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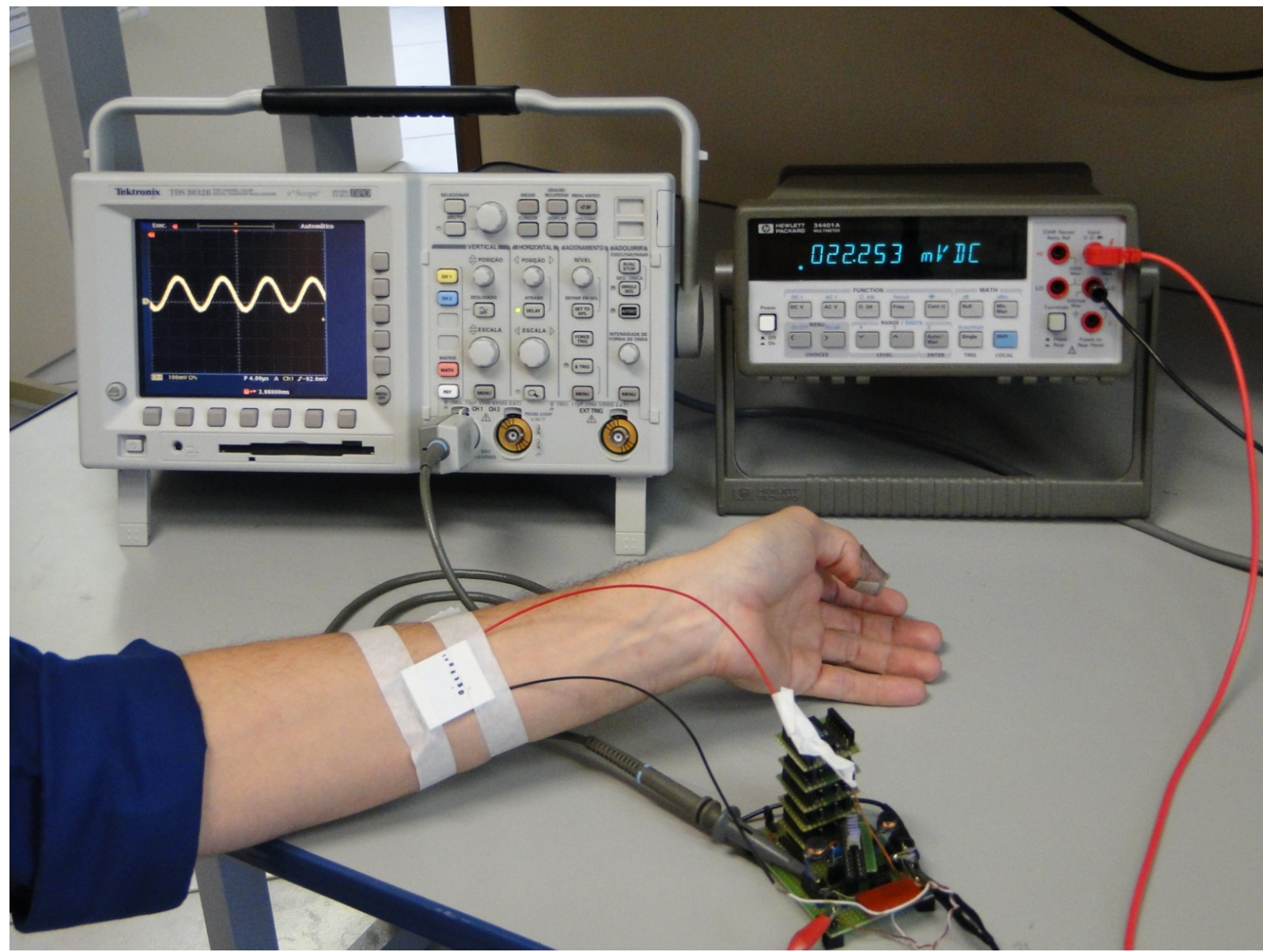2012 IEEE International Symposium on Circuits and Systems
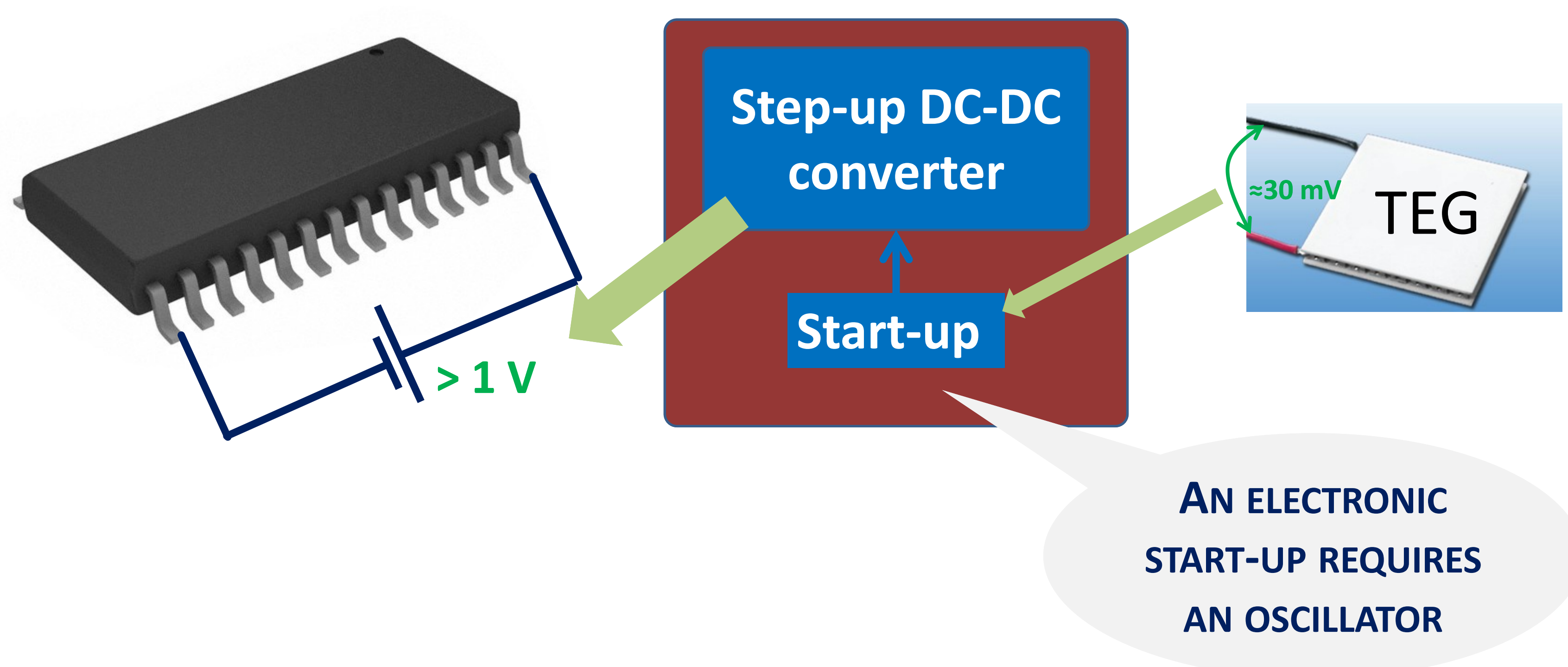
A 20 mV Colpitts Oscillator powered by a thermoelectric generator

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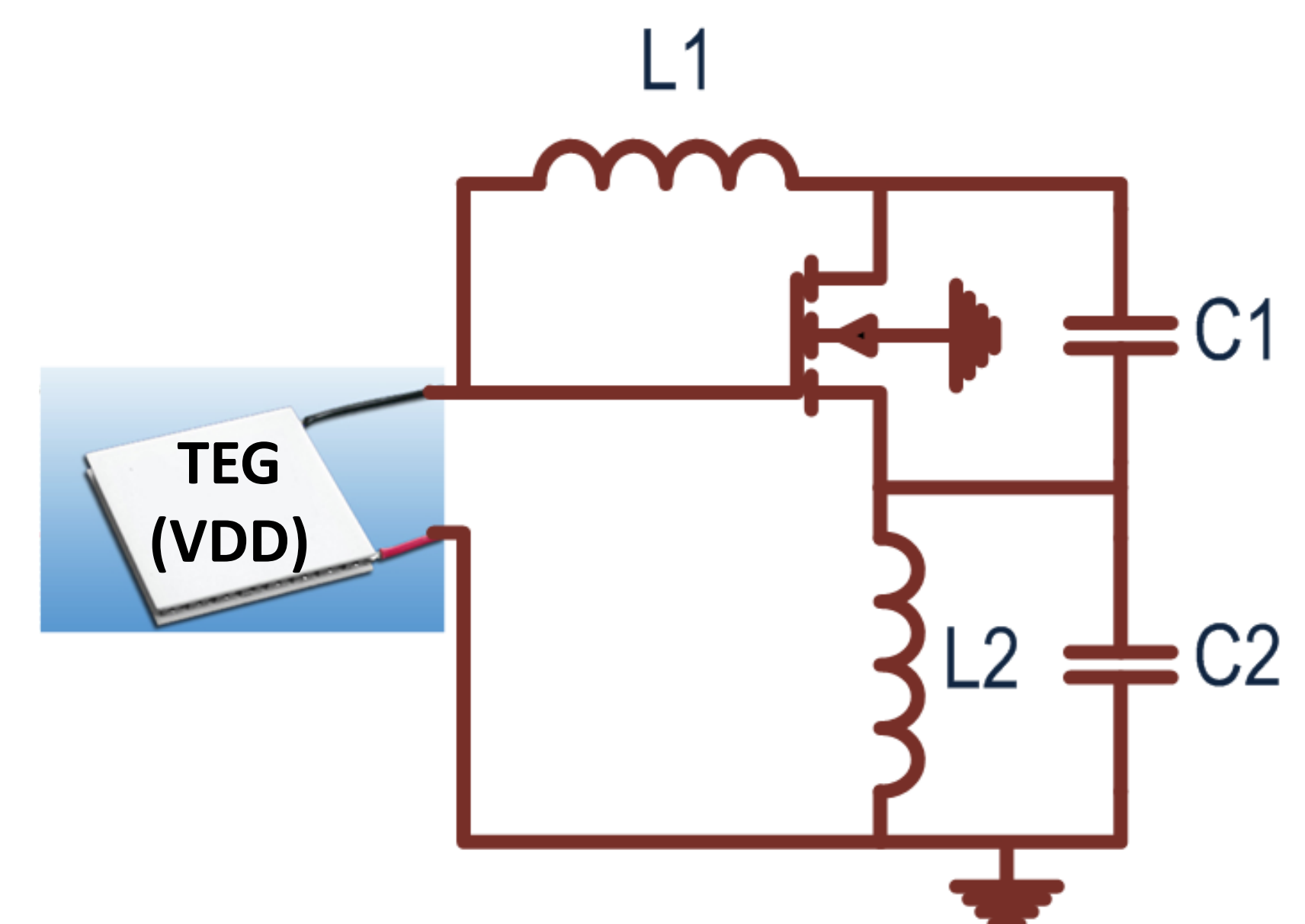rangel@ieee.org

Abstract

In this paper, we present a Colpitts oscillator based on a "zero-VTH" MOSFET operating at a supply voltage below 20 mV. The circuit was carefully analyzed and expressions relating the start-up conditions and the voltage supply, as well as the oscillation frequency were developed. Measurement results obtained on a discrete prototype confirmed the low-voltage operation of the oscillator, which sustained oscillations of 130 mV (peak-to-peak) at 97 kHz when the voltage supply was 19.8 mV. The circuit was also powered from a thermoelectric generator (TEG) connected to a persons arm in a room with temperature of 24°C. Under these conditions, the TEG supplied 22 mV and the circuit operated as expected.
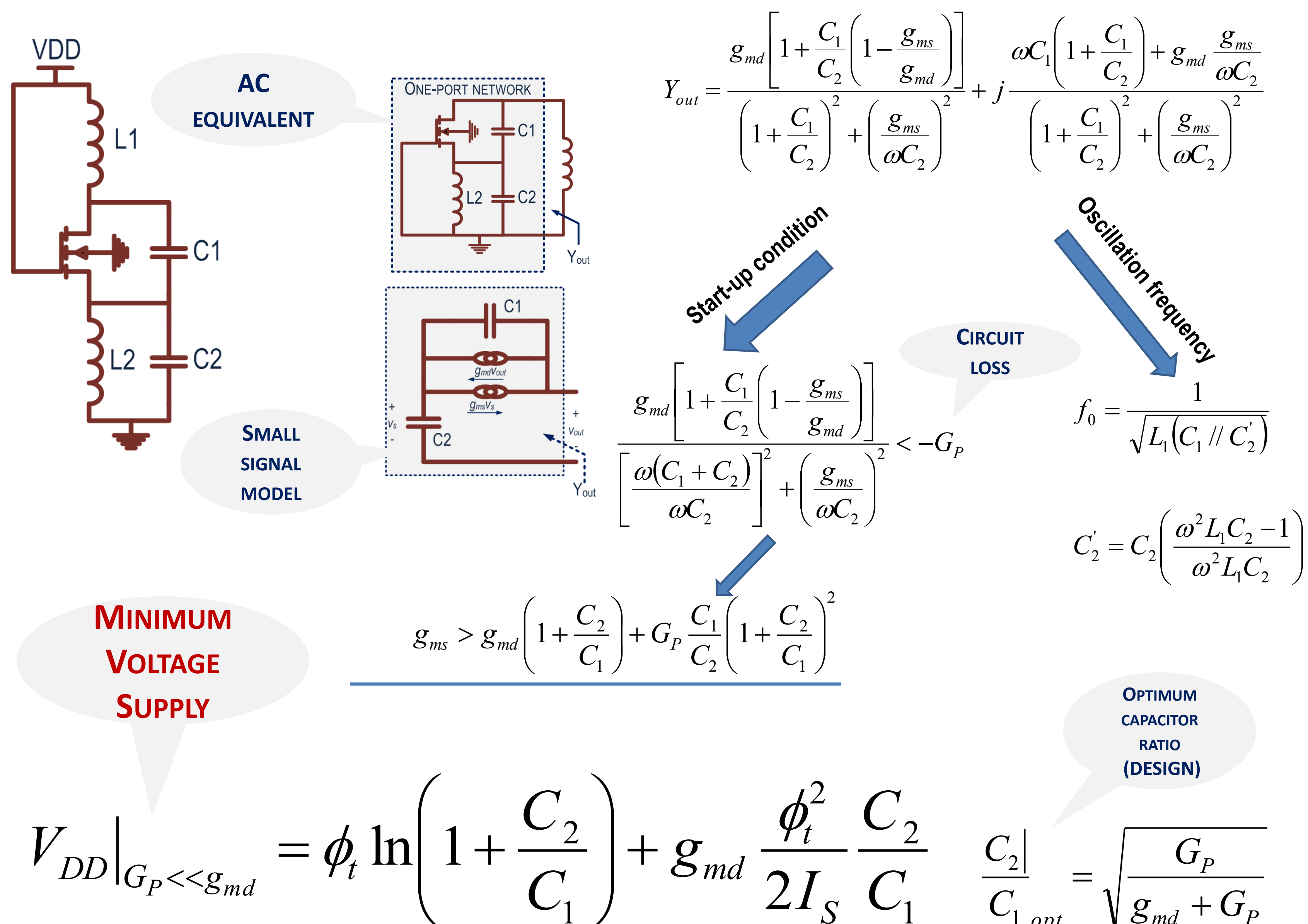
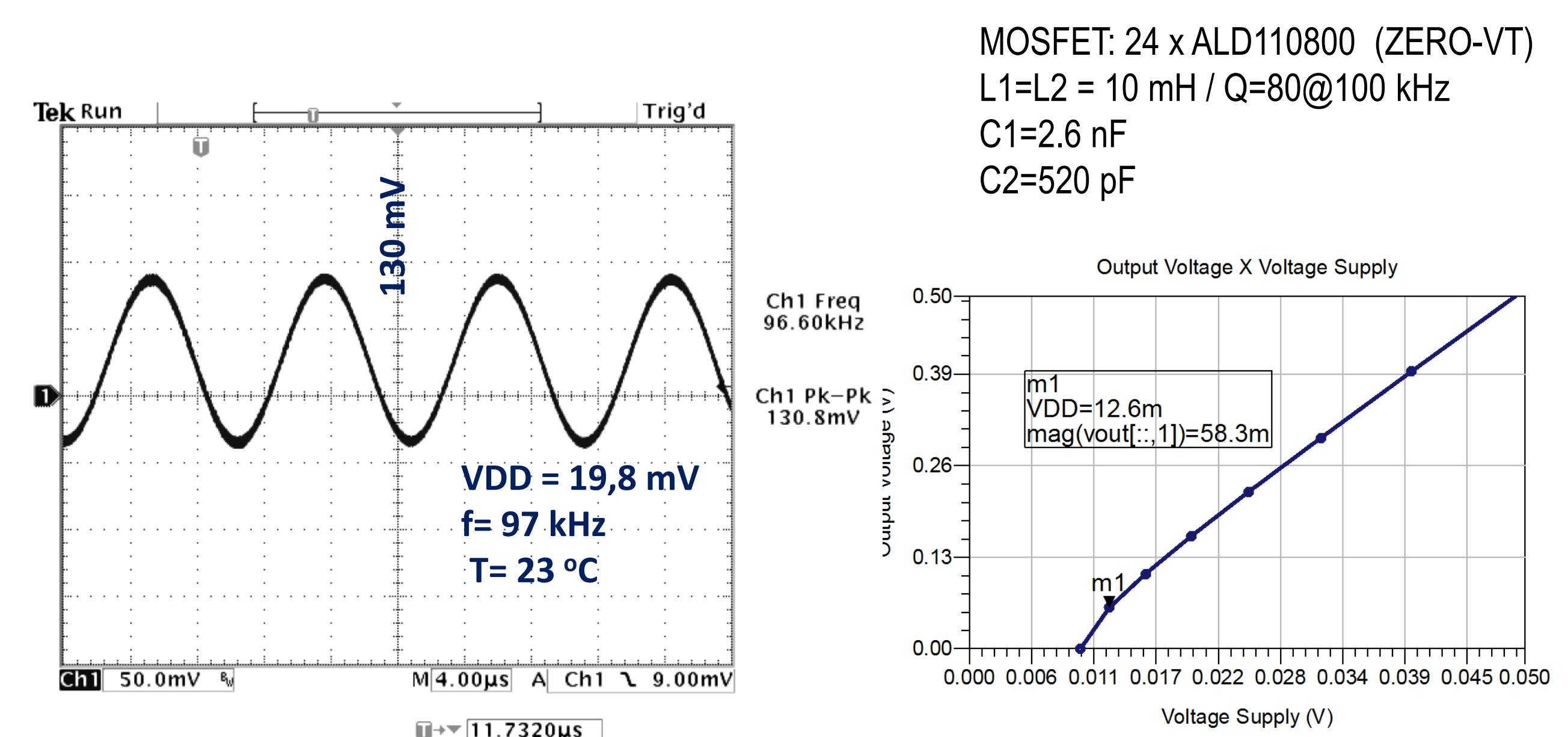## Motivation: How can we power electronics from a TEG?

Step-up DC-DC converter

≈30 mV

TEG

Start-up

> 1 V

AN ELECTRONIC START-UP REQUIRES AN OSCILLATOR

Ultra-low-voltage Colpitts oscillator

L1

C1

TEG (VDD)

L2   C2

Oscillator analysis

VDD

AC EQUIVALENT

L1

C1

L2   C2

ONE-PORT NETWORK

C1

L2 C2

Y_{out}

SMALL SIGNAL MODEL

$$Y_{out} = \frac{g_{md}\left[1 + \frac{C_1}{C_2}\left(1 - \frac{g_{ms}}{g_{md}}\right)\right]}{\left(1 + \frac{C_1}{C_2}\right)^2 + \left(\frac{g_{ms}}{\omega C_2}\right)^2} + j\frac{\omega C_1\left(1 + \frac{C_1}{C_2}\right) + g_{md}\frac{g_{ms}}{\omega C_2}}{\left(1 + \frac{C_1}{C_2}\right)^2 + \left(\frac{g_{ms}}{\omega C_2}\right)^2}$$

Start-up condition

$$\frac{g_{md}\left[1 + \frac{C_1}{C_2}\left(1 - \frac{g_{ms}}{g_{md}}\right)\right]}{\left[\frac{\omega(C_1 + C_2)}{\omega C_2}\right]^2 + \left(\frac{g_{ms}}{\omega C_2}\right)^2} < -G_P$$

CIRCUIT LOSS

Oscillation frequency

$$f_0 = \frac{1}{\sqrt{L_1\left(C_1 // C_2'\right)}}$$

$$C_2' = C_2\left(\frac{\omega^2 L_1 C_2 - 1}{\omega^2 L_1 C_2}\right)$$

MINIMUM VOLTAGE SUPPLY

$$g_{ms} > g_{md}\left(1 + \frac{C_2}{C_1}\right) + G_P\frac{C_1}{C_2}\left(1 + \frac{C_2}{C_1}\right)^2$$

$$V_{DD}\big|_{G_P << g_{md}} = \phi_t \ln\left(1 + \frac{C_2}{C_1}\right) + g_{md}\frac{\phi_t^2}{2I_S}\frac{C_2}{C_1}$$

OPTIMUM CAPACITOR RATIO (DESIGN)

$$\frac{C_2}{C_1}\bigg|_{opt} = \sqrt{\frac{G_P}{g_{md} + G_P}}$$

Results

MOSFET: 24 x ALD110800 (ZERO-VT)
L1=L2 = 10 mH / Q=80@100 kHz
C1=2.6 nF
C2=520 pF

Tek Run   Trig'd

130 mV

Ch1 Freq 96.60kHz
Ch1 Pk–Pk 130.8mV

VDD = 19,8 mV
f= 97 kHz
T= 23 °C

Ch1   50.0mV   M 4.00µs A Ch1 ↗ 9.00mV
11.7320µs

Output Voltage X Voltage Supply

m1
VDD=12.6m
mag(vout[::,1])=58.3m

m1

Voltage Supply (V)

References

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