High Resolution ADC Using a Delta-Sigma Architecture

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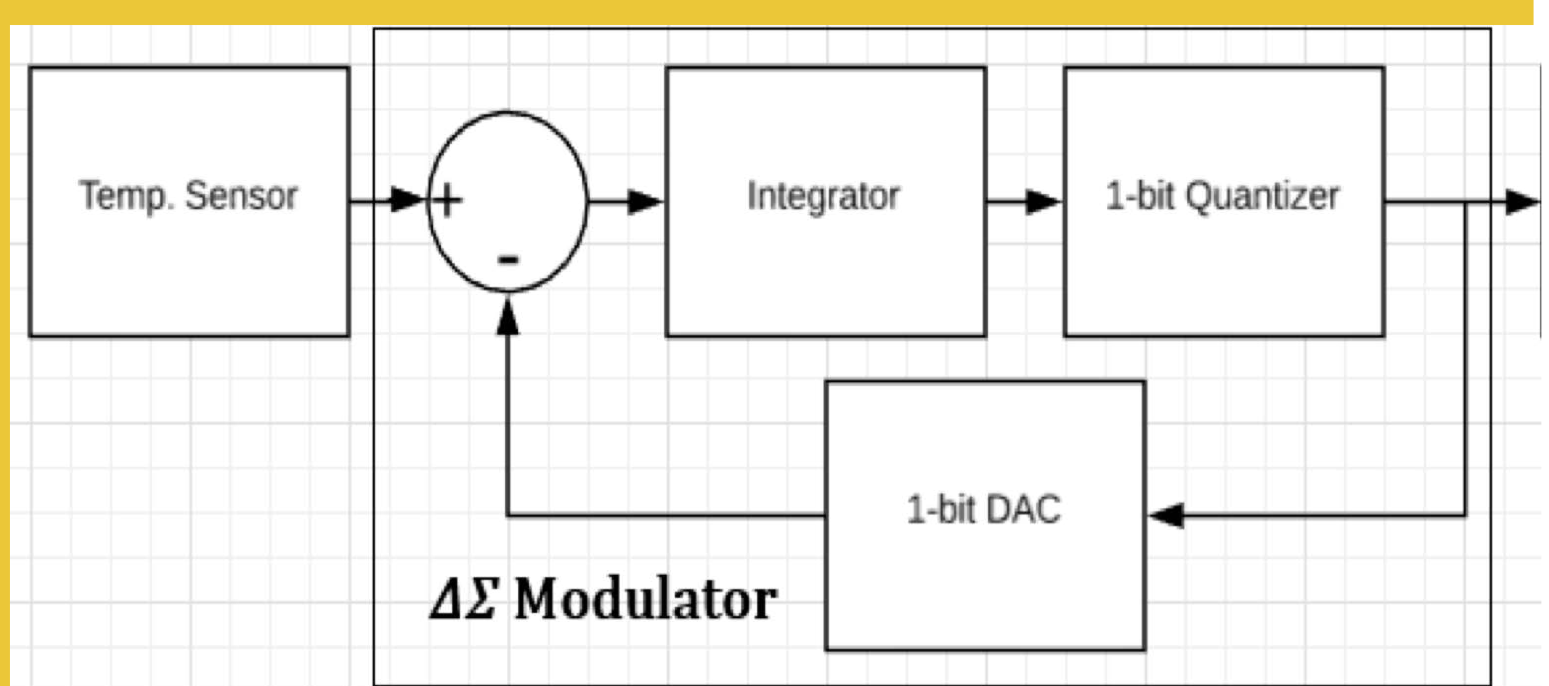
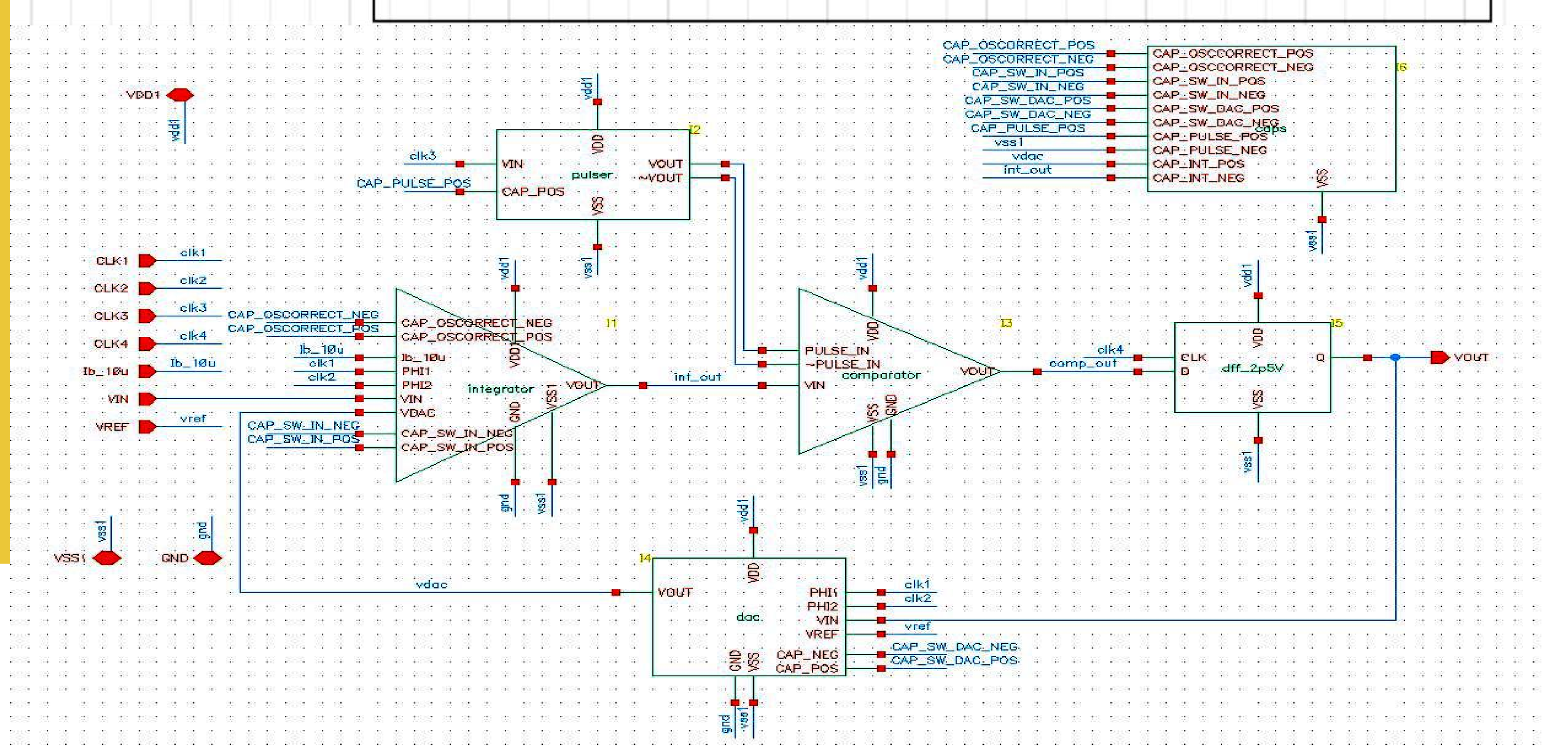
Problem: Overheating can cause an integrated circuit to malfunction. There is a need for a method to measure and communicate the chip temperature to circuitry that will throttle the circuit activity when necessary.
Our Solution: A temperature sensor connected to the input of a delta-sigma analog-to-digital converter. This circuit will accurately measure and communicate the temperature of the integrated circuit. Thus, the temperature of the IC can be monitored and controlled ensuring that it doesn't overheat.

Temperature Sensor and Delta Sigma Modulator





Design Requirements

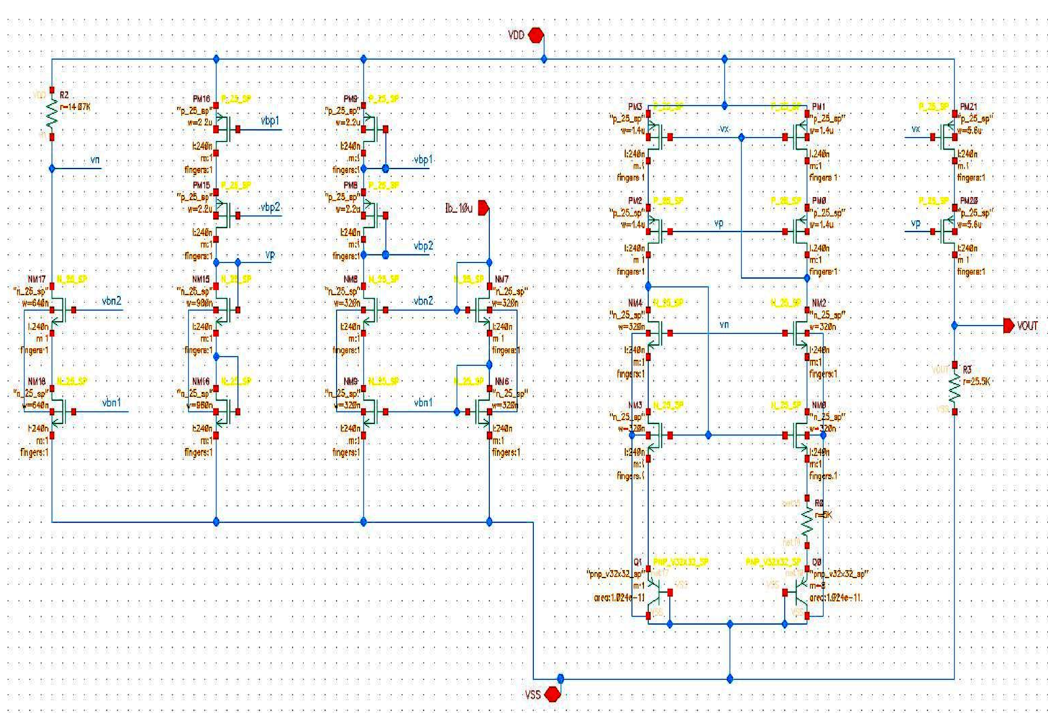
Functional:

- The circuit is designed in a 65nm CMOS process
- The ADC should output at least 1 code per 10 milliseconds
- The temperature sensor should have a monotonic relationship between temperature and its output voltage
- The temperature sensor should be able to measure temperatures from 10° C to 60° C

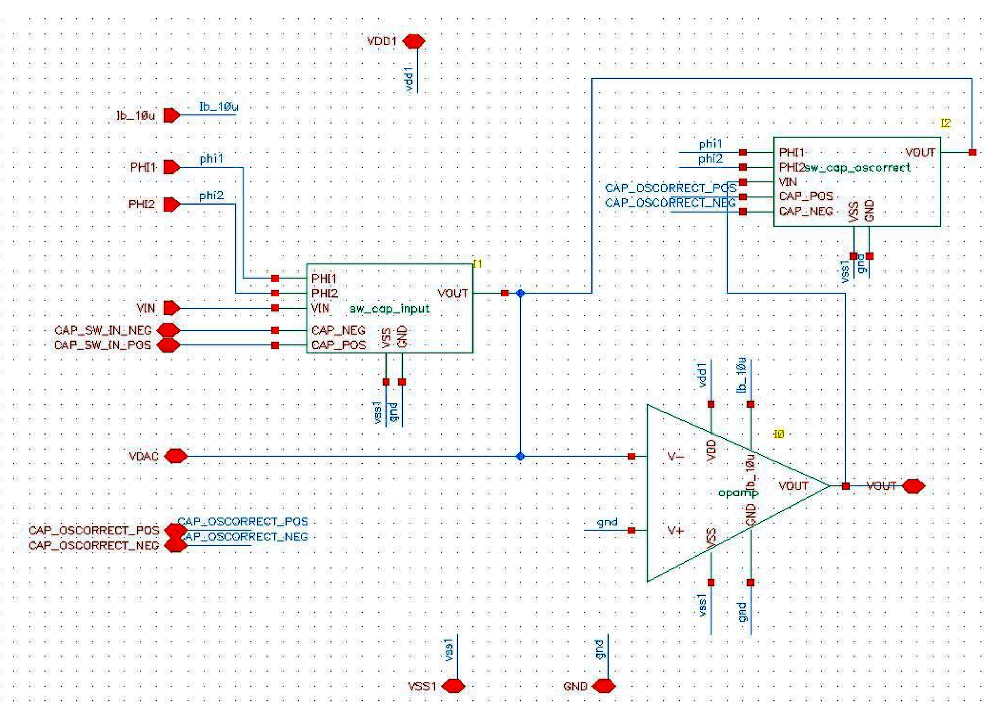
Non-Functional:

- The circuit layout dimensions should not exceed 0.5mm by 1mm
- The circuit should not use more than 20 I/O pins

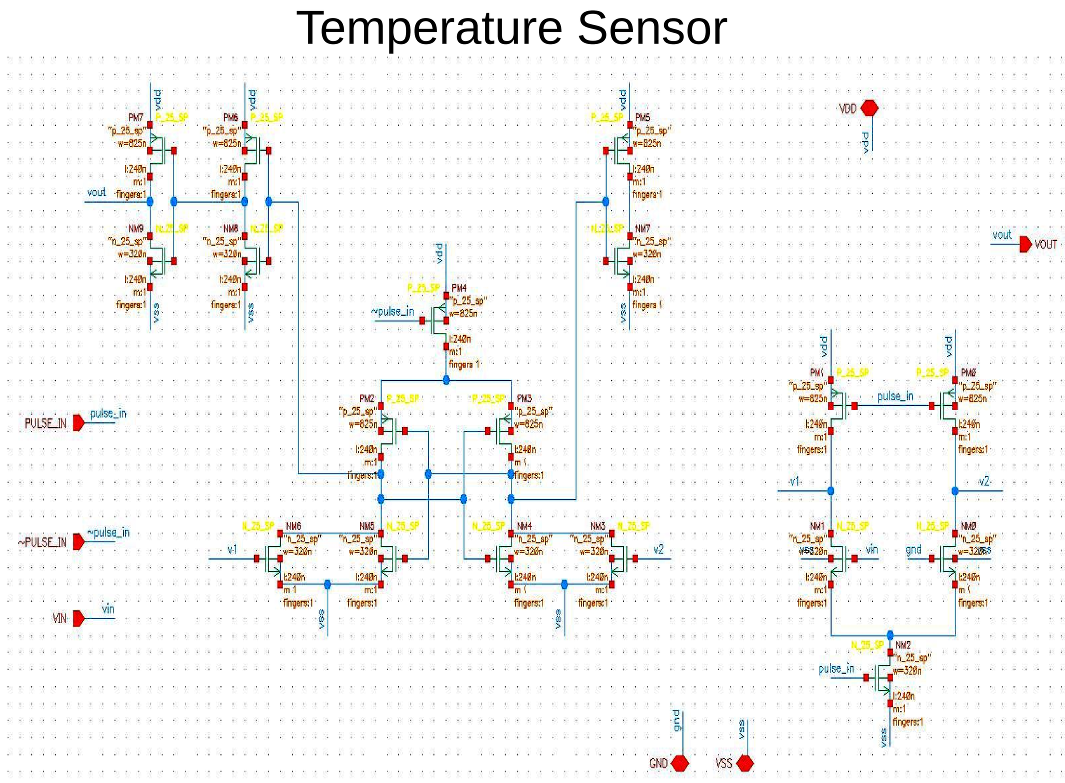
Functional Blocks



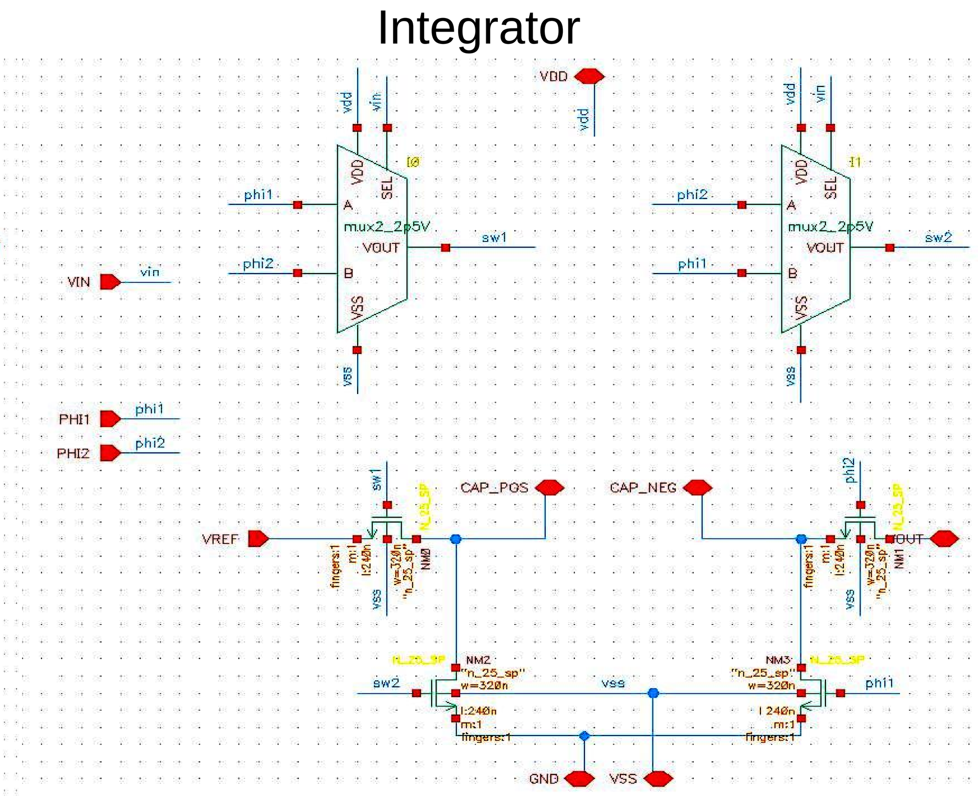
Temperature Sensor



Integrator



1-bit Quantizer

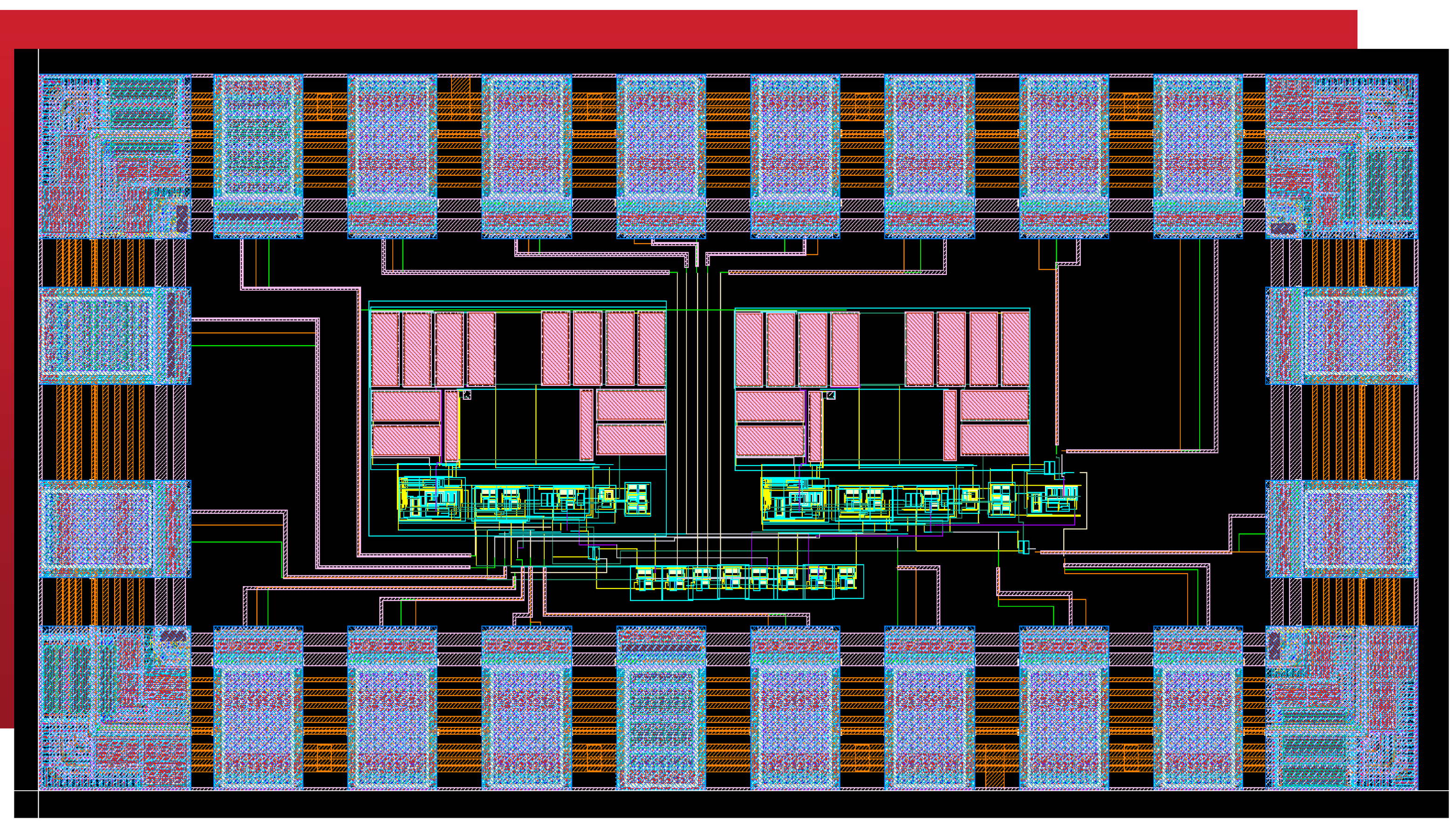


1-bit DAC

Temperature Sensor: To measure temperature, the sensor needed to be designed using a temperature dependent device. Diodes are temperature dependent devices and when their current is set to a fixed value the voltage across the diode will change along with thermal voltage. Our design implemented diodes using diode connected transistors.
Modulator: This circuit is comprised of several sub-circuits: an integrator, a 1-bit quantizer, and a 1-bit DAC. It takes the analog output of the temperature sensor as its input, and outputs a digital signal that contains the temperature data in the form of a binary data stream whose proportion of 1's to total values in a 10-millisecond time span is equal to the magnitude of the input voltage to the modulator relative to the input voltage range.
Integrator: This circuit generates a sawtooth wave that acts as the input to the comparator. The voltage output of the integrator progresses in a negative or positive direction depending on the sign of the input voltage.
1-bit Quantizer: This circuit is implemented as a dynamic comparator. It reads in the output voltage of the integrator and on the rising edge of the clock produces a 1-bit digital output. It compares the input voltage to it's voltage reference, if the input voltage is greater than the reference voltage the comparator will output a 1 if not it will output a 0.
The 1-bit DAC: This circuit takes in the digital output of the comparator and converts it to an analog signal to be fed back to the input of the integrator.

Operating Environment: Our circuit can be implemented into any integrated circuit as it is intended to monitor the temperature of that integrated circuit.
Intended Users: Our product is to be used by integrated circuit designers to implement into their integrated circuits during the design process. The circuit is intended to be used in both industry and in academic research.
Intended Use: Our product will be used to measure and communicate the temperature of an integrated circuit to other circuitry within the integrated circuit that is responsible for temperature control. Based on the output of our circuit, the connected circuitry will change the integrated circuit's behavior to reduce heat dissipation.

Resources: MOSIS (for fabrication), Cadence software (for design and testing), UMC 65nm process, IEEE Journals (for research)
Standards: IEEE Standard for Terminology and Test Methods for Analog to Digital Converters



Layout of Full Circuit

Input Voltage (mV)	First Code	Second Code	Expected Code
730.068359375	3	2	1
752.5	257	256	256
765V	512	512	512
782.5	767	767	768
799.931640625	1023	1023	1023

Table showing the output of the Delta-Sigma ADC

Testing Strategy:

- Pre-Fabrication: Each functional block was tested individually using Cadence and then the entire system was tested as a whole. After the layout was created, the circuit was tested again with parasitic capacitances extracted, thus ensuring the circuit would function as intended post-fabrication.
- Post-Fabrication: A test file has been created to use a DAQ to extract data from the output of the delta-sigma modulator and convert it into a file which is used to determine frequency characteristics, integral non-linearity, effective number of bits, signal-to-noise ratio and signal-to-noise-and-distortion ratio.