide- Poly capacitor

• Determining the Unit Cell capacitance
  – Maximum $\Delta f$ is $\pm 30$ppm
  – The value of unit capacitor is chosen to be $36\text{fF}$
    to compensate with $0.2$ppm accuracy,
Operation of the Controller

- Task flow diagram of the Controller
  - Calibration Mode
  - Programming Mode
  - Memory Test Mode
  - Operation Mode
Operation of the Controller

• Capacitor Bank Selection
  - Region I: Frequency changes rapidly
  - Region II: Frequency changes slowly
Experimental Results

- Trimming characteristics of proposed DTCXO
- 0.2ppm resolution is obtained.
Experimental Results

- Oscillator output spectrum showing the harmonic characteristics.
Features

- **Technology**
  - 0.5um CMOS process
  - 2 poly and 3 metal

- **Chip size**
  - 2.8x3.2mm²

- **Power consumption**
  - 6.6mW

- **Accuracy**
  - 0.2ppm
Summary

• To obtain high accuracy and fine resolution temperature compensation, EEPROM and Controller is integrated.

• To reduce power consumption, every components which includes temperature sensor, ADC, EEPROM, controller and oscillator are fabricated into one chip.

• Experimental results show the frequency compensation is successfully performed with 0.2ppm trimming accuracy.