AN1519

Recommended Crystals for Microchip Stand-Alone Real-Time Clock/Calendar Devices

Author: *Florian Gheorghe*
Microchip Technology Inc.

This document is designed to serve as a starting point when choosing a crystal to operate alongside the Microchip Stand-Alone Real-Time Clock/Calendar devices (Figure 1). To oscillate as closely as possible to the desired frequency, a crystal must have load capacitors that match the value recommended by the manufacturer, according to Equation 1.

EQUATION 1:

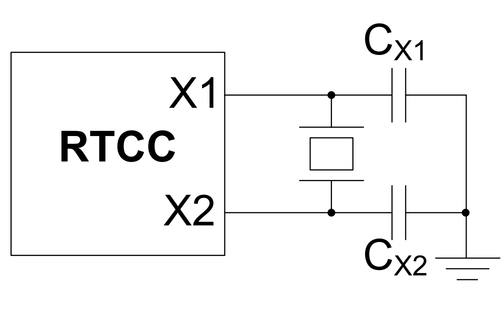
$$C_{load} = \frac{C_{x2} \bullet C_{x1}}{C_{x2} + C_{x1}} + C_{stray}$$

Where:

C_{x1} = Capacitor value on pin X1 + C_{pin}
C_{x2} = Capacitor value on pin X2 + C_{pin}
C_{stray} = Trace capacitance
C_{pin} = 3 pF

Also, the oscillator pin capacitance (available in the device data sheet as COSC) must be included in CX1 and CX2, and stray board capacitance (C_{stray}) must be taken into consideration when choosing the capacitors.

FIGURE 1: OSCILLATOR DIAGRAM



CONSIDERATIONS

The Microchip stand-alone RTCC's have been designed to work with 32.768 kHz tuning fork crystals with a load capacitance (CLOAD or CL) of 6-9pF. For tuning fork crystals, the frequency has a parabolic dependence on temperature. Therefore, when it changes, the frequency decreases accordingly, as shown in Equation 2 and Figure 2. See AN1413, *"Temperature Compensation of a Tuning Fork Crystal Based on MCP79410"* (DS01413).

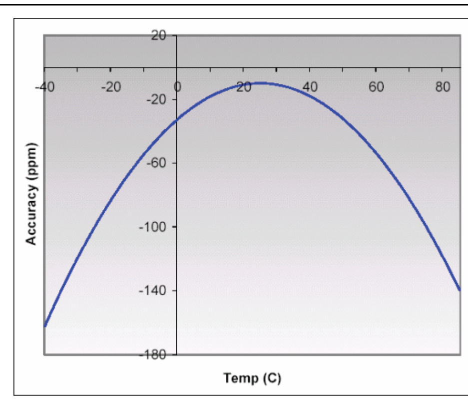
EQUATION 2:

$$f = f_0 \times [1\text{-}Tc \times (T - T_0)^2]$$

Where:

f_0 – frequency at turnover point
Tc – temperature coefficient
$T\text{-}T_0$ – deviation from turnover point
T – current temperature (°C)
T_0 – turnover point (°C)

FIGURE 2: PARABOLIC CURVE FOR TUNING FORK CRYSTALS



For best results, it is recommended that a ground ring should encompass the crystal and the X1 and X2 pins. See AN1365, *"Recommended Usage of Microchip Serial RTCC Devices"* (DS01365). Also, the traces from the RTCC to the capacitors and crystal should be as short as possible in order to minimize the stray board capacitance (C_{STRAY}). See AN1288, *"Design Practices for Low-Power External Oscillators"* (DS01288).

Table 1 shows recommended crystals and load capacitors.

Some vendors use the term oscillation allowance as the sum of negative R value and ESR (Equation 3). The negative R (-R) which has been measured on the AC164140 RTCC PICtail™ board is a measure of the ability of the oscillator to drive the crystal over temperature (Figure 3). An oscillation allowance value of three to five times the crystal ESR will provide an acceptable margin. See AN943, *"Practical PICmicro® Oscillator Analysis and Design"* (DS00943) and AN949, *"Making Your Oscillator Work"* (DS00949).

EQUATION 3:

$$\text{Oscillation Allowance} = |-R| + ESR\ [\Omega]$$

FIGURE 3: NEGATIVE RESISTANCE TEST SETUP

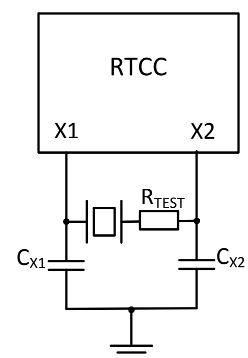


TABLE 1: CRYSTALS

Crystal Vendor	Crystal Part Number	ESR (Max.)	C_{LOAD} (pF)	C1 Capacitor Value (pF)	C2 Capacitor Value (pF)	PPM Error (at 25°C)	Seconds /Day	Oscillation Allowance	Oscillation Allowance /ESR Ratio
Citizen	CMR200T-32.768KDZB-UT	50 kΩ	6	10	10	-3.17	-0.274	480 kΩ	9.6
Citizen	CFS206-32.768KDZB-UB	35 kΩ	6	10	12	-9.60	-0.829	780 kΩ	22.28
ECS	ECS.327-6-13X	35 kΩ	6	12	10	1.07	0.092	360 kΩ	10.28
ECS	ECS.327-6-17X-TR	40 kΩ	6	10	8.2	10.93	0.944	540 kΩ	13.5
Epson Crystals	MC405-32.7KE3R	50 kΩ	6	10	10	-1.71	-0.148	300 kΩ	6
Epson Crystals	C002RX32.76K-EPB	60 kΩ	6	12	10	-0.66	-0.057	370 kΩ	6.16
AVX Crystals	ST3215SB32768C0HP-WBB	70 kΩ	7	10	12	-1.22	-1.105	800 kΩ	11.42
FOX Crystals	NC38LF-32.768kHz	35 kΩ	6	8.2	8.2	1.47	0.127	600 kΩ	17.14
Micro Crystal (**Note**)	CM7V-T1A	70 kΩ	7	10	12	3	0.259	300 kΩ	4.28
Citizen (**Note**)	CM200S32.768KDZB-UT	50 kΩ	6	10	8	1.2	0.104	480 kΩ	9.6
Seiko (**Note**)	SSP-T7-F	65 kΩ	7	10	12	-0.76	0.066	390 kΩ	6
Seiko (**Note**)	VT-200-F	50 kΩ	6	9	9	-2.14	0.185	460 kΩ	9.2

Note: Not included in this document.

CRYSTAL TEST RESULTS

The crystals detailed above have been tested on the AC164140 RTCC PICtail board (unless noted). The results are in Table 2.

TABLE 2: CRYSTAL TEST RESULTS

Crystal	Appendix
Citizen CMR200T-32.768KDZB-UT	**Appendix A: "CMR200T-32.768KDZB-UT"**
Citizen CFS206-32.768KDZB-UB	**Appendix B: "CMR-32.768KDZB-UB"**
ECS ECS.327-6-13X	**Appendix C: "ECS327-6-13X"**
ECS ECS.327-6-17X-TR	**Appendix D: "ECS.327-6-17X-TR"**
Epson MC405-32.7KE3R	**Appendix E: "EPSON MC405-32.7KE3R"**
Epson C002RX32.76K-EPB	**Appendix F: "EPSON C002RX32.76K-EPB"**
AVX ST3215SB32768C0HPWBB	**Appendix G: "AVX ST3215SB32768C0HPWBB"**
FOX NC38LF-32.768kHz	**Appendix H: "FOX NC38LF-32.768kHz"**

APPENDIX A: CMR200T-32.768KDZB-UT

FIGURE 4: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{BAT} = 1.3V, V_{CC} = 1.3V)

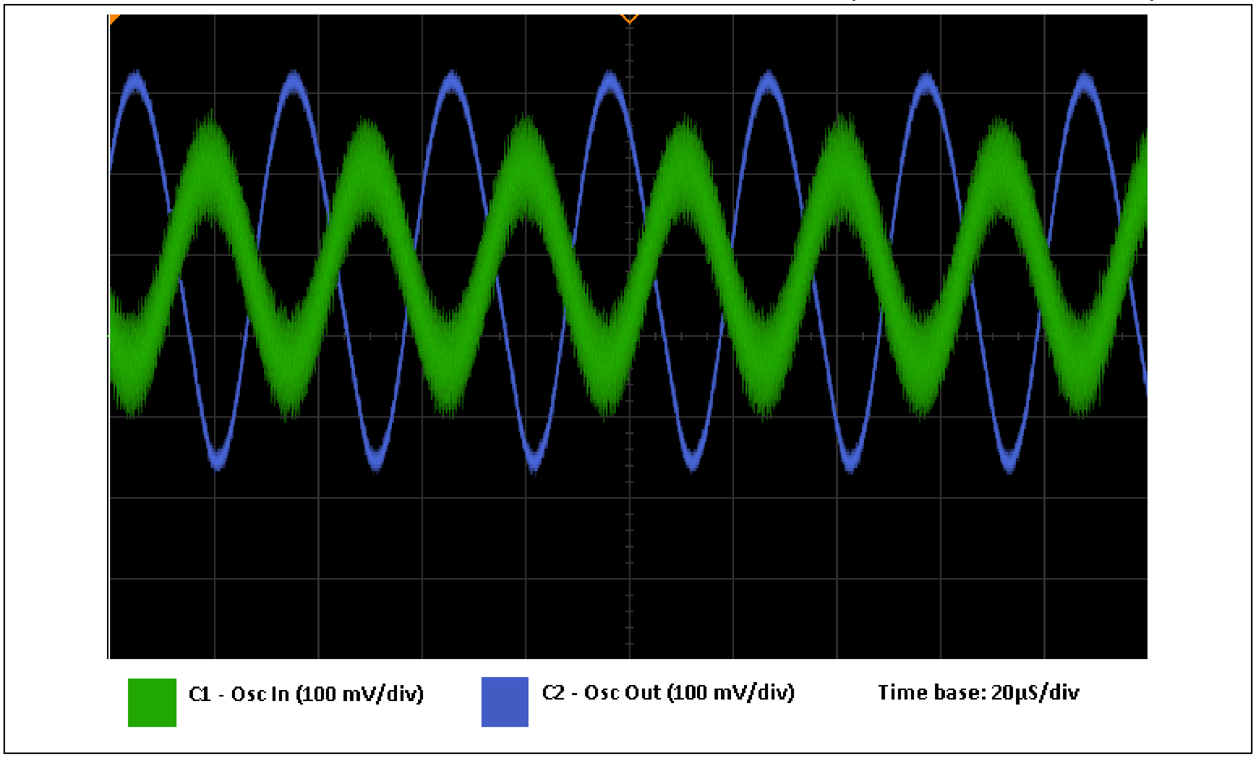


FIGURE 5: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 3.3V)

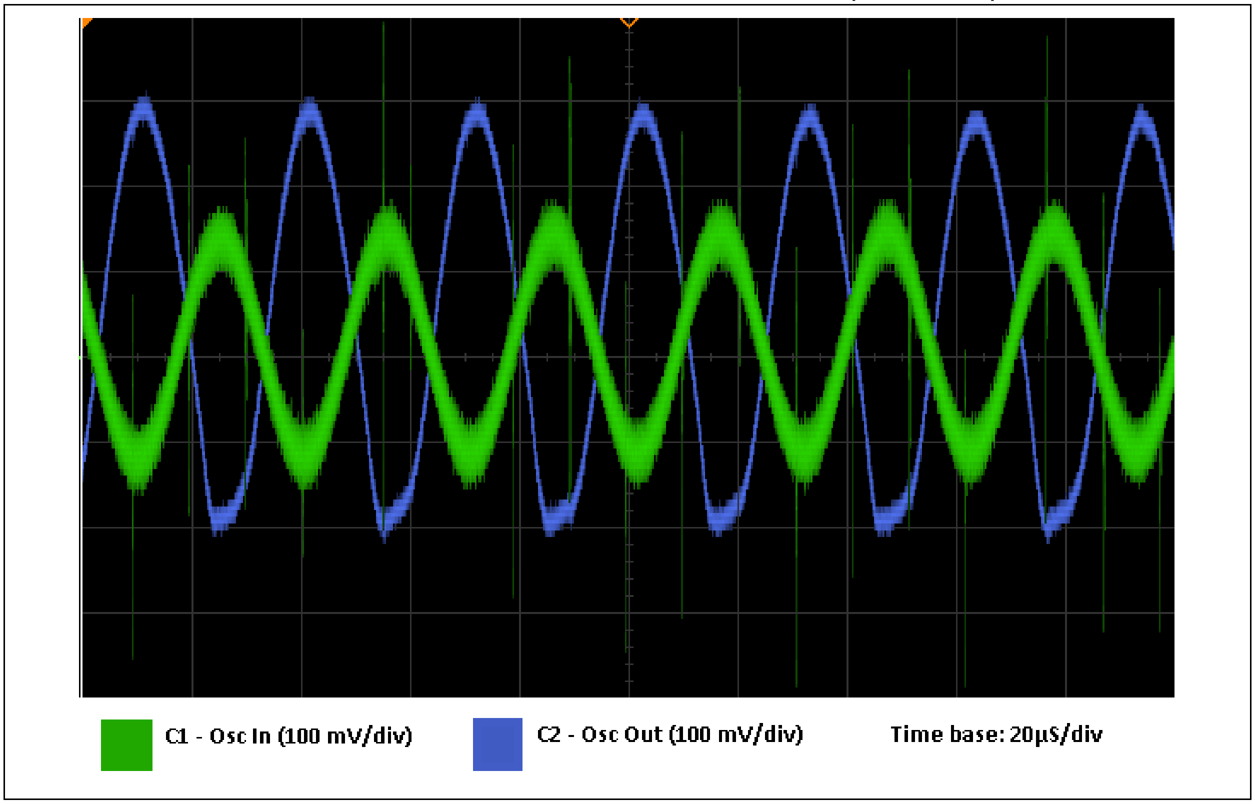


FIGURE 6: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 5.0V)

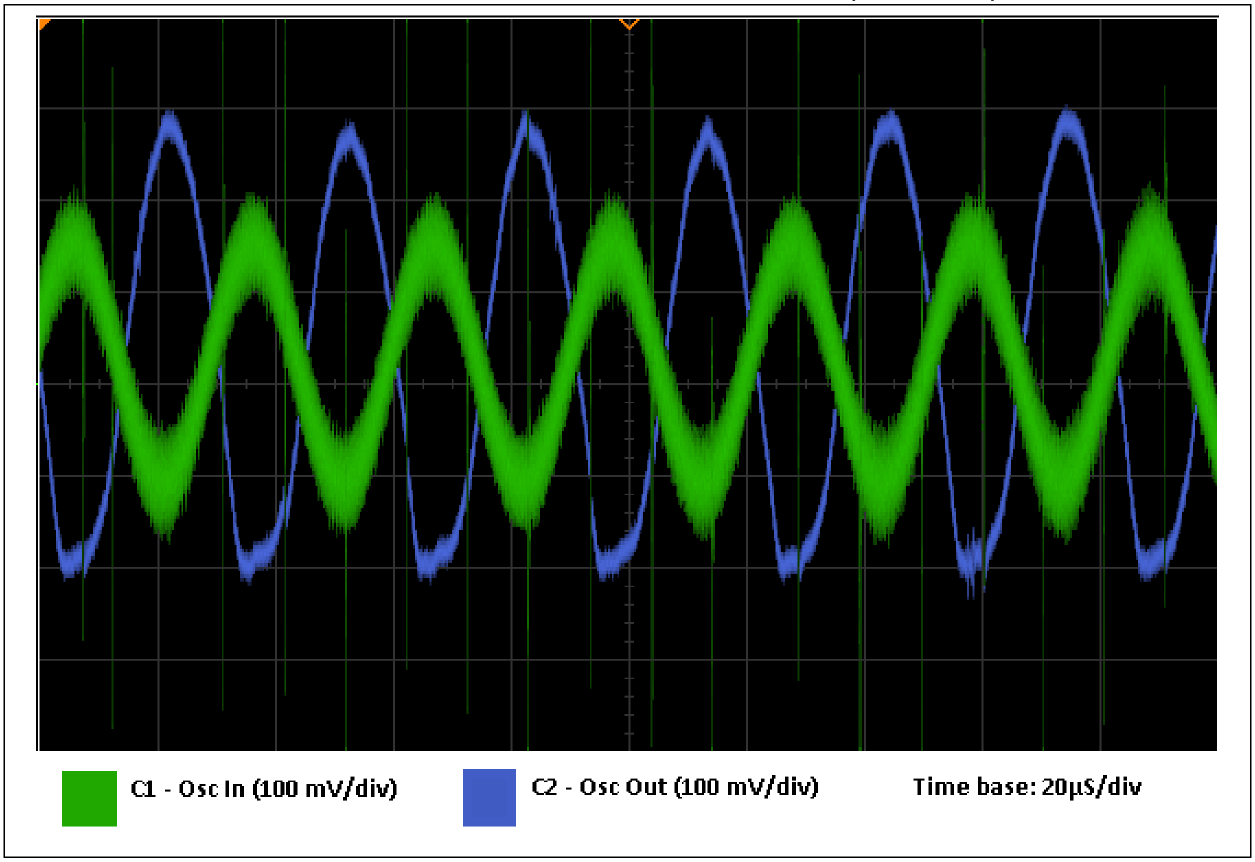


FIGURE 7: OSCILLATOR INPUT AND OUTPUT (V_{CC} = 5.5V)

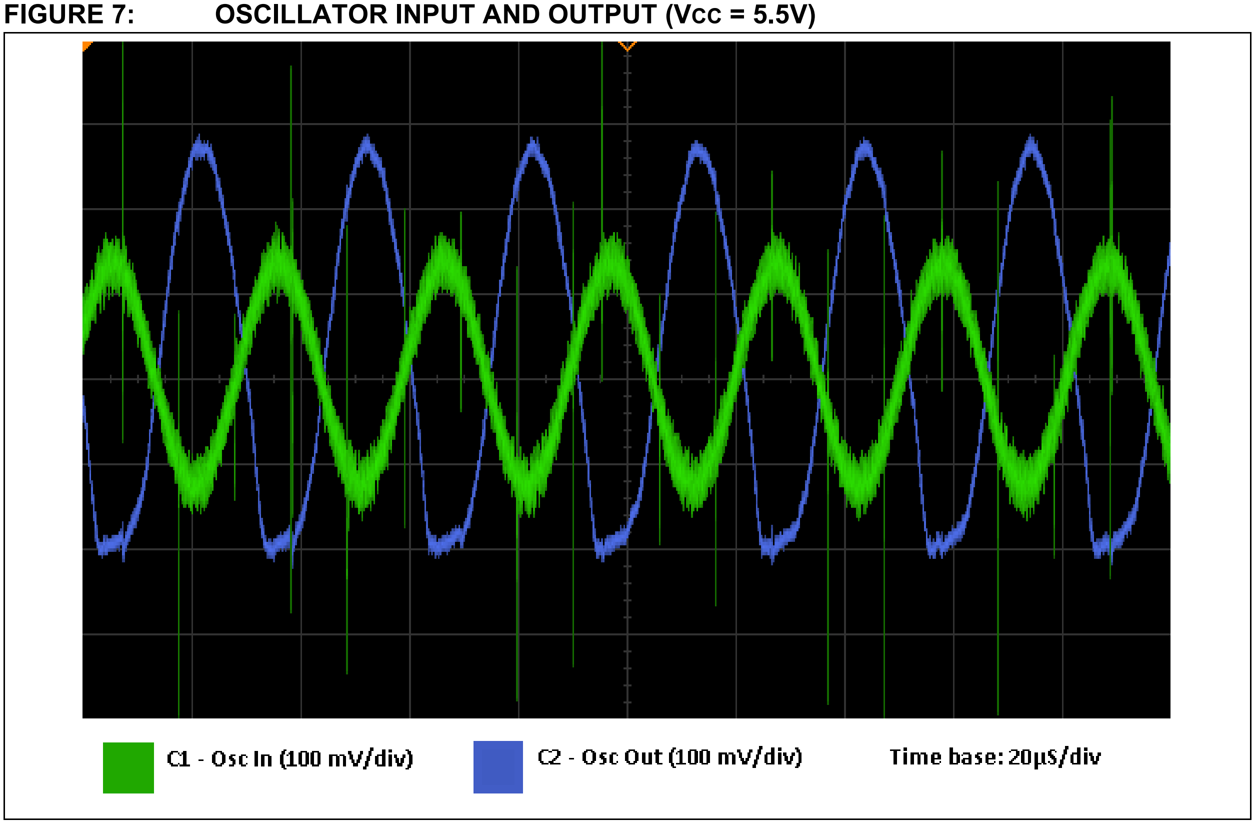


FIGURE 8: OSCILLATOR START-UP WAVEFORM (Vcc = 3.3V)

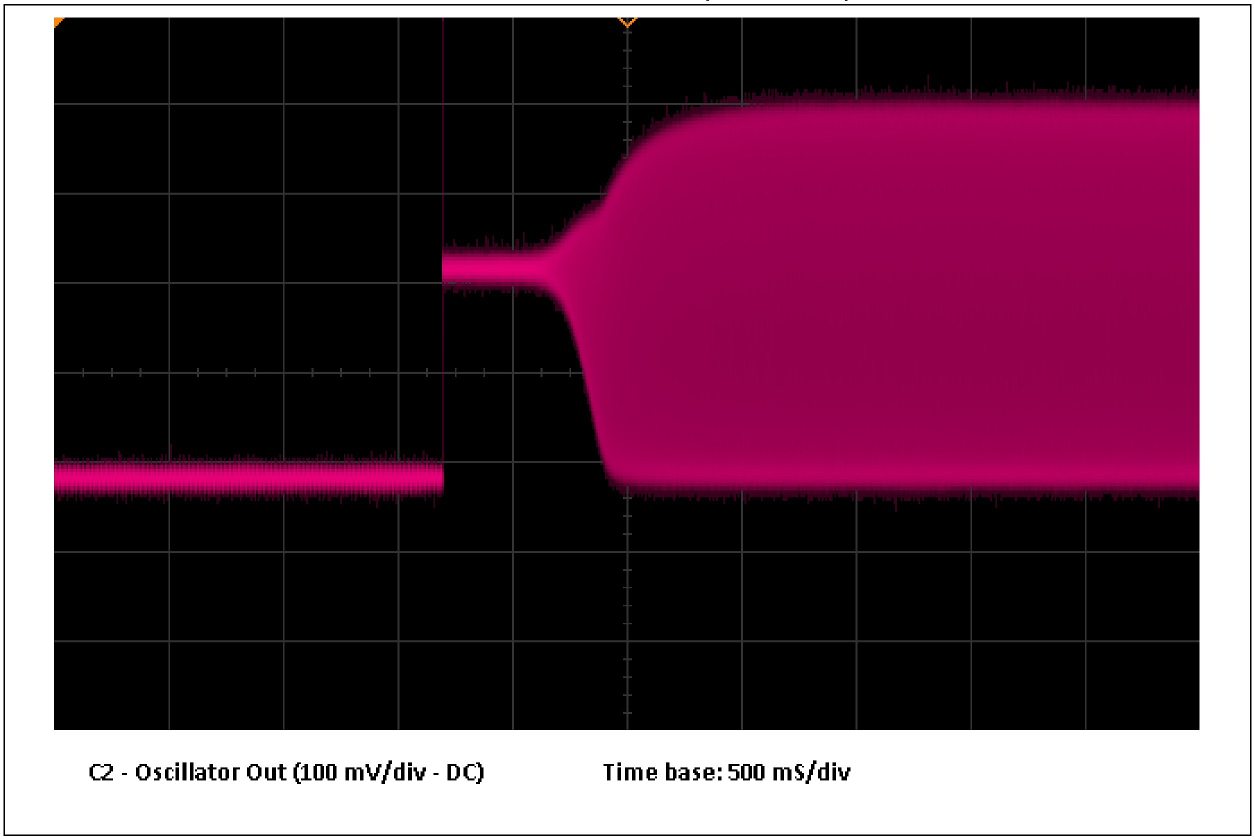


FIGURE 9: OSCILLATOR START-UP WAVEFORM (Vcc = 5.0V)

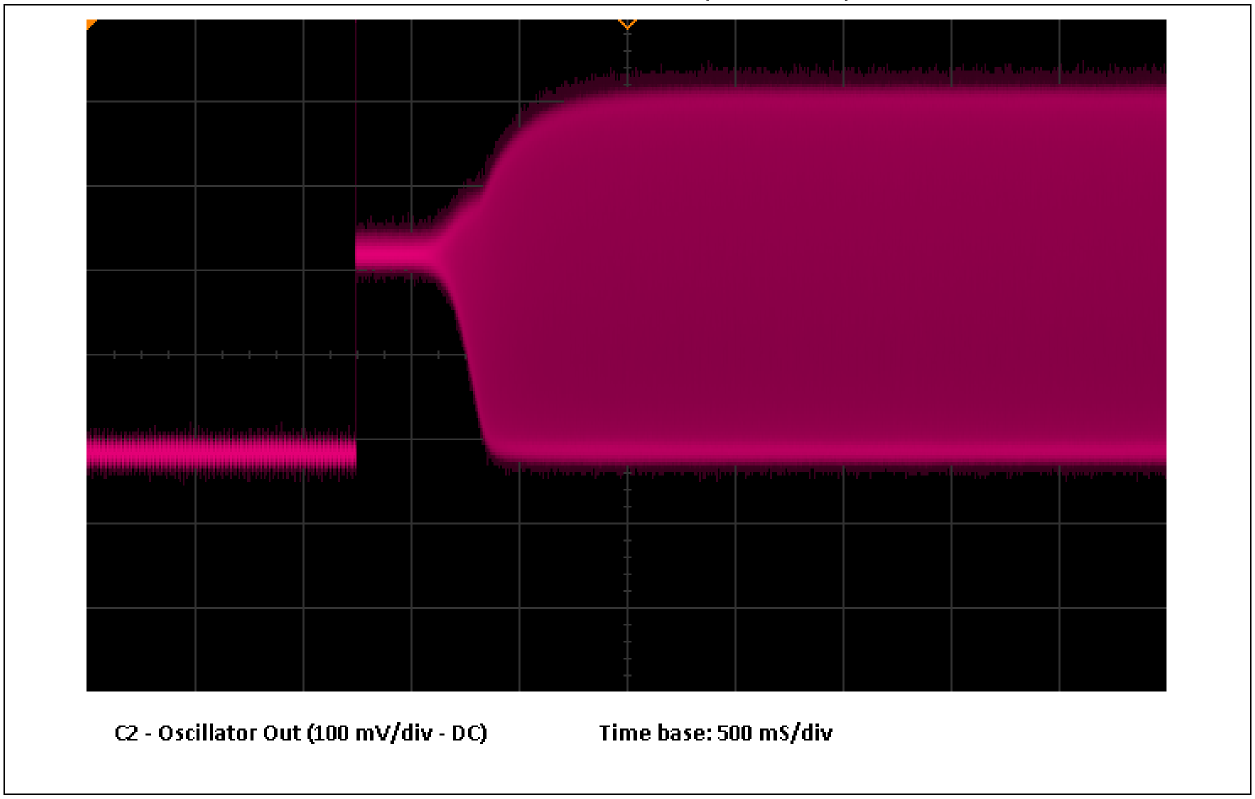
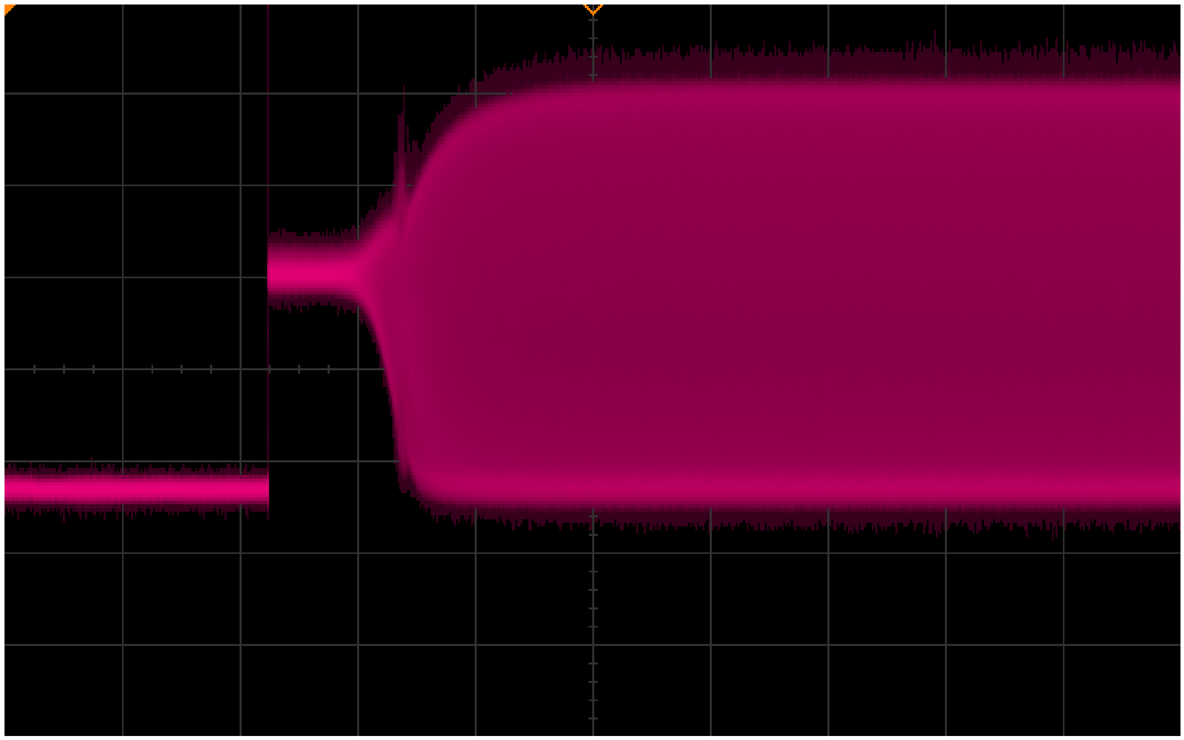
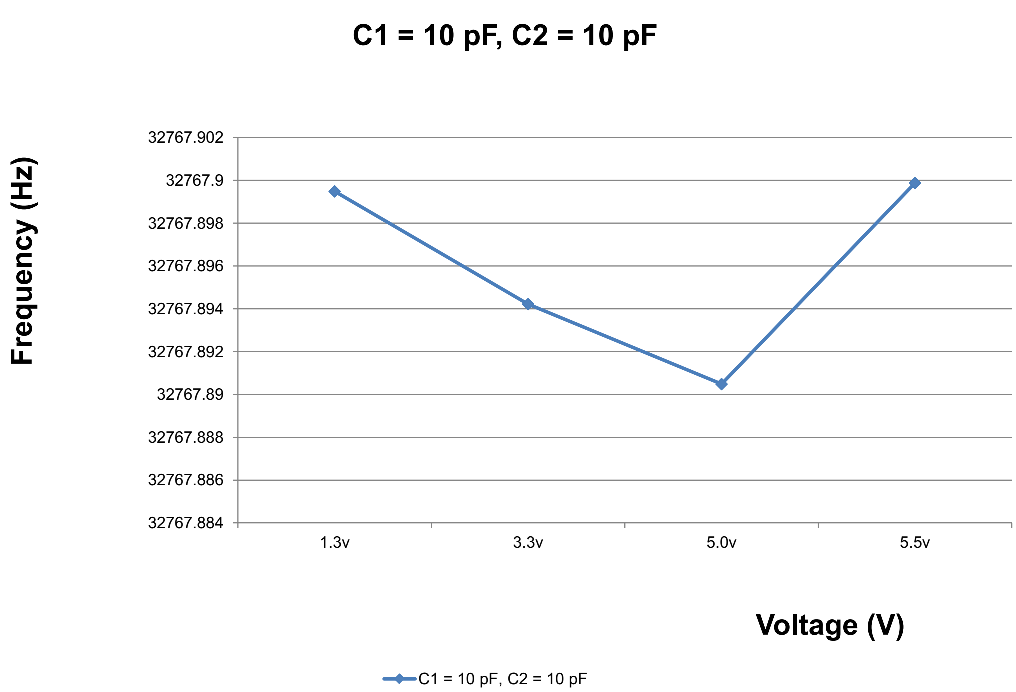


FIGURE 10: OSCILLATOR START-UP WAVEFORM (V_{CC} = 5.5V)



C2 - Oscillator Out (100 mV/div - DC)   Time base: 500 mS/div

FIGURE 11: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 10 PF; C2 = 10 PF



APPENDIX B: CMR-32.768KDZB-UB

FIGURE 12: OSCILLATOR INPUT AND OUTPUT WAVEFORM (V_{BAT} = 1.3V, V_{CC} = 1.3V)

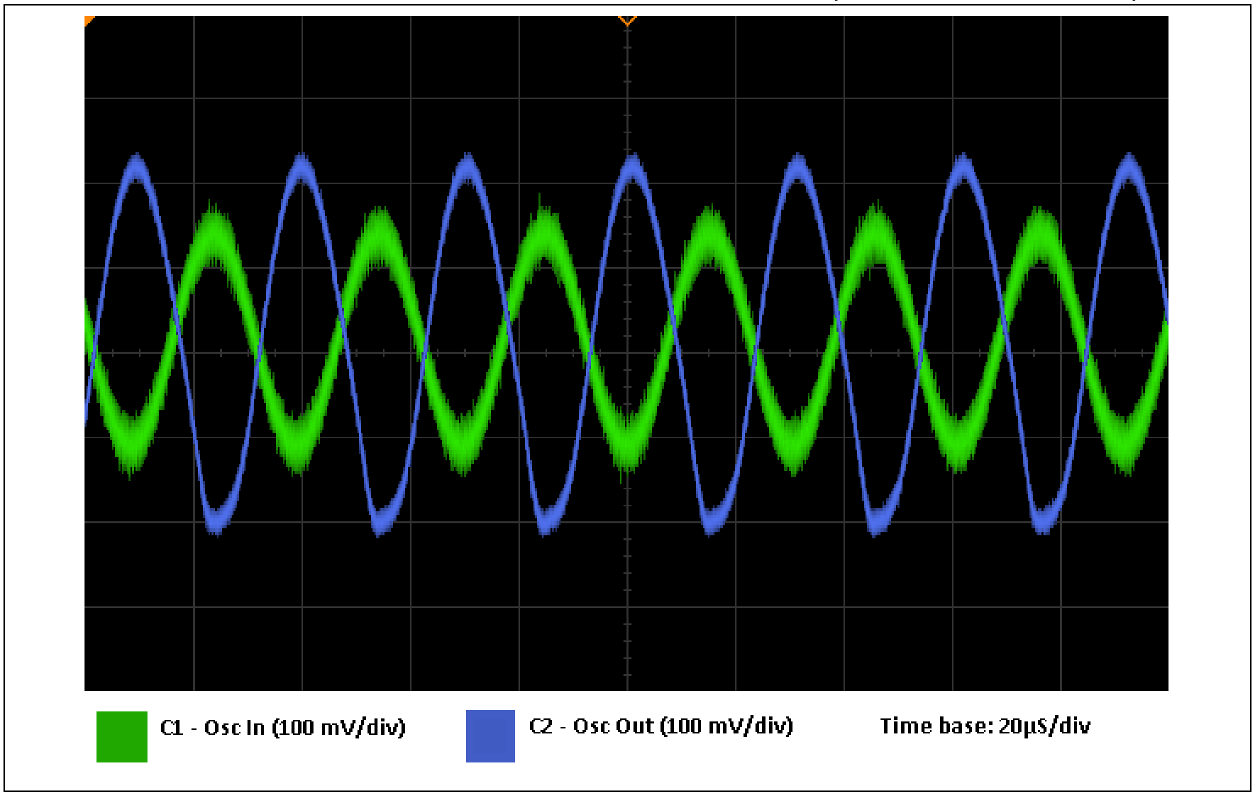


FIGURE 13: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 3.3V)

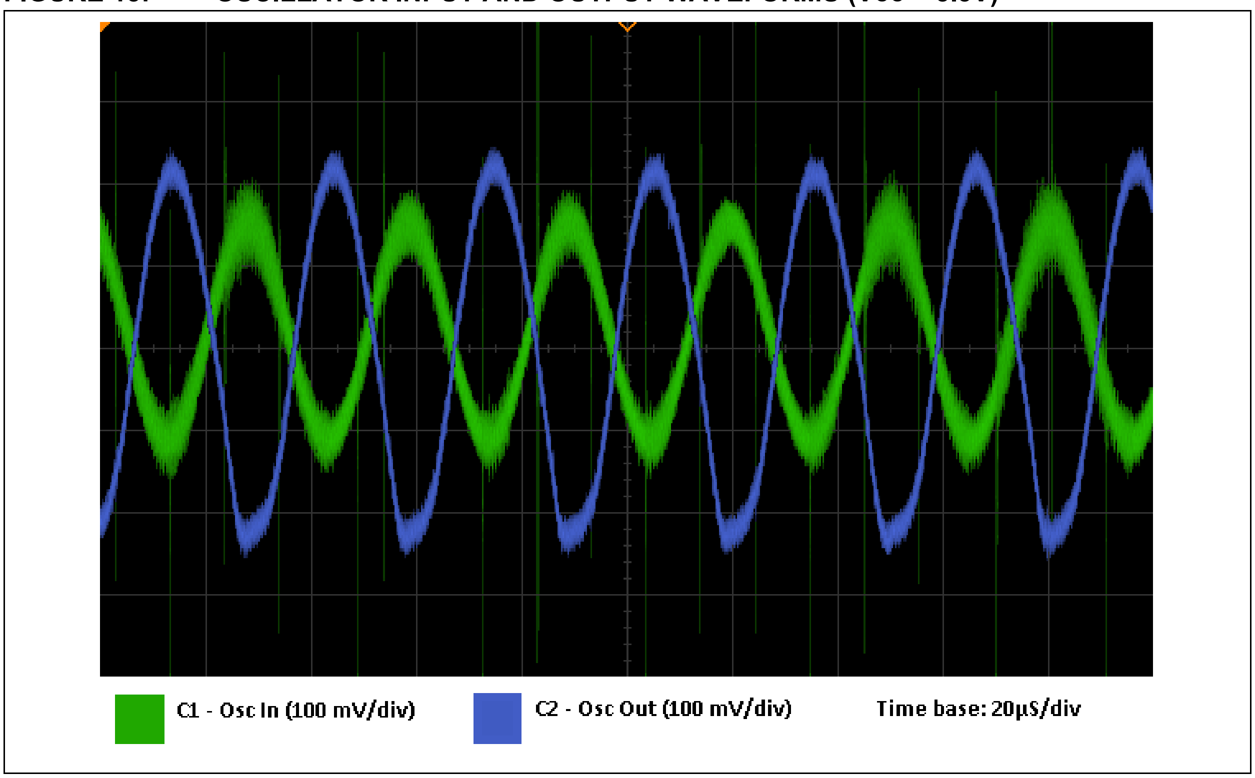


FIGURE 14: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (VCC = 5.0V)

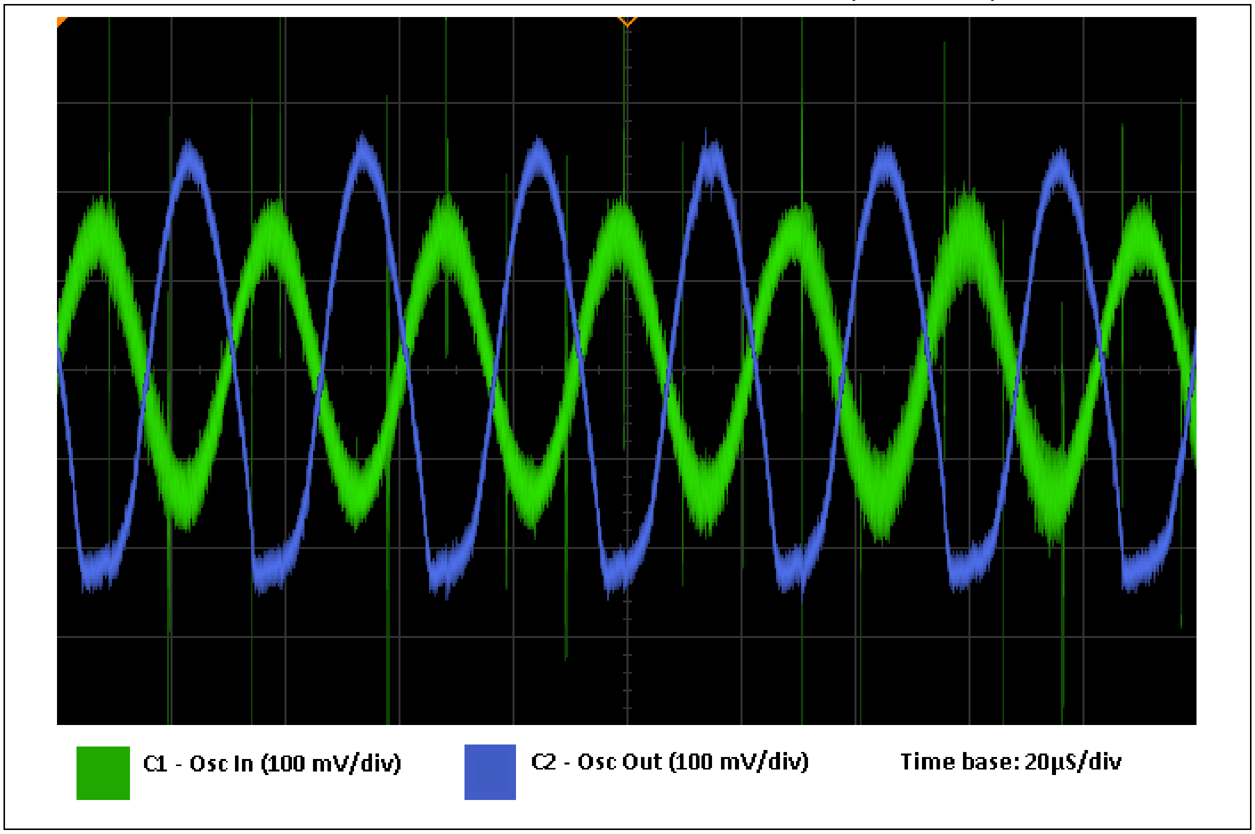


FIGURE 15: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (VCC = 5.5V)

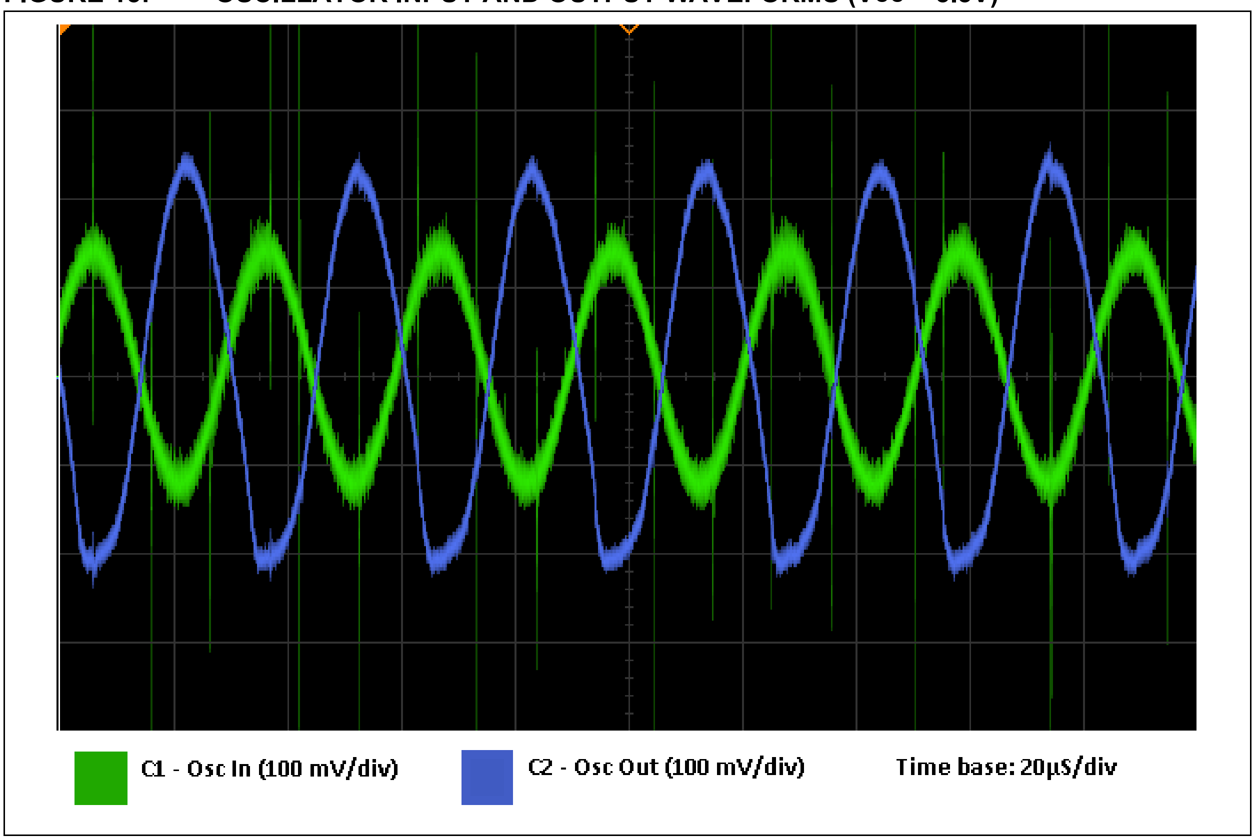


FIGURE 16: OSCILLATOR START-UP WAVEFORM (Vcc = 3.3V)

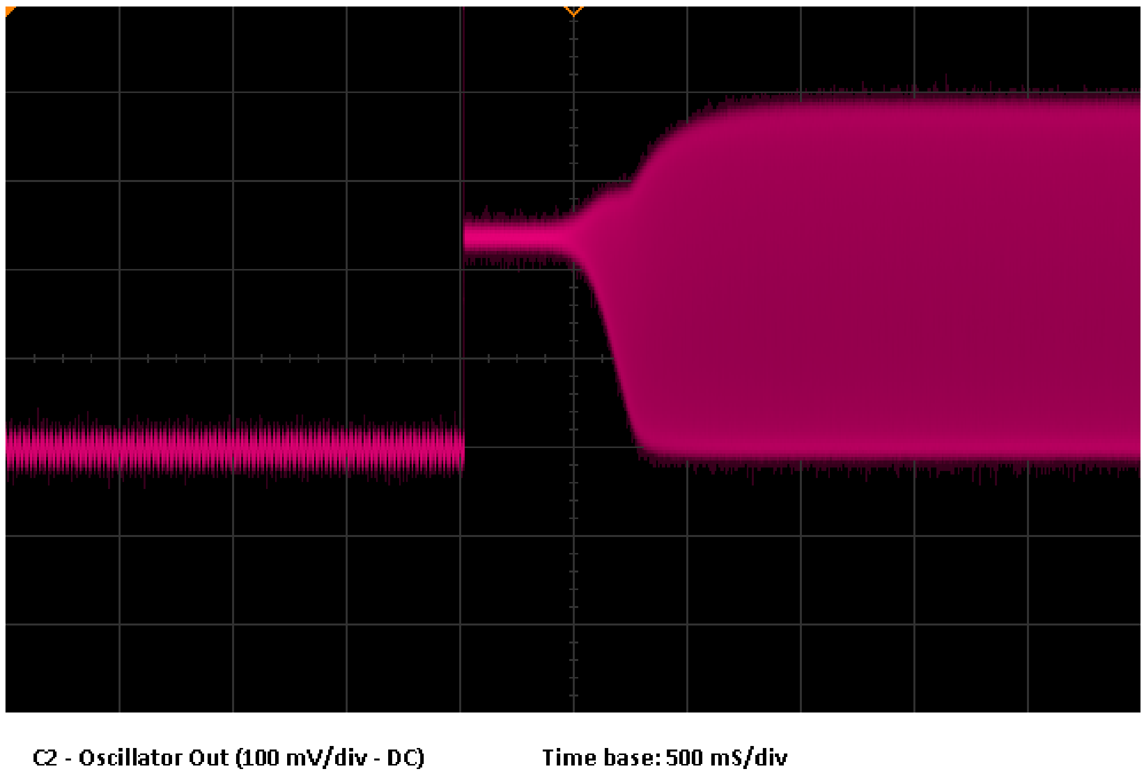


FIGURE 17: OSCILLATOR START-UP WAVEFORM (Vcc = 5.0V)

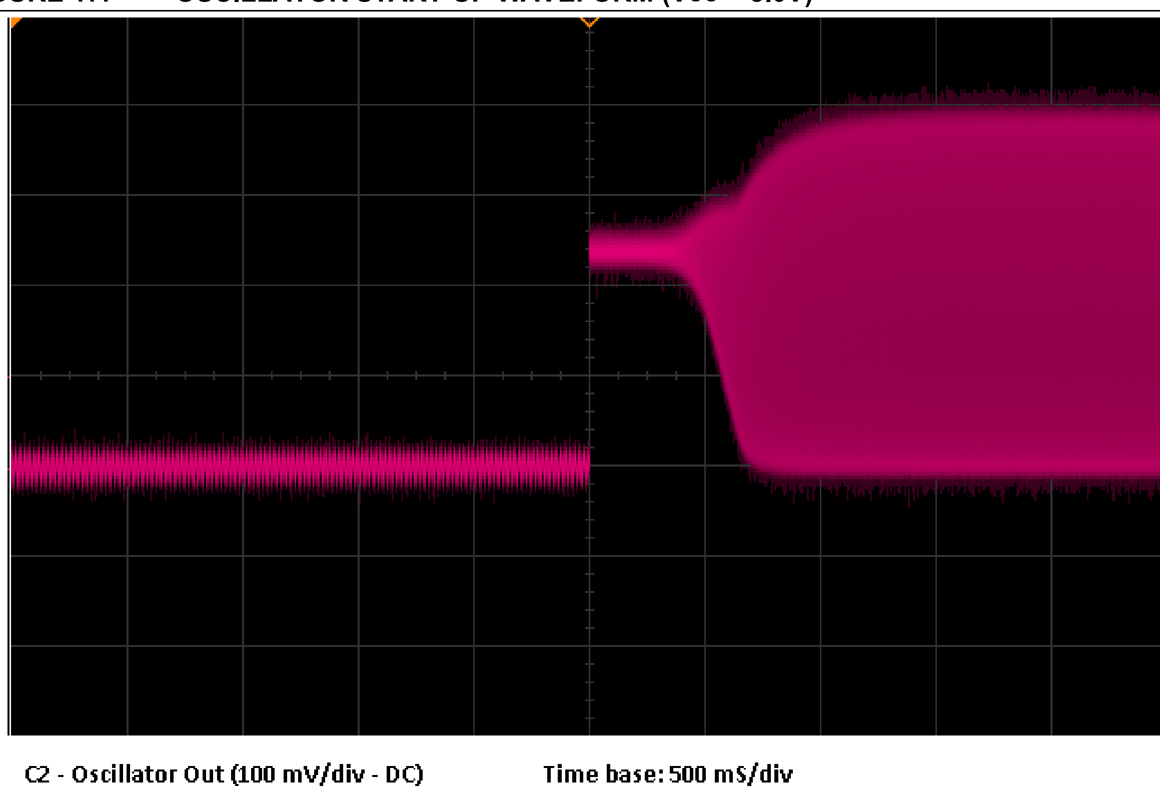


FIGURE 18: OSCILLATOR START-UP WAVEFORM (VCC = 5.5V)

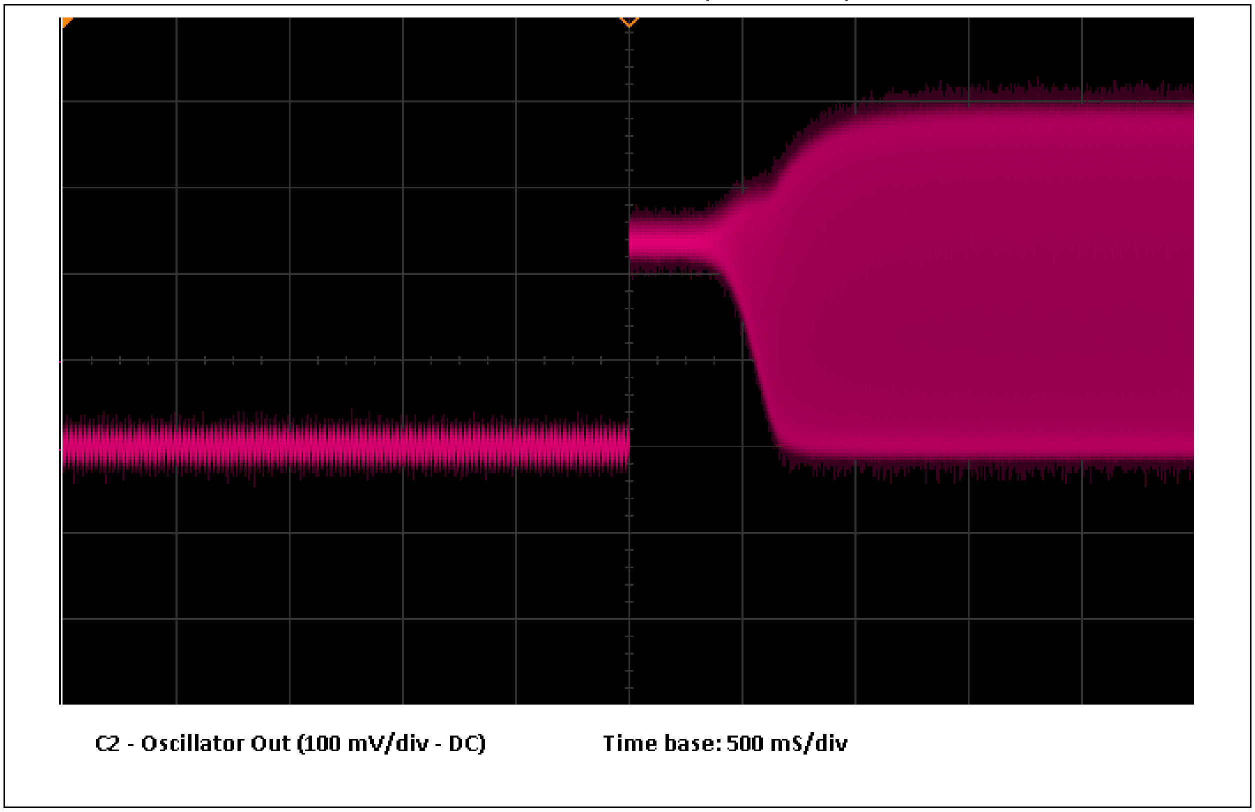
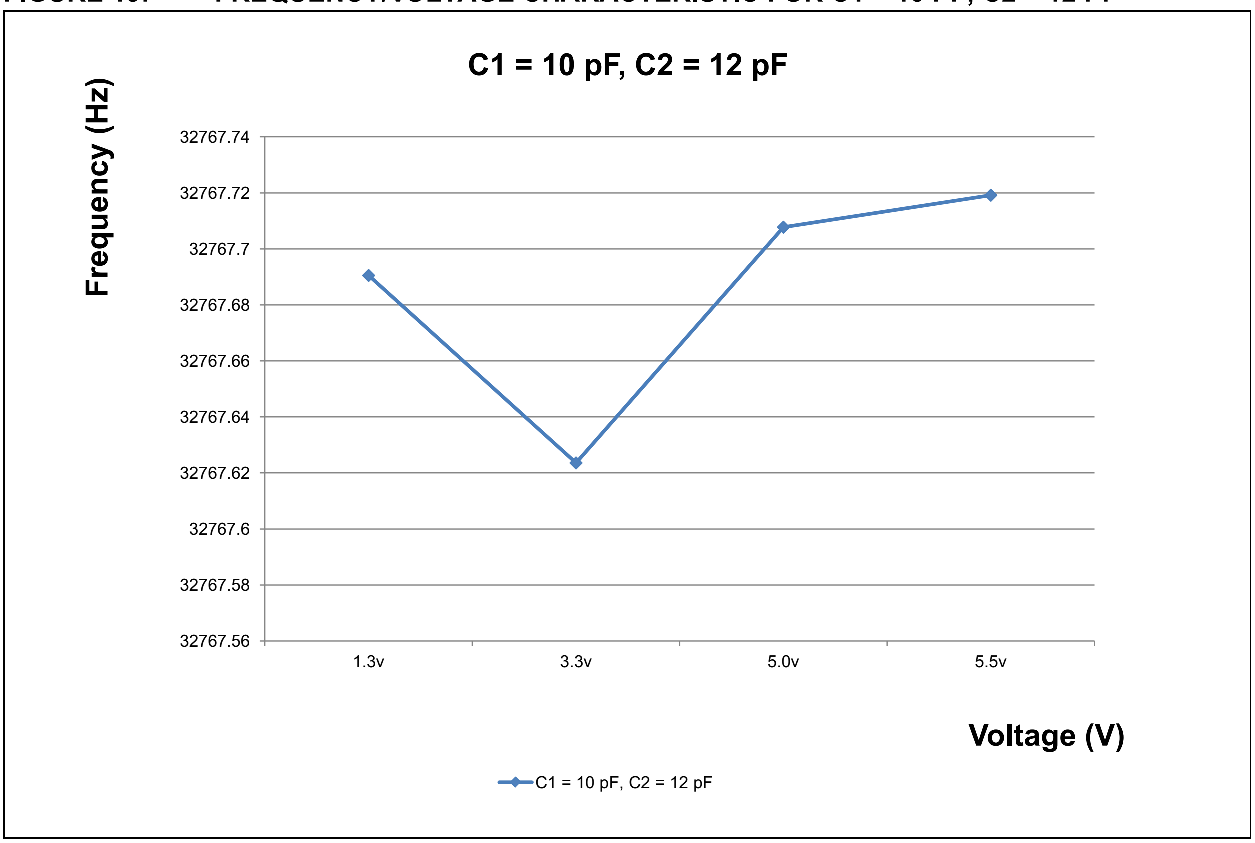


FIGURE 19: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 10 PF; C2 = 12 PF



APPENDIX C: ECS327-6-13X

FIGURE 20: OSCILLATOR INPUT AND OUTPUT WAVEFORM (V_{BAT} = 1.3V, V_{CC} = 1.3V)

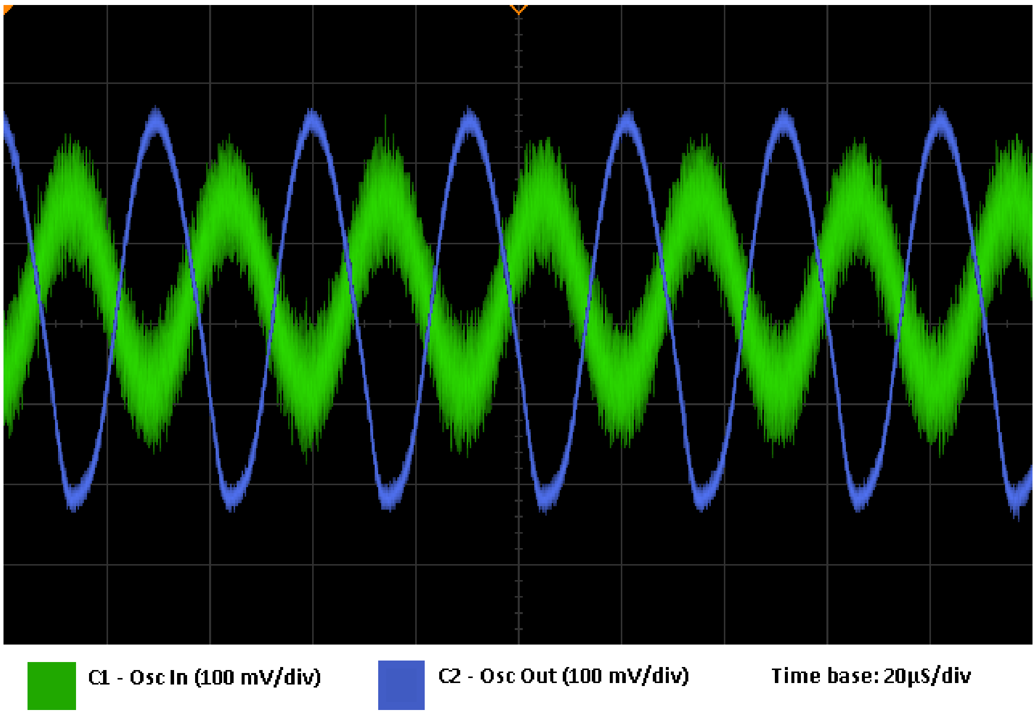


FIGURE 21: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 3.3V)

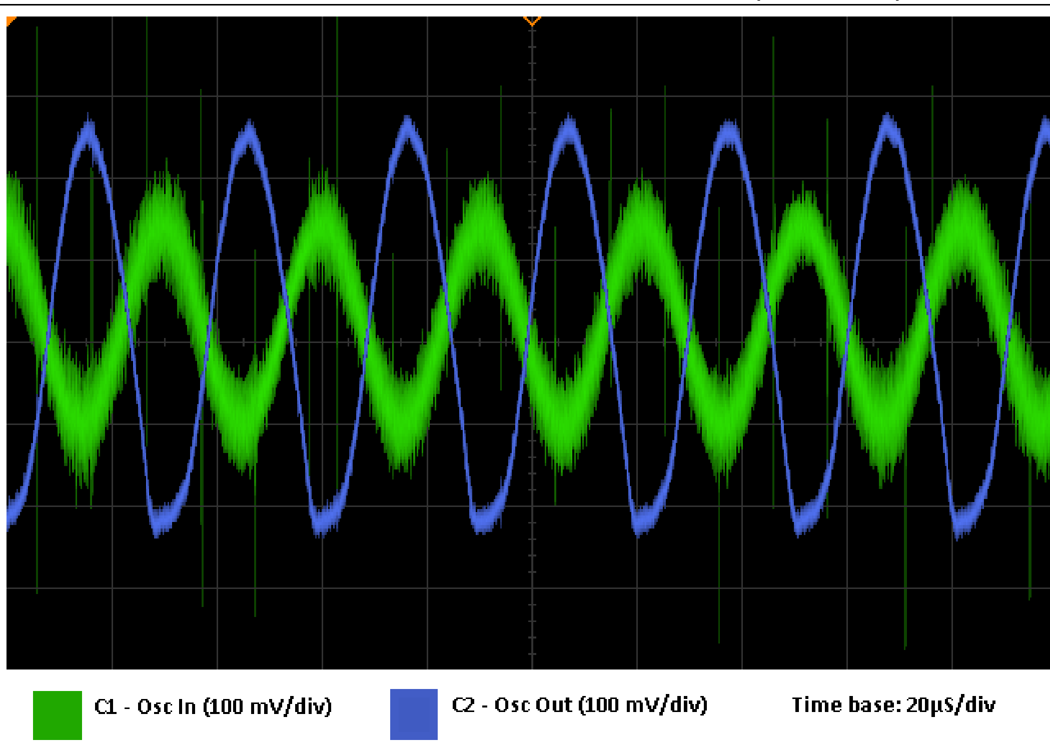


FIGURE 22: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (VCC = 5.0V)

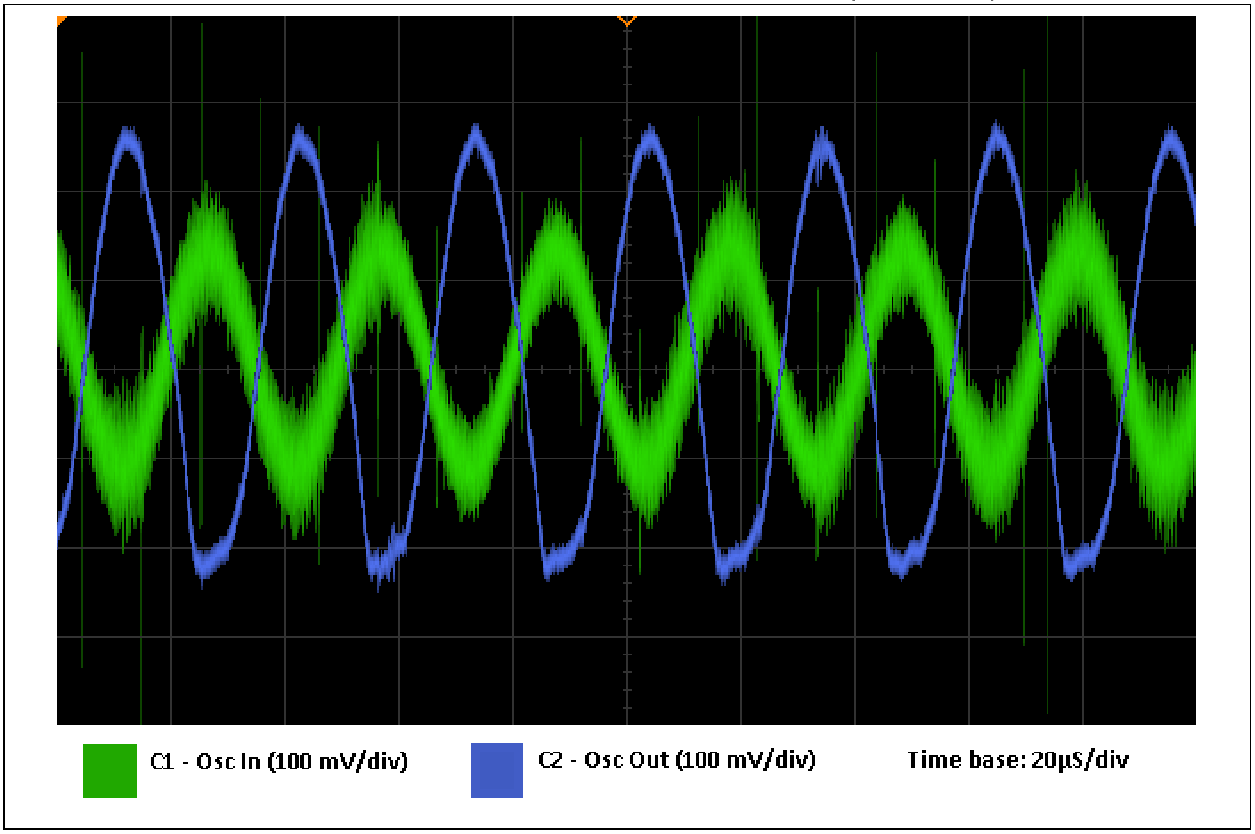


FIGURE 23: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (VCC = 5.5V)

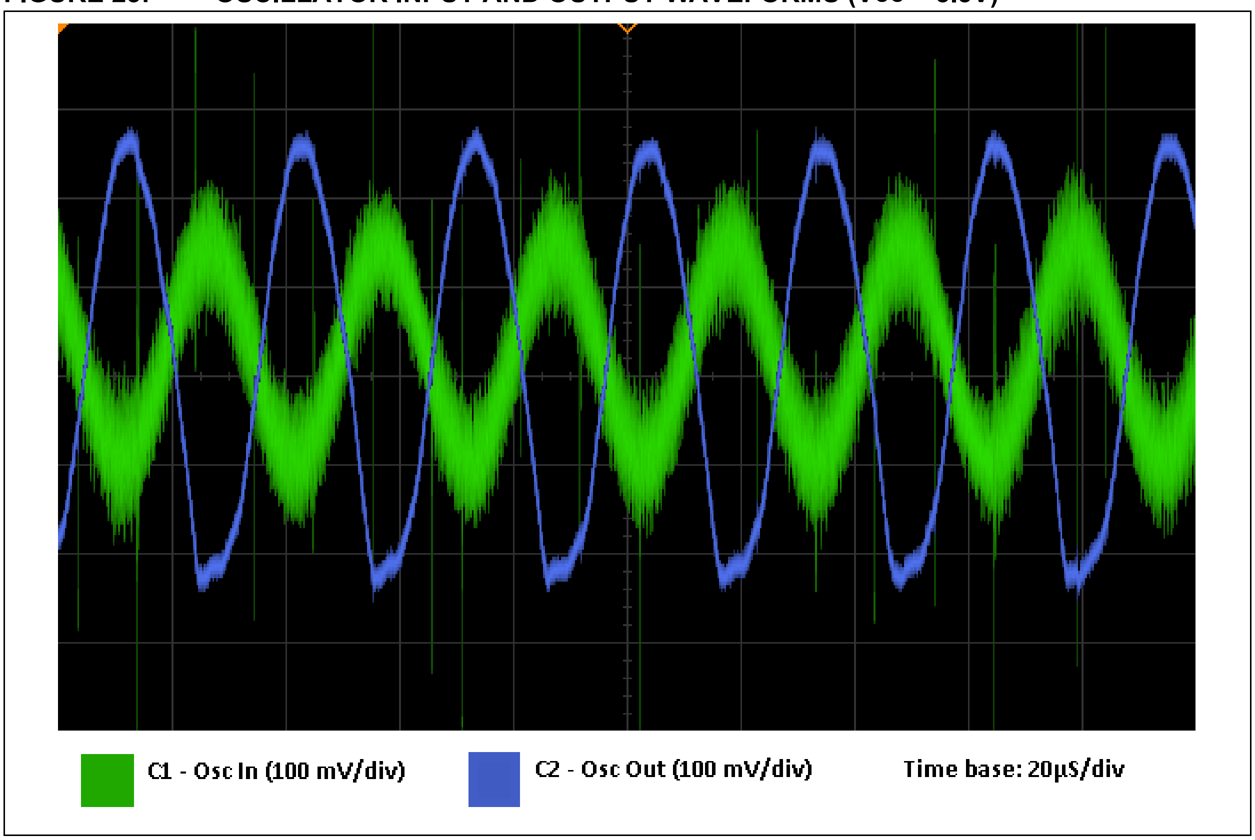


FIGURE 24: OSCILLATOR START-UP WAVEFORM (Vcc = 3.3V)

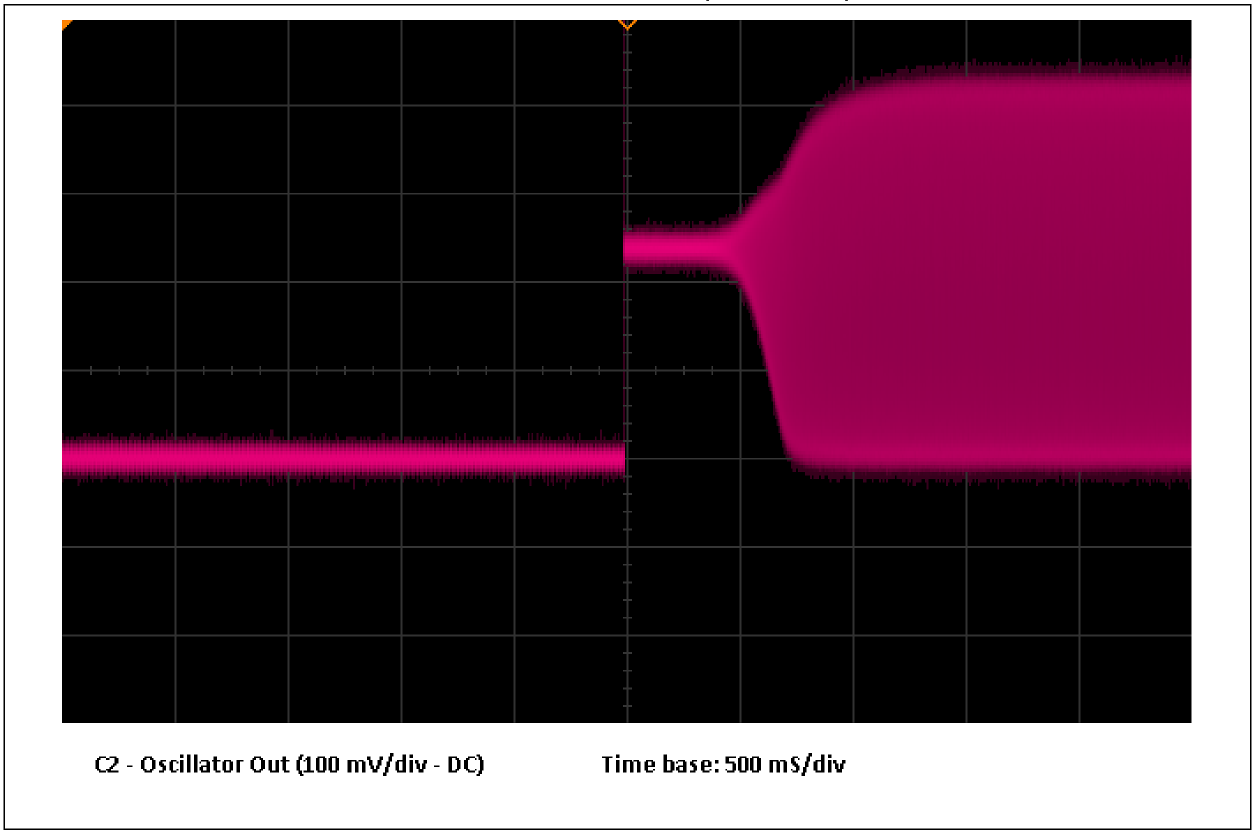


FIGURE 25: OSCILLATOR START-UP WAVEFORM (Vcc = 5.0V)

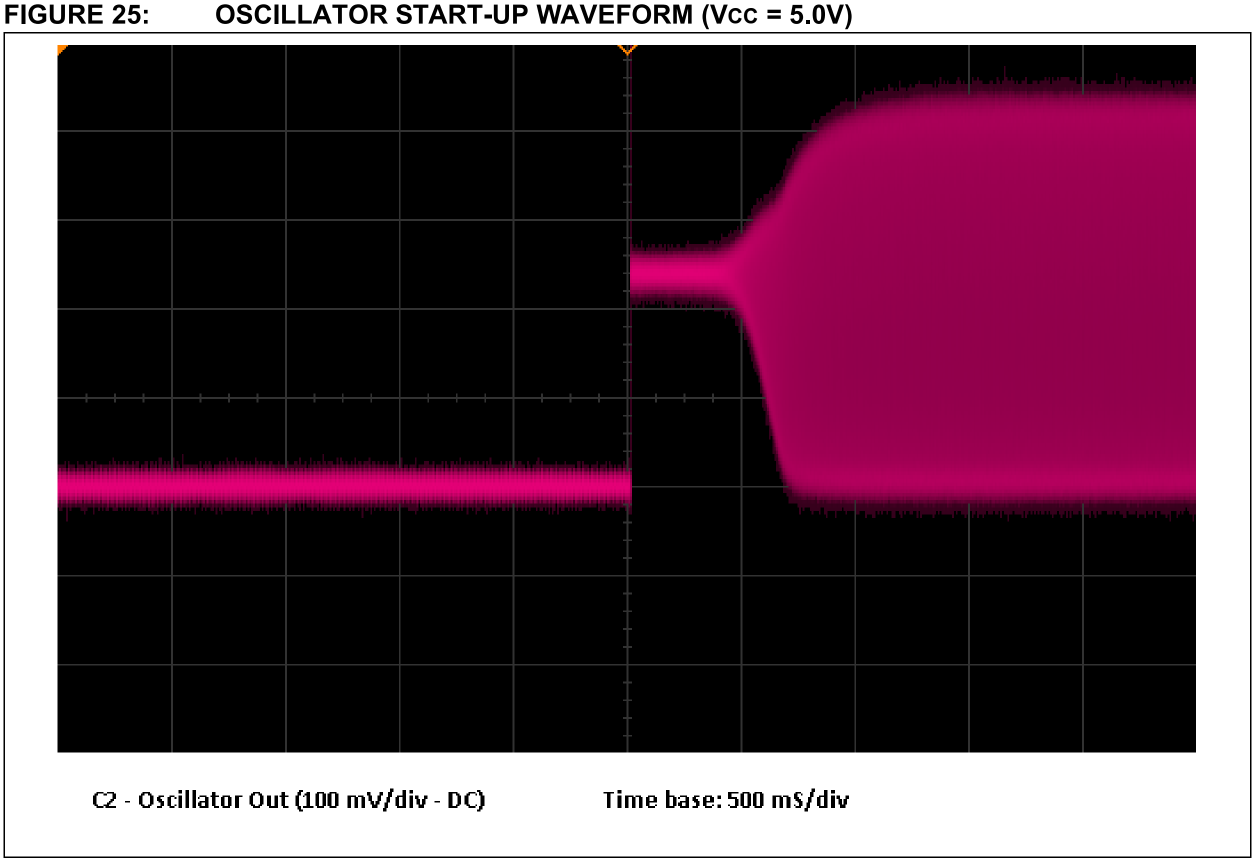


FIGURE 26: OSCILLATOR START-UP WAVEFORM (V_{CC} = 5.5V)

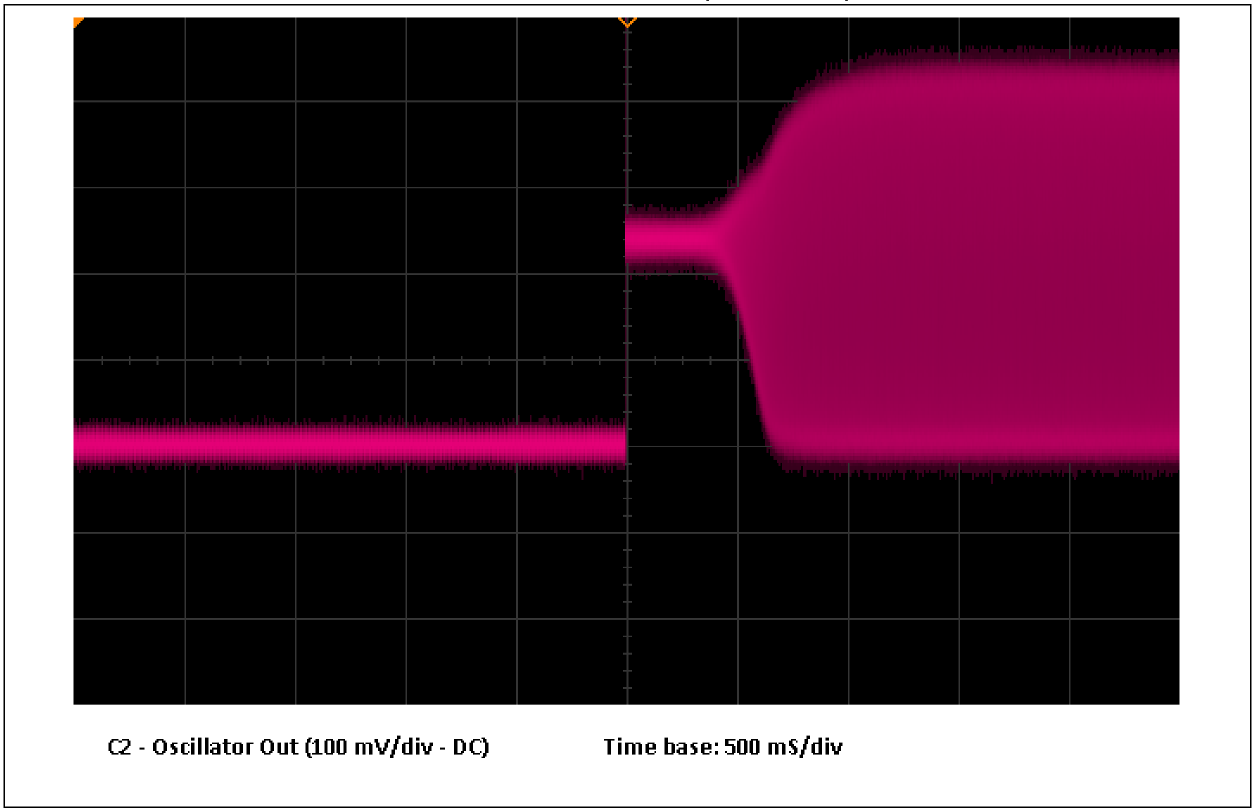
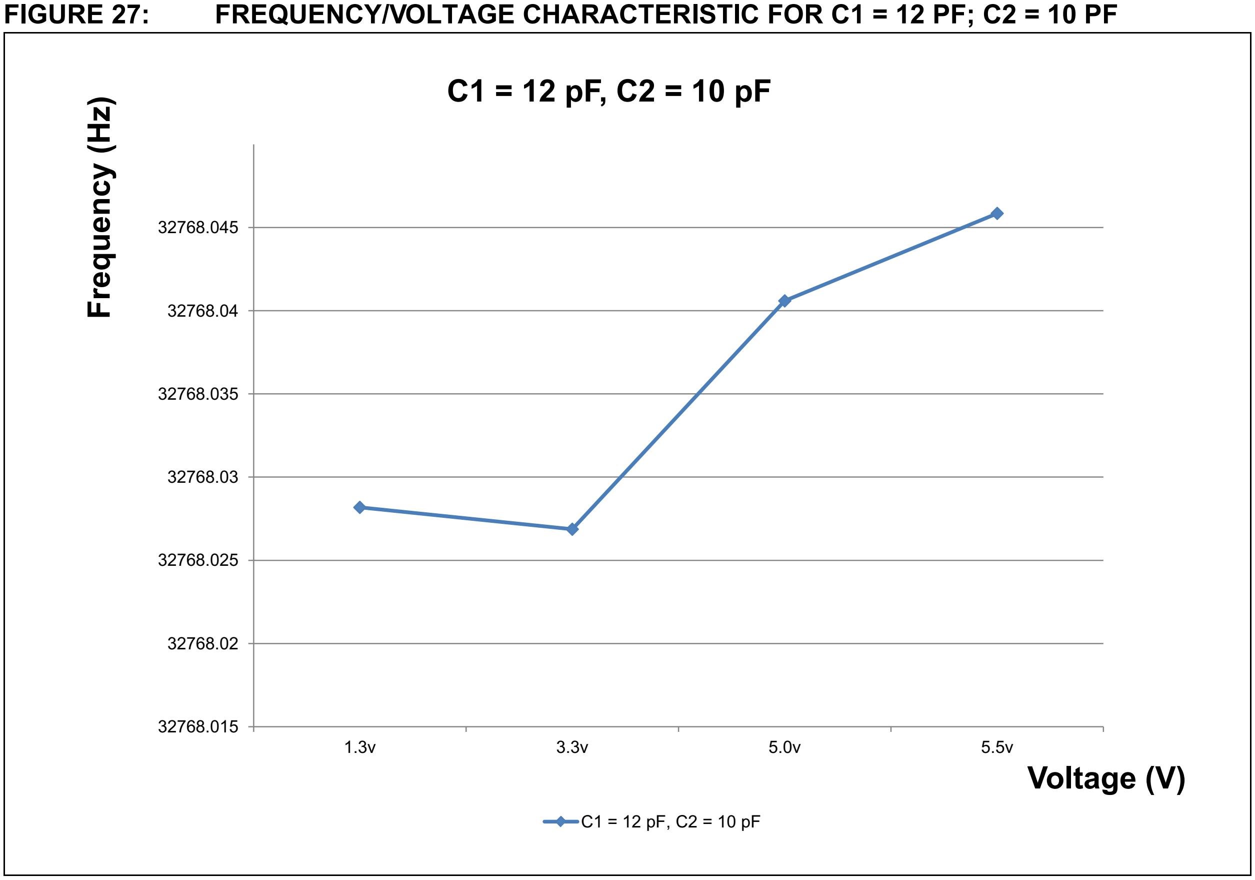


FIGURE 27: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 12 PF; C2 = 10 PF



APPENDIX D: ECS.327-6-17X-TR

FIGURE 28: OSCILLATOR INPUT AND OUTPUT WAVEFORM (VBAT = 1.3VL, VCC = 1.3V)

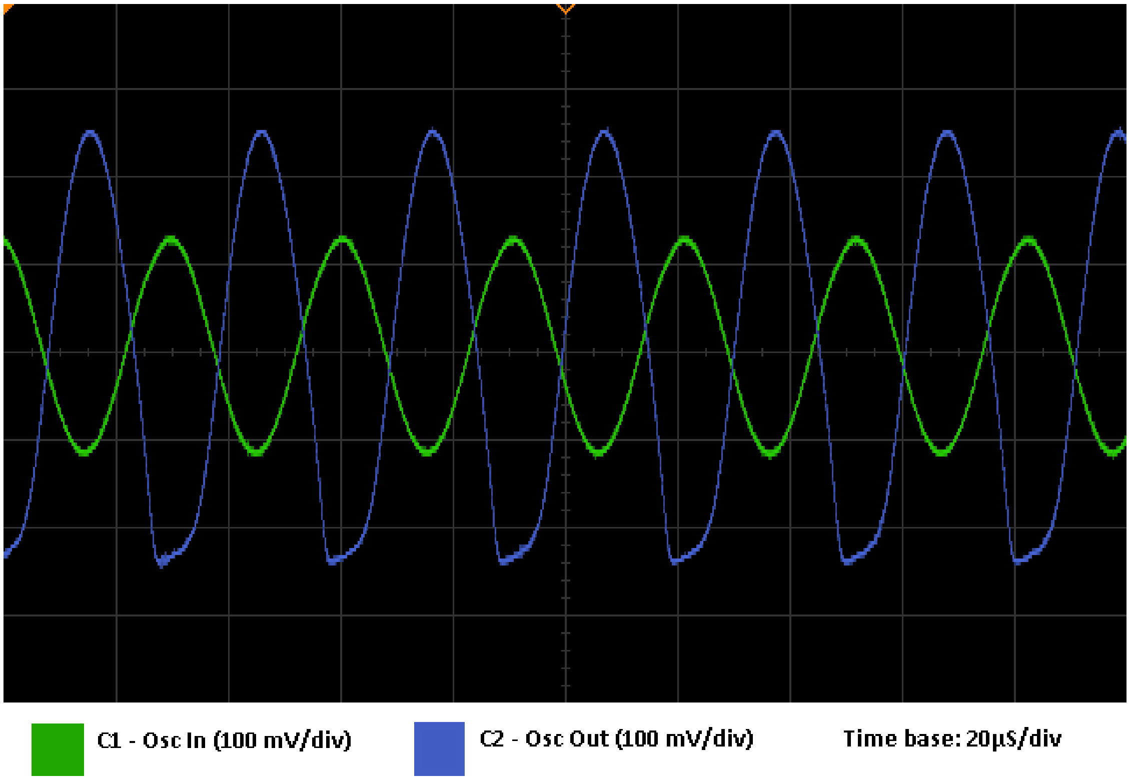


FIGURE 29: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (VCC = 3.3V)

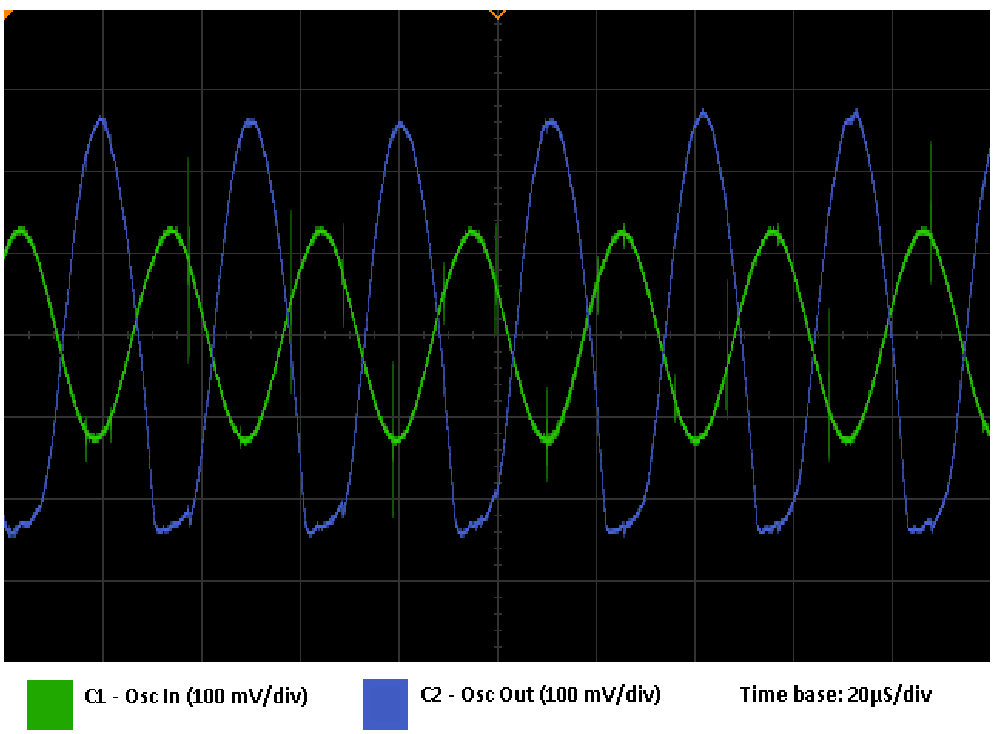


FIGURE 30: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.0V)

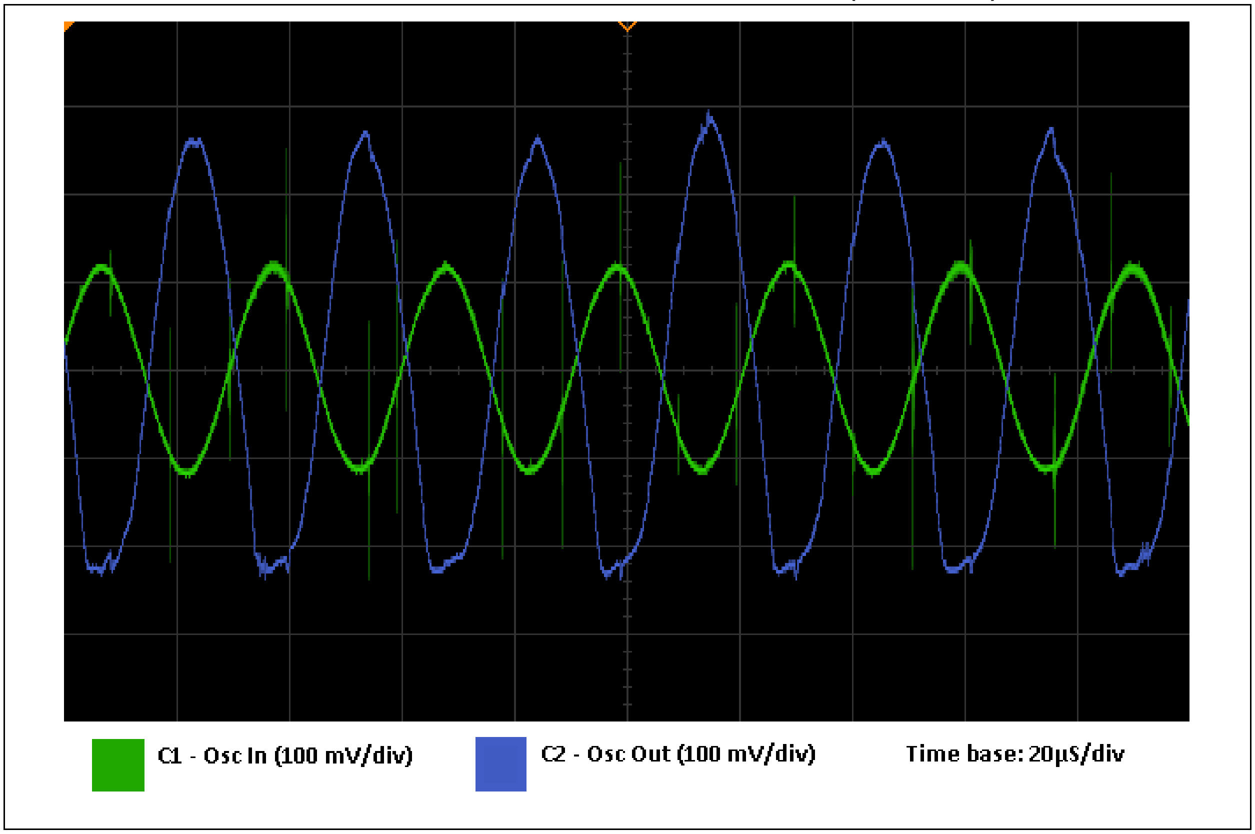


FIGURE 31: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.5V)

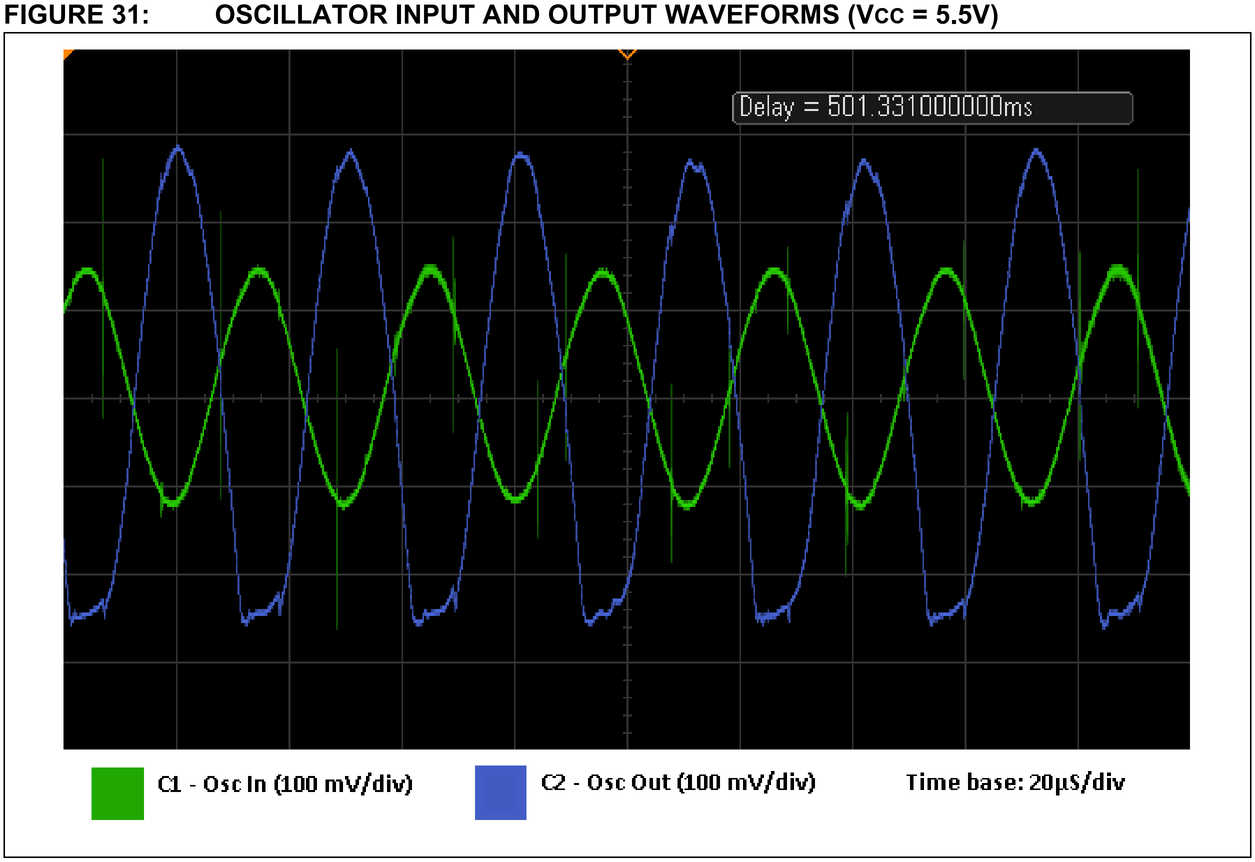


FIGURE 32: OSCILLATOR START-UP WAVEFORM (Vcc = 3.3V)

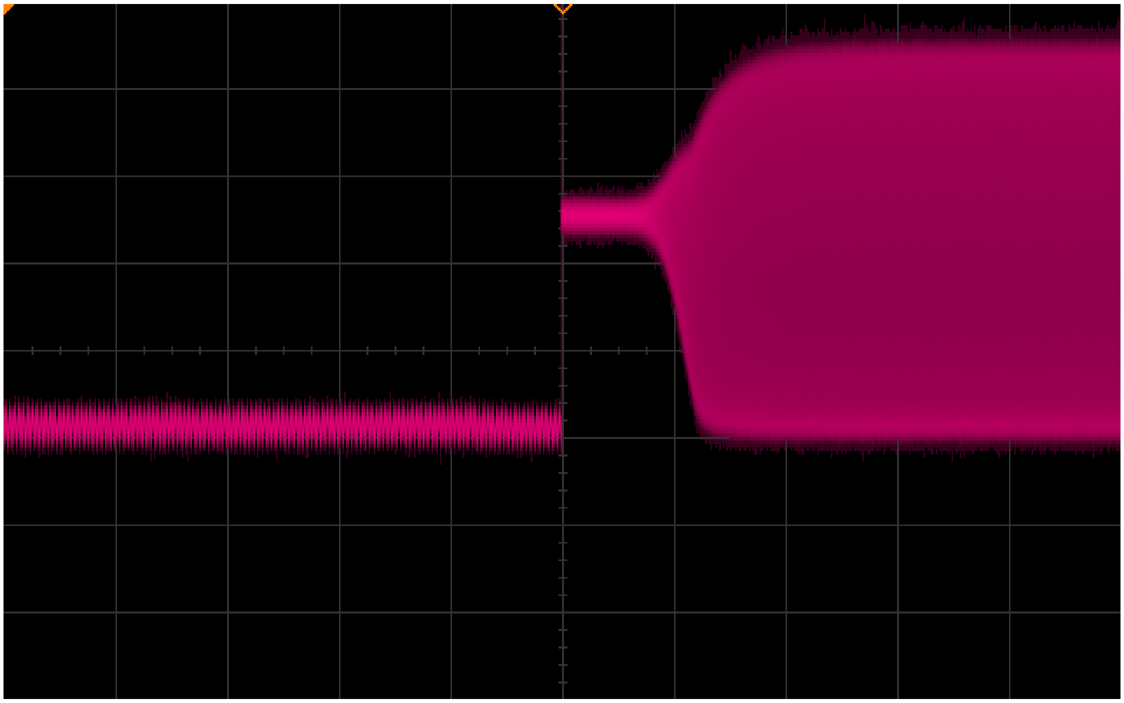


FIGURE 33: OSCILLATOR START-UP WAVEFORM (Vcc = 5.0V)

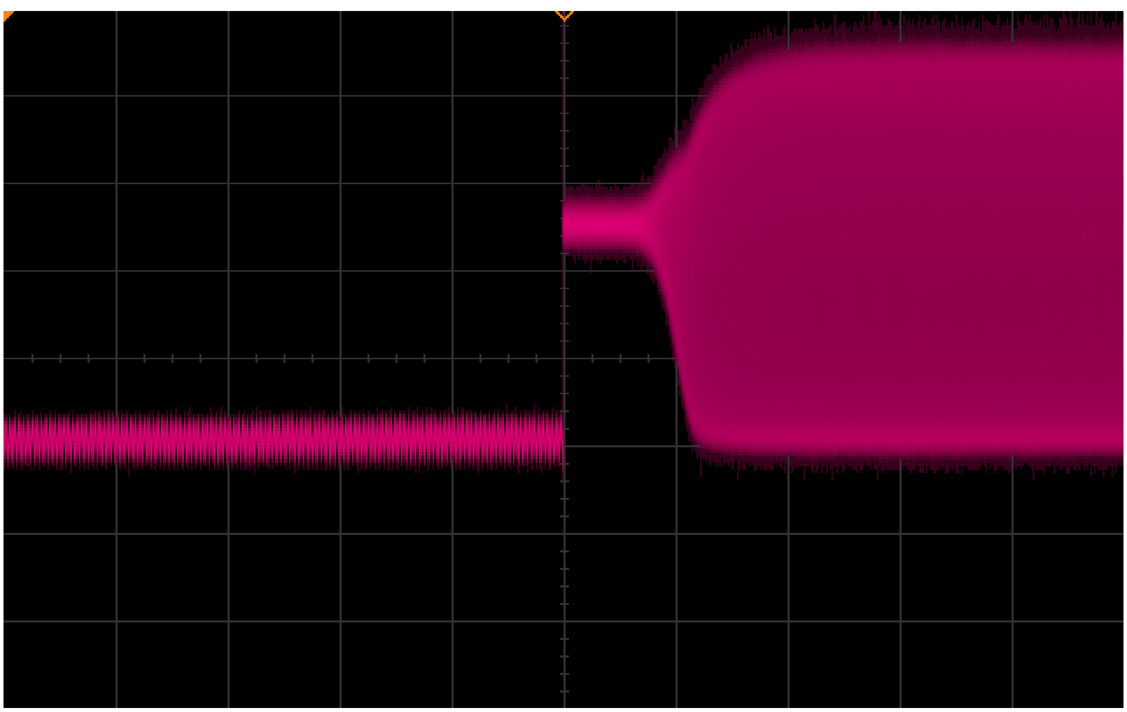


FIGURE 34: OSCILLATOR START-UP WAVEFORM (VCC = 5.5V)

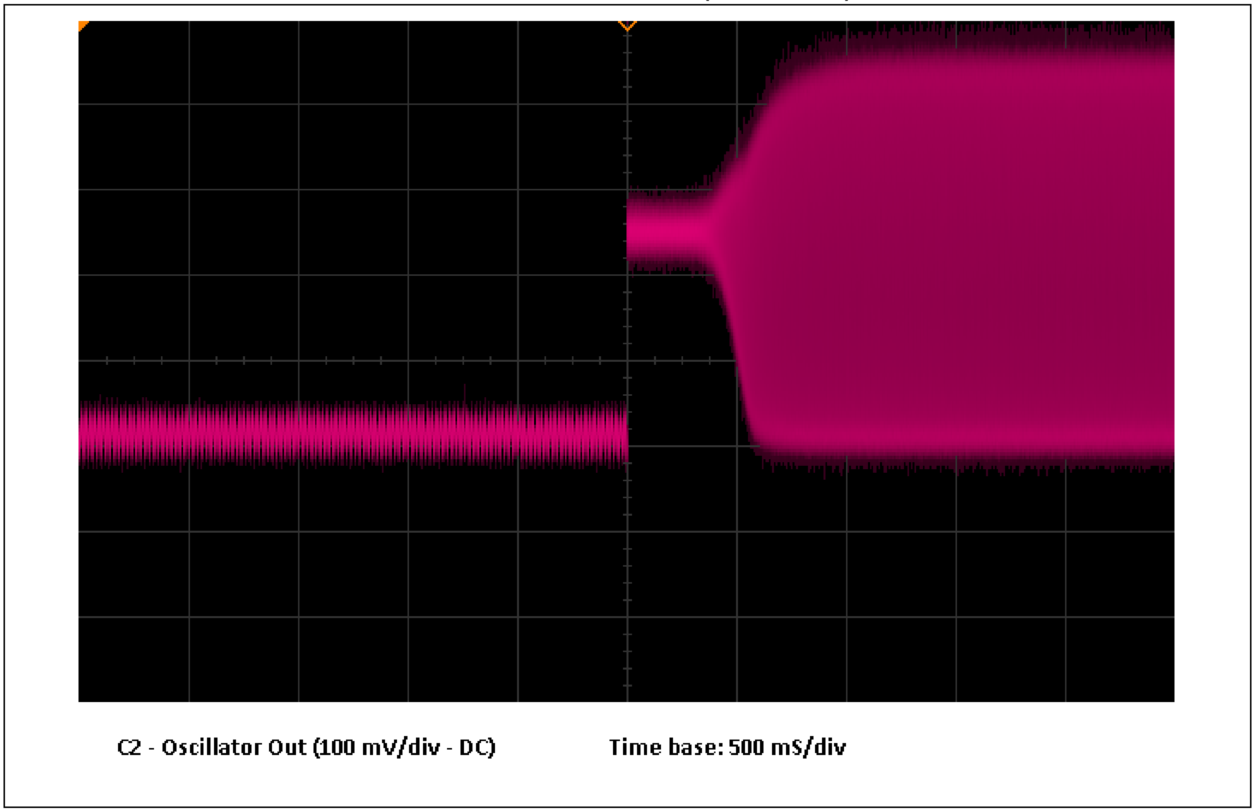
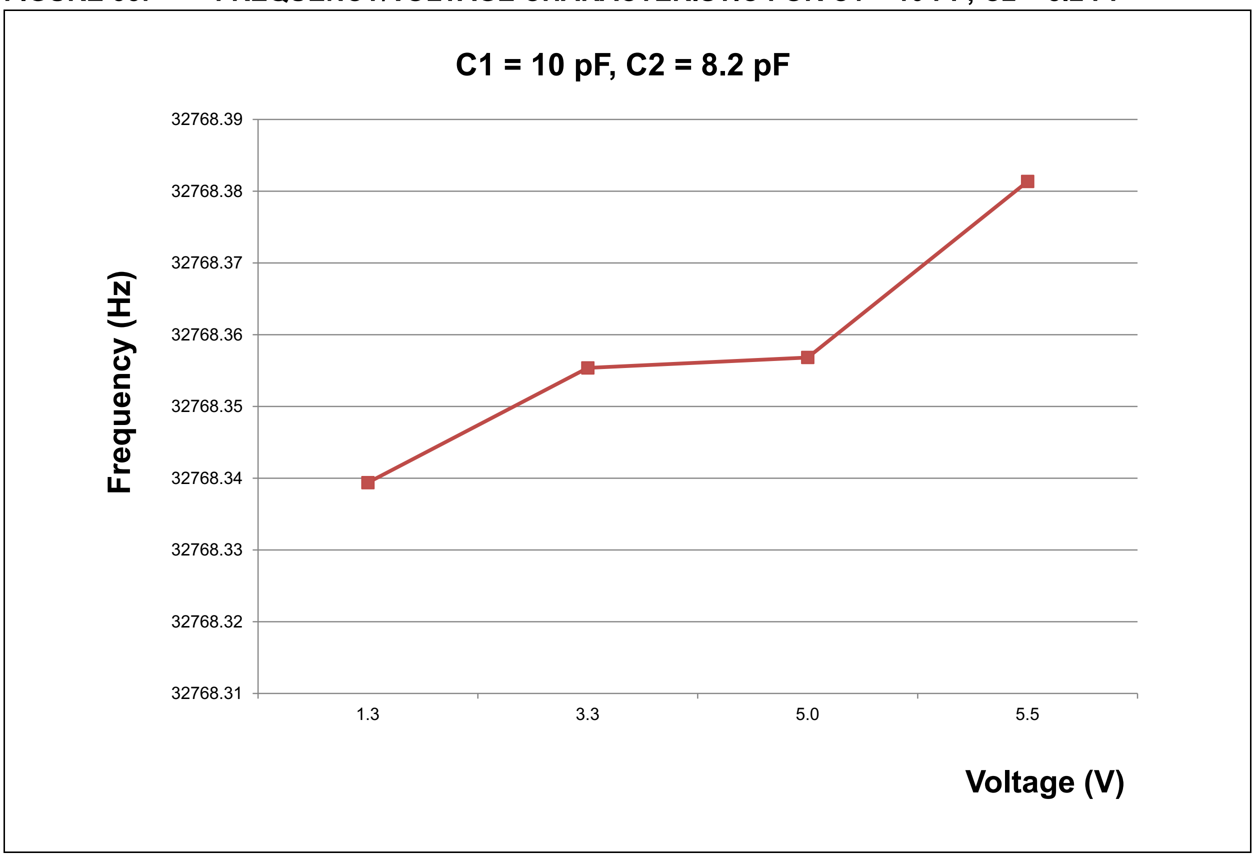


FIGURE 35: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 10 PF; C2 = 8.2 PF



APPENDIX E: EPSON MC405-32.7KE3R

FIGURE 36: OSCILLATOR INPUT AND OUTPUT WAVEFORM (V_{BAT} = 1.3V, V_{CC} = 1.3V)

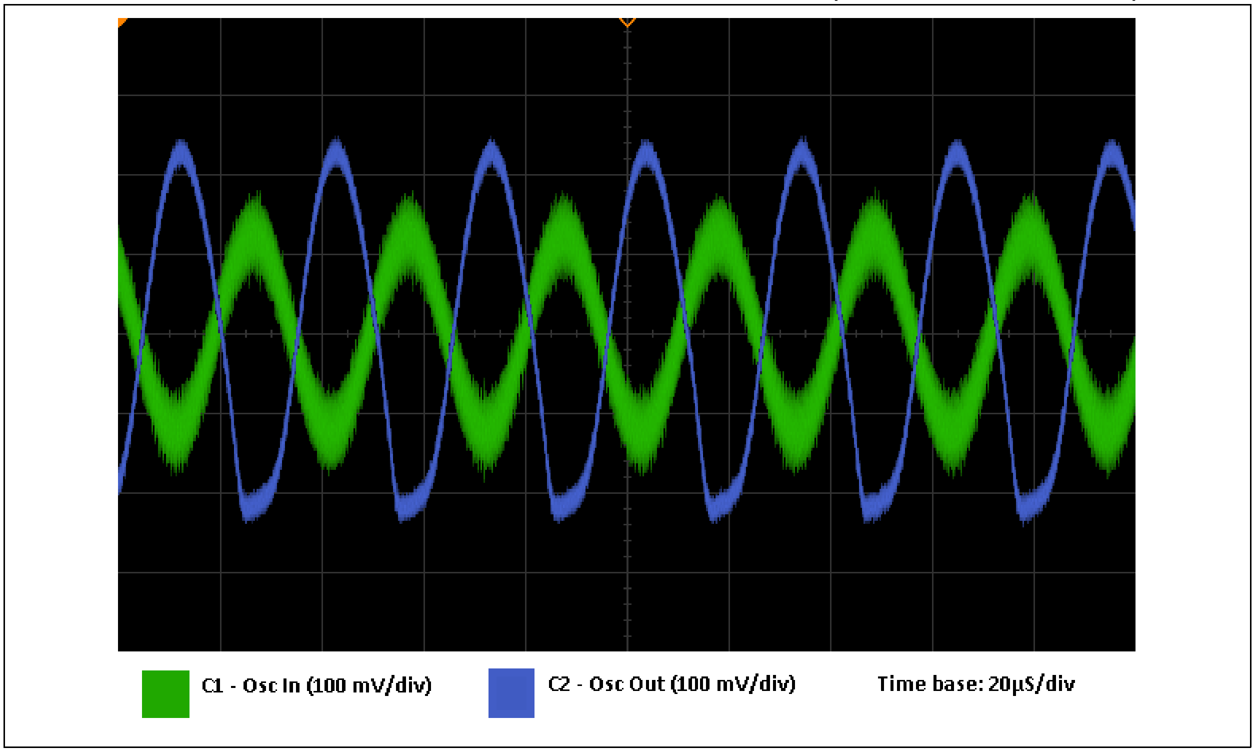


FIGURE 37: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 3.3V)

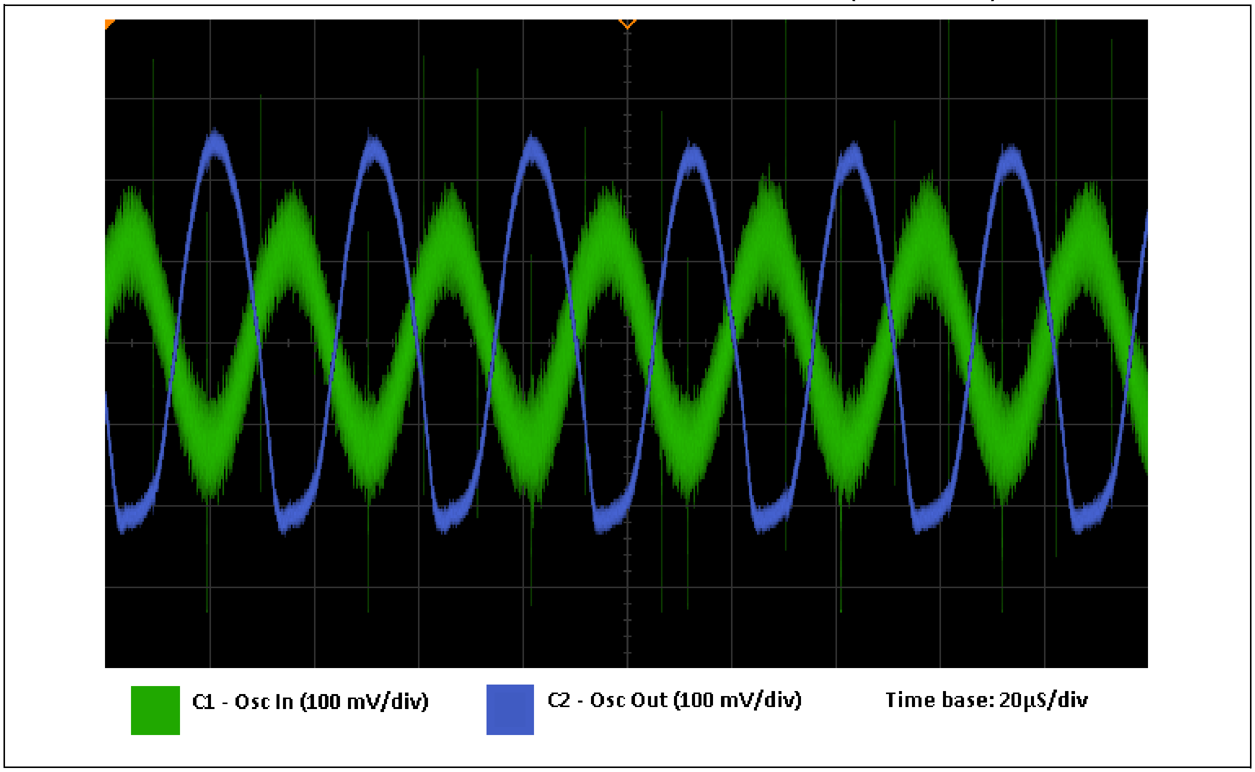


FIGURE 38: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (VCC = 5.0V)

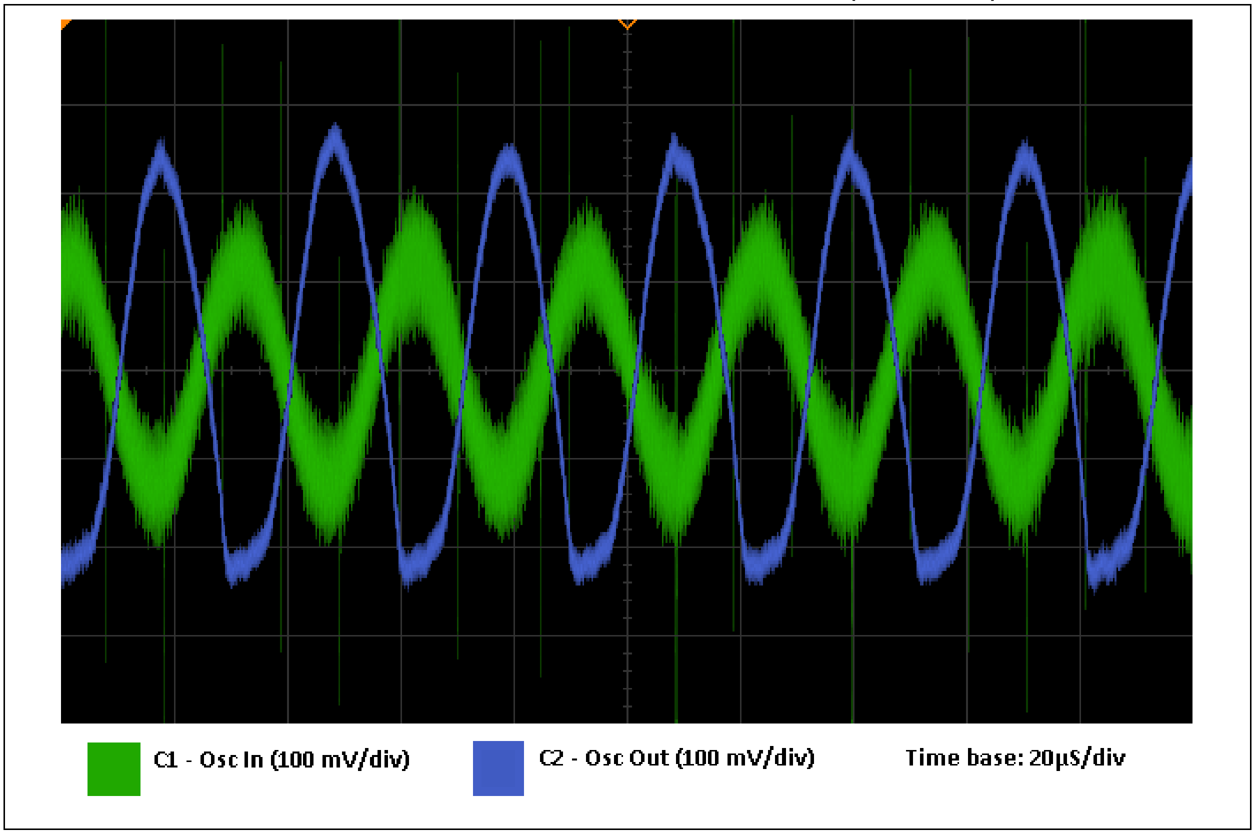


FIGURE 39: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (VCC = 5.5V)

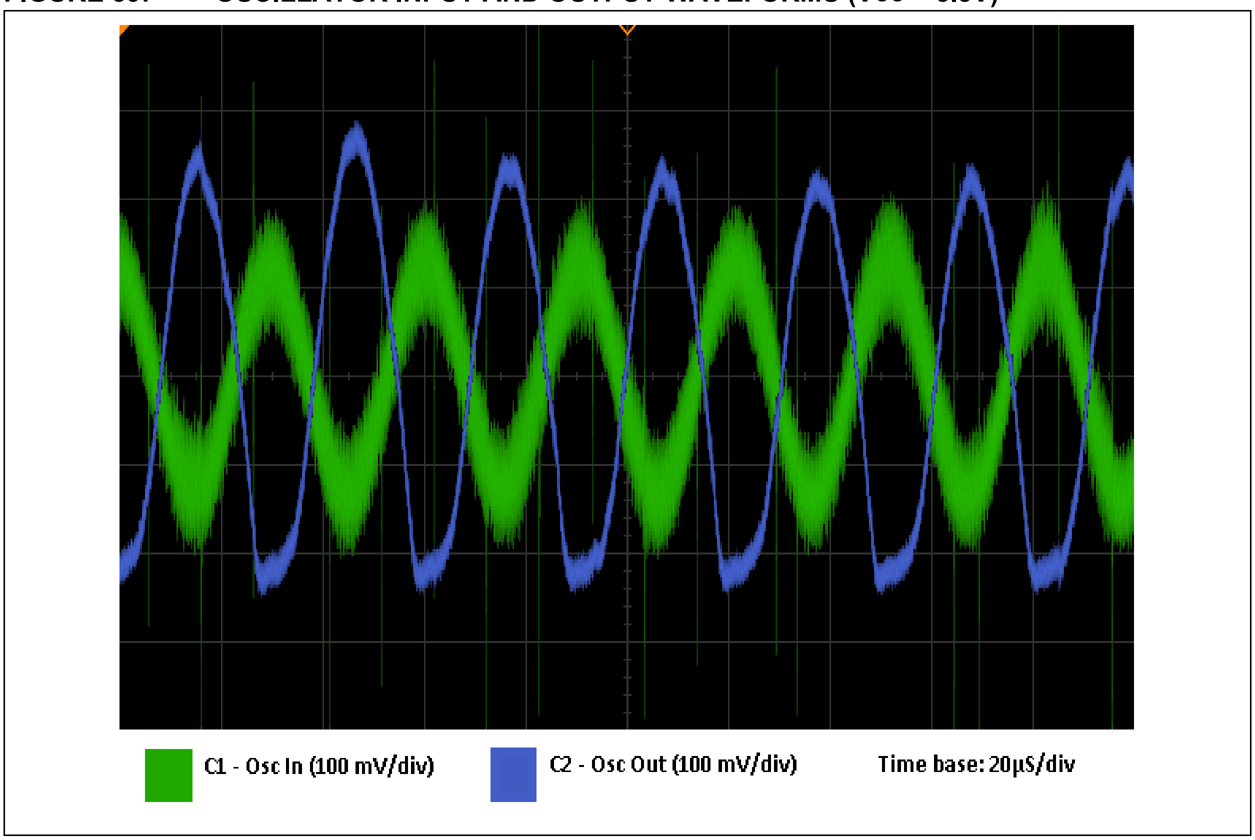
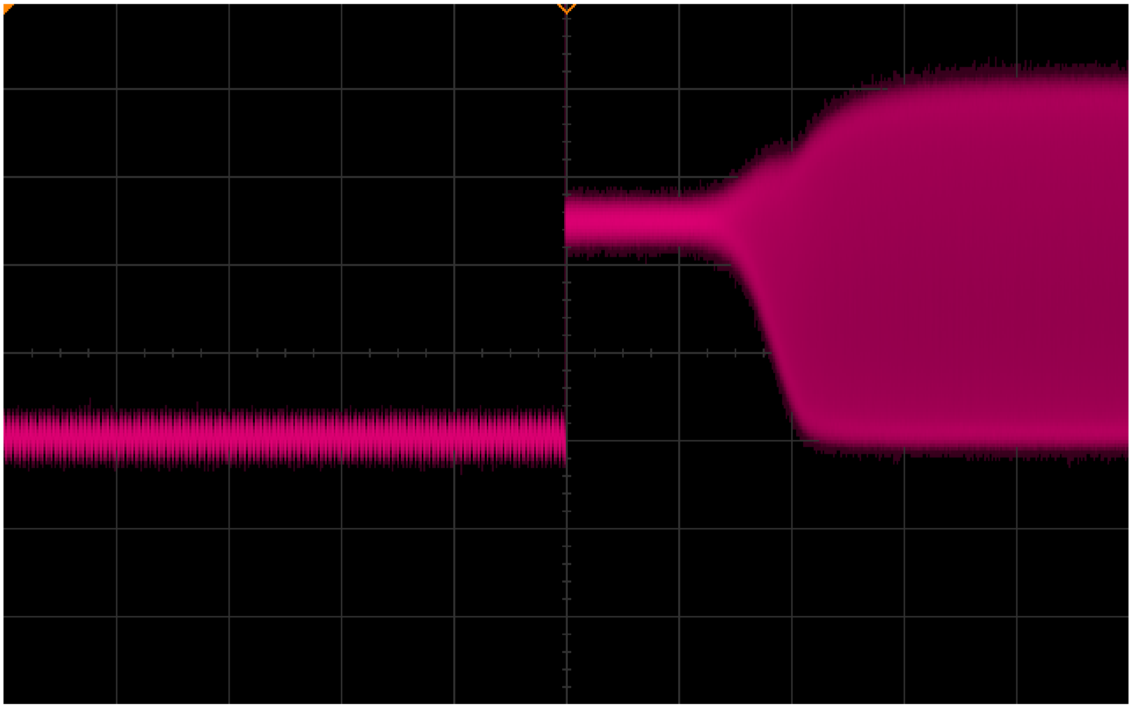
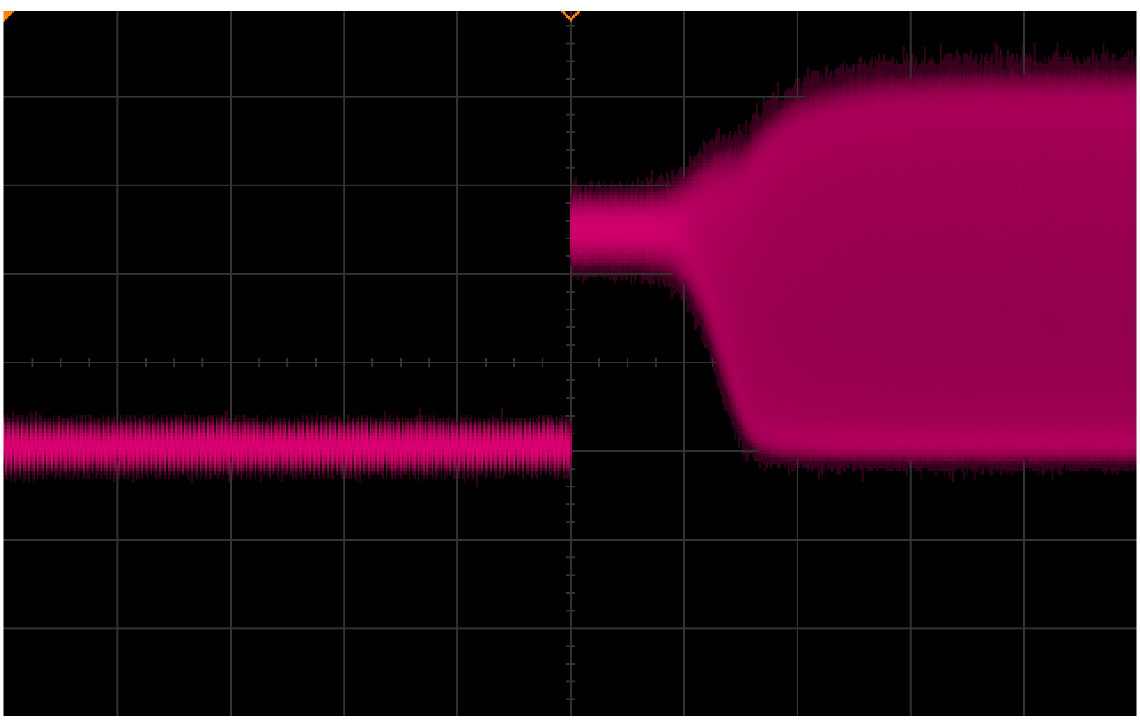


FIGURE 40: OSCILLATOR START-UP WAVEFORM (V_{CC} = 3.3V)



C2 - Oscillator Out (100 mV/div - DC) Time base: 500 mS/div

FIGURE 41: OSCILLATOR START-UP WAVEFORM (V_{CC} = 5.0V)



C2 - Oscillator Out (100 mV/div - DC) Time base: 500 mS/div

FIGURE 42: OSCILLATOR START-UP WAVEFORM (VCC = 5.5V)

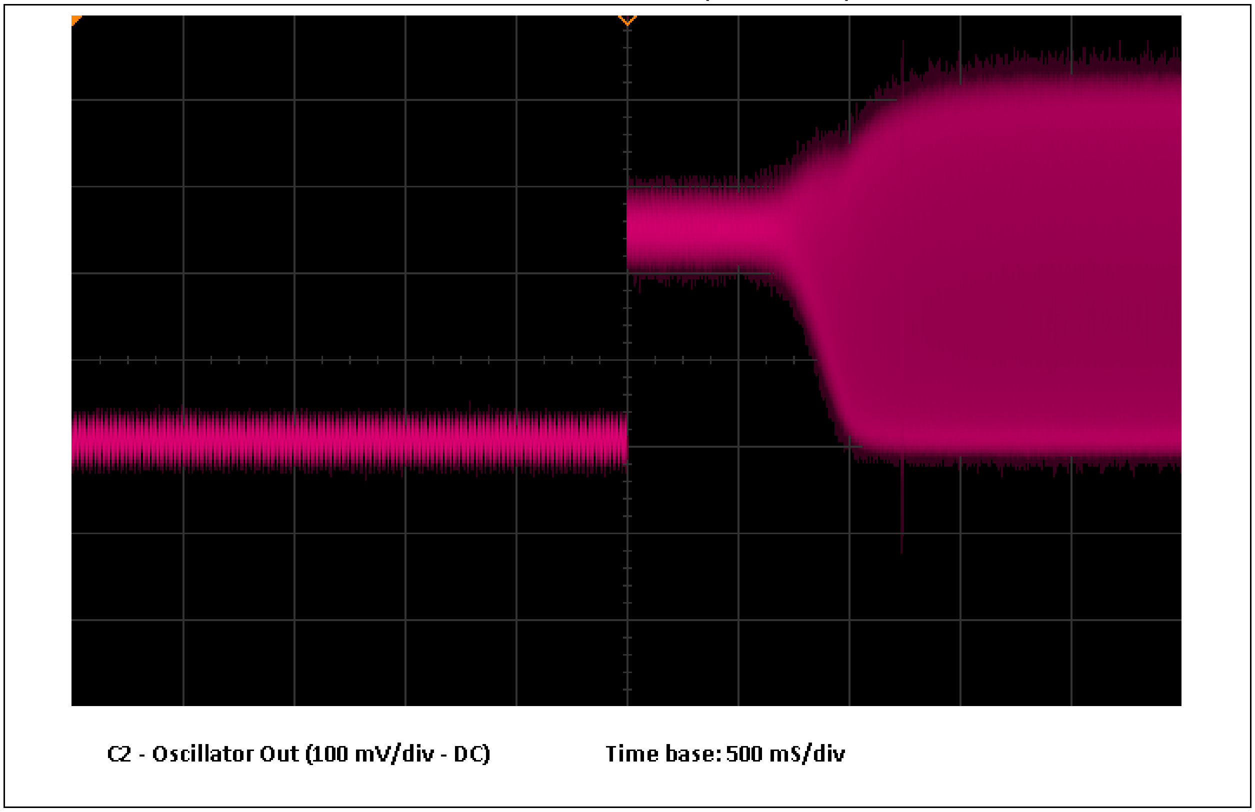
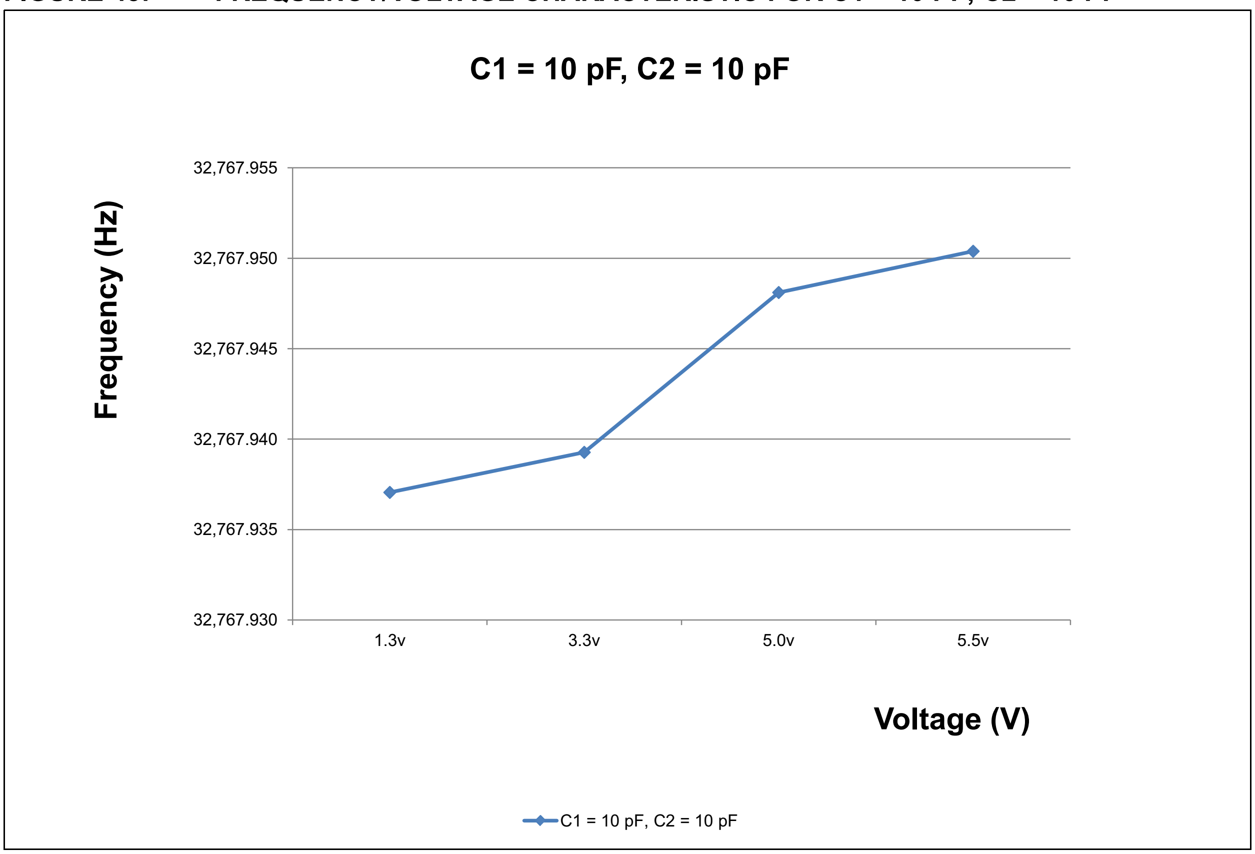


FIGURE 43: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 10 PF; C2 = 10 PF



APPENDIX F: EPSON C002RX32.76K-EPB

FIGURE 44: OSCILLATOR INPUT AND OUTPUT WAVEFORM (VBAT = 1.3V, VCC = 1.3V)

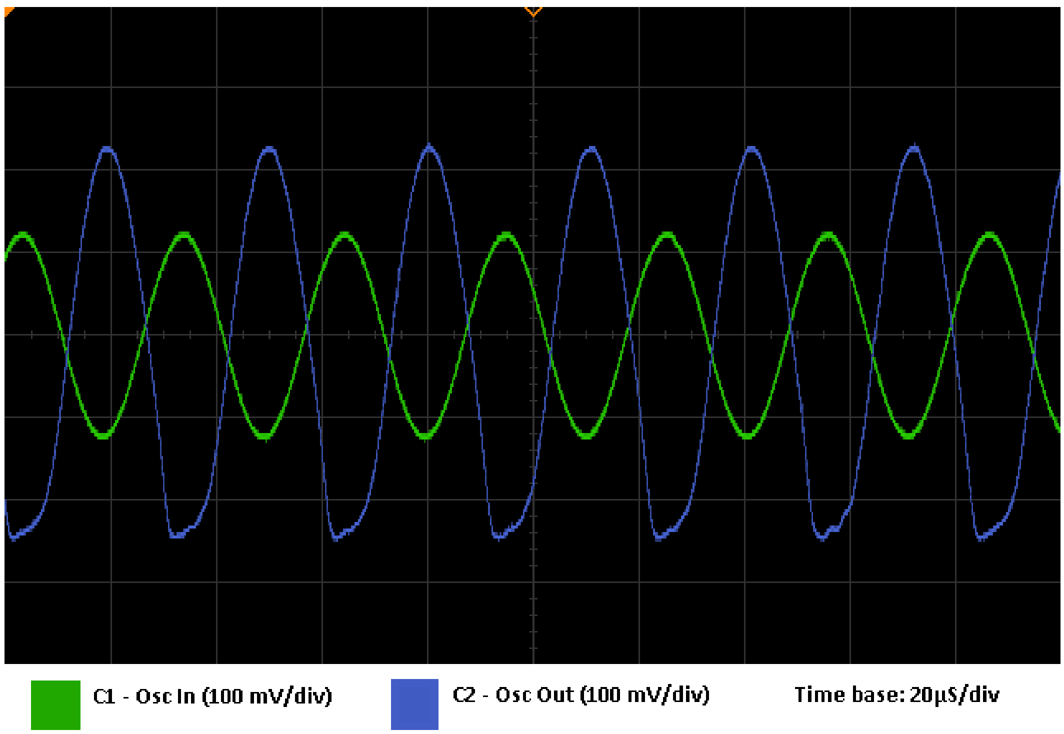


FIGURE 45: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (VCC = 3.3V)

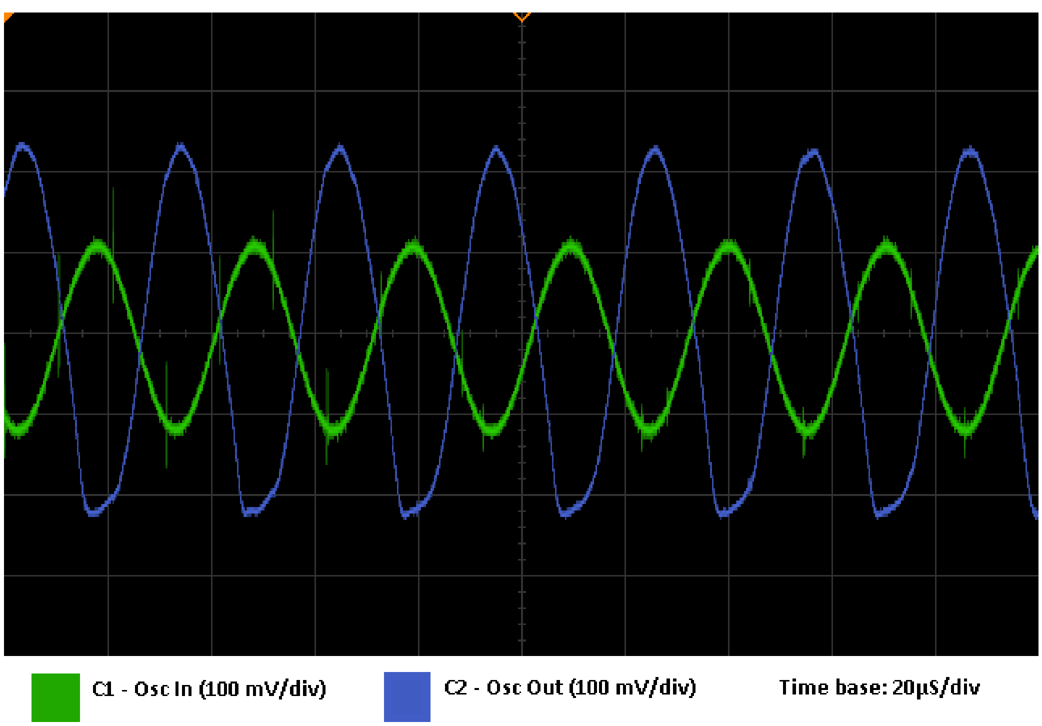


FIGURE 46: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (VCC = 5.0V)

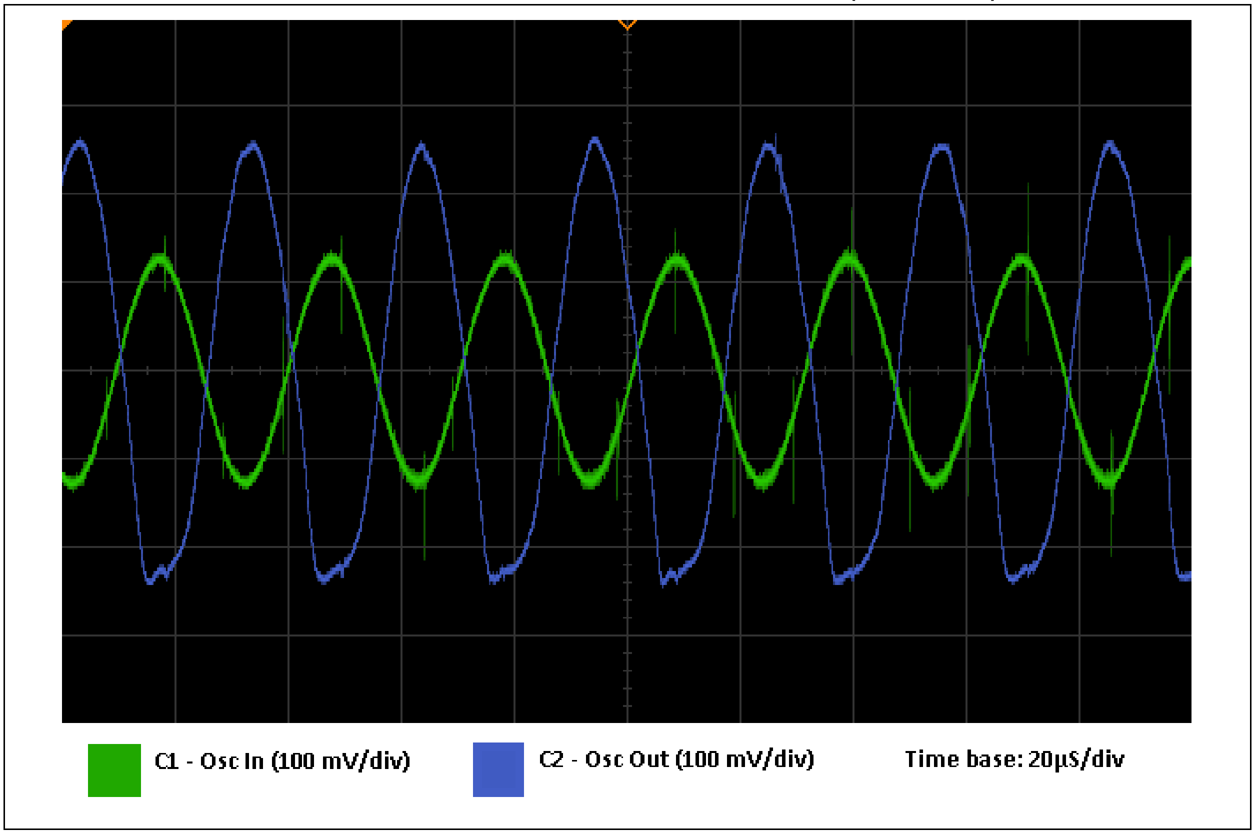


FIGURE 47: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (VCC = 5.5V)

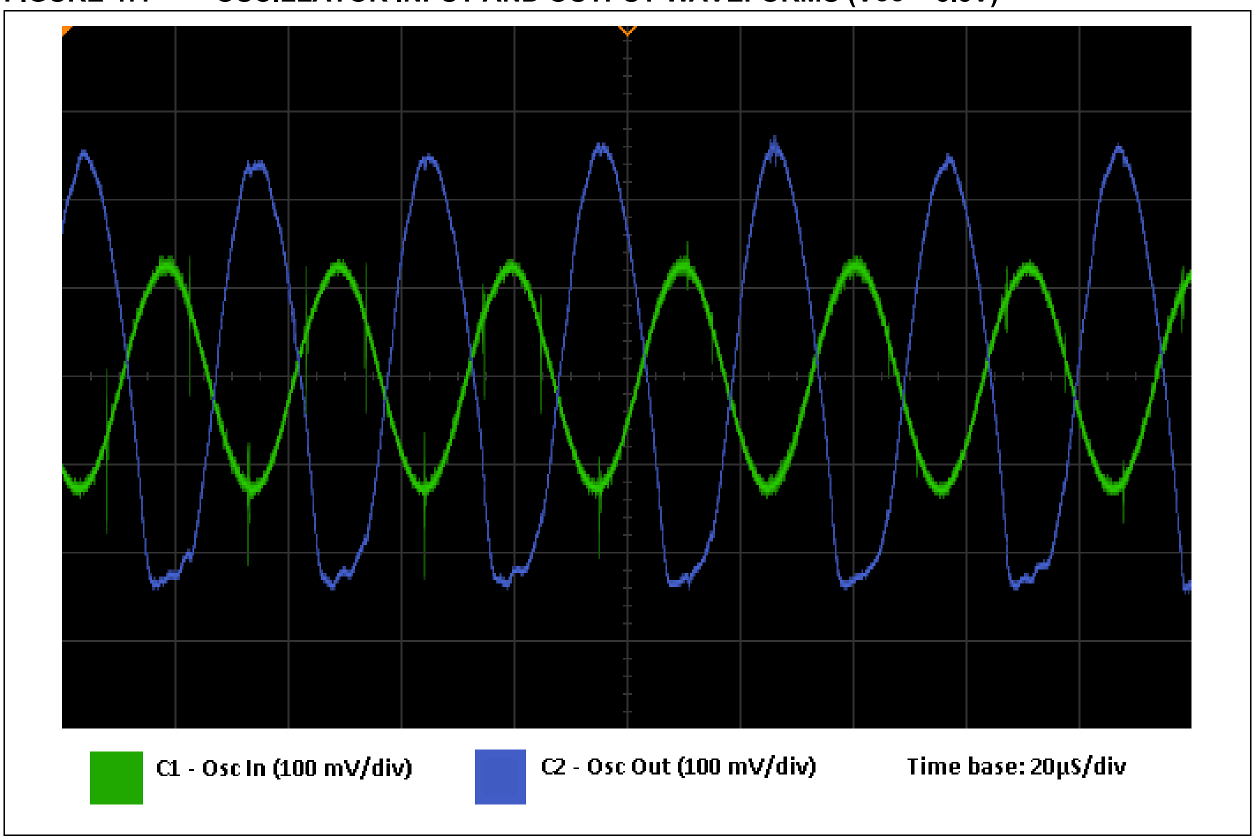


FIGURE 48: OSCILLATOR START-UP WAVEFORM (VCC = 3.3V)

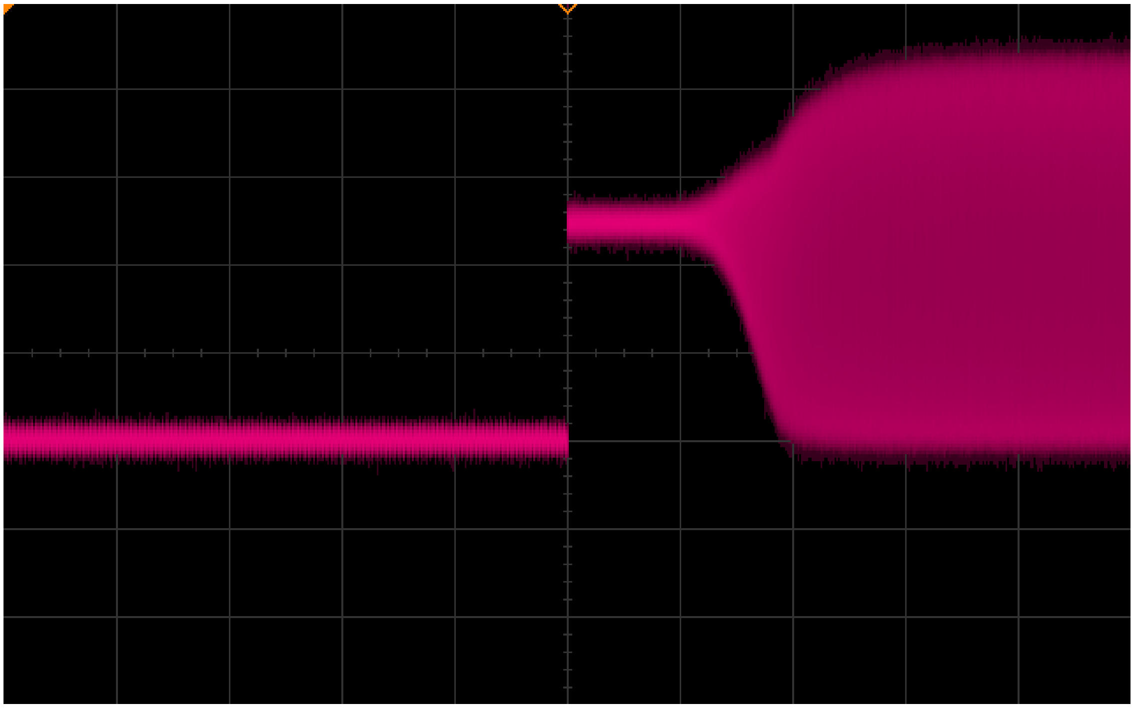


FIGURE 49: OSCILLATOR START-UP WAVEFORM (VCC = 5.0V)

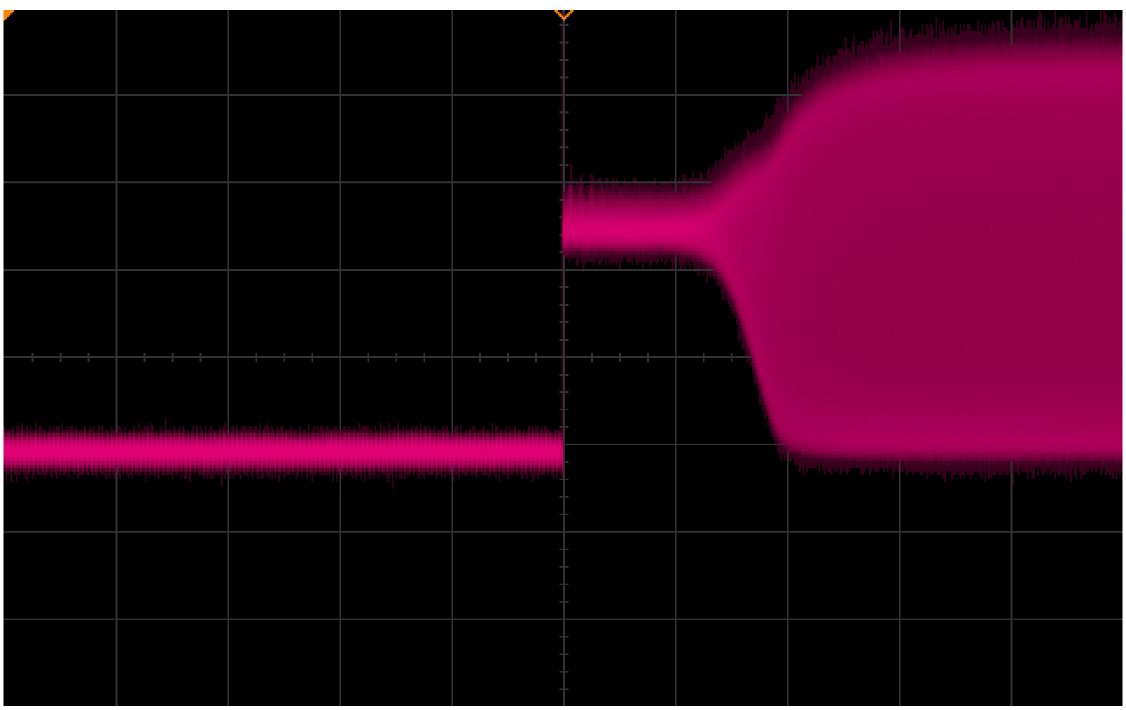


FIGURE 50: OSCILLATOR START-UP WAVEFORM (VCC = 5.5V)

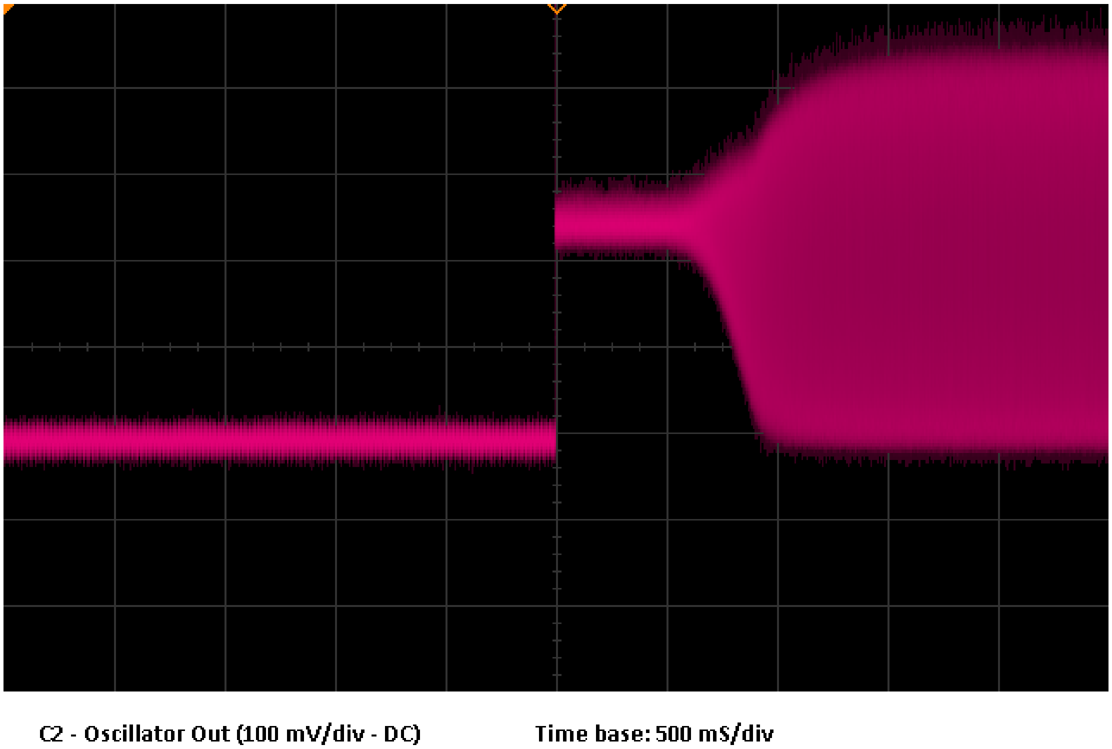
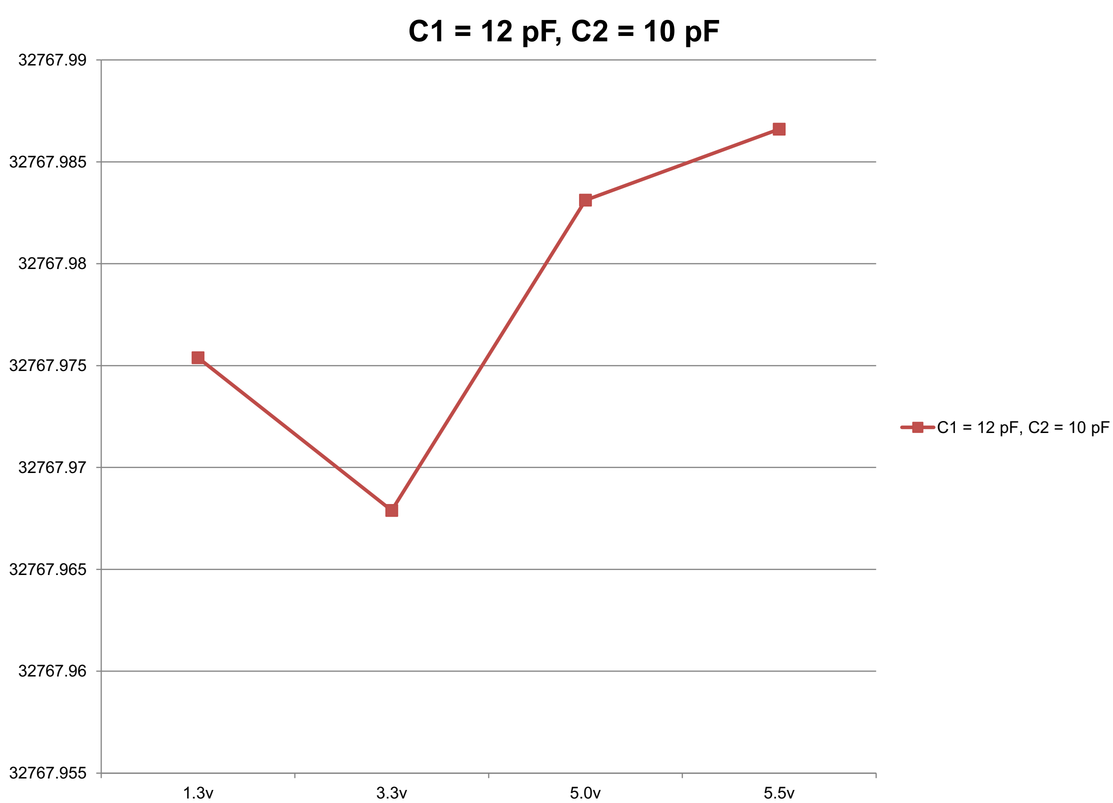


FIGURE 51: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 12 PF; C2 = 10 PF



APPENDIX G: AVX ST3215SB32768C0HPWBB

FIGURE 52: OSCILLATOR INPUT AND OUTPUT WAVEFORM (V_{BAT} = 1.3V, V_{CC} = 1.3V)

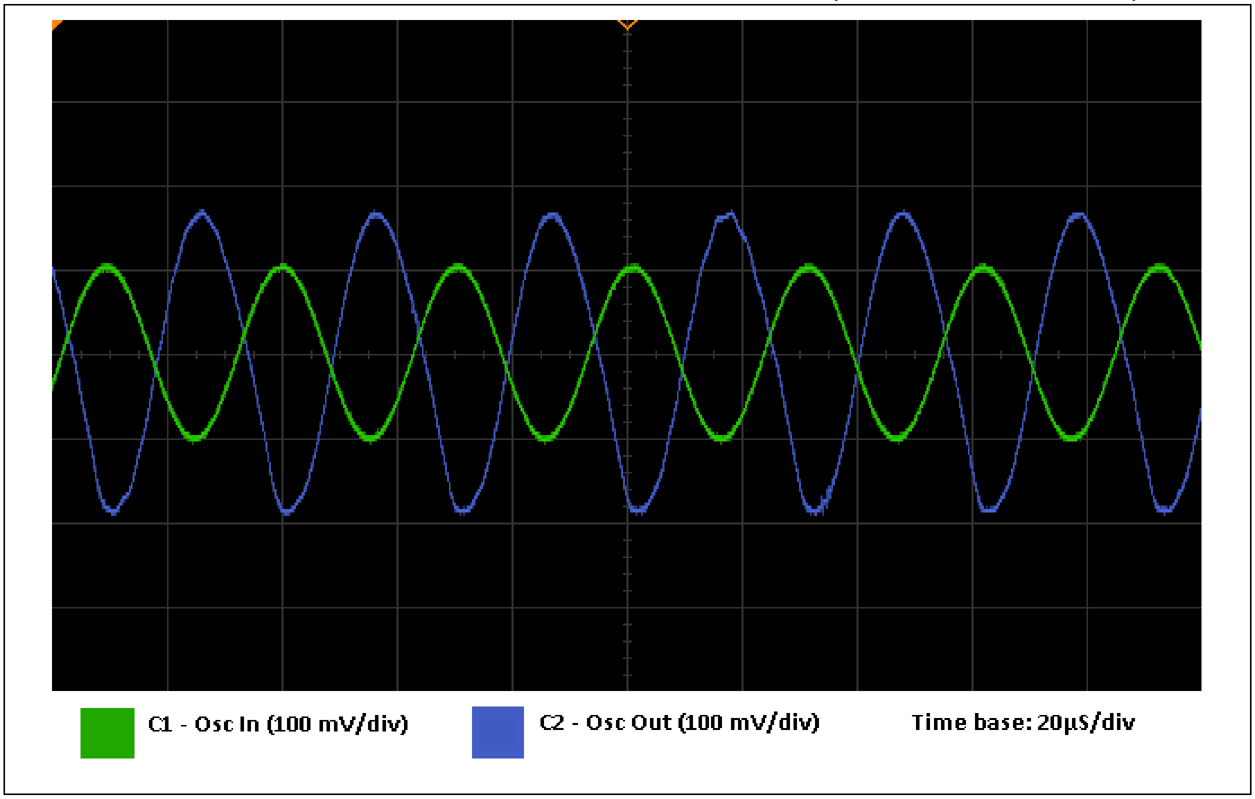


FIGURE 53: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 3.3V)

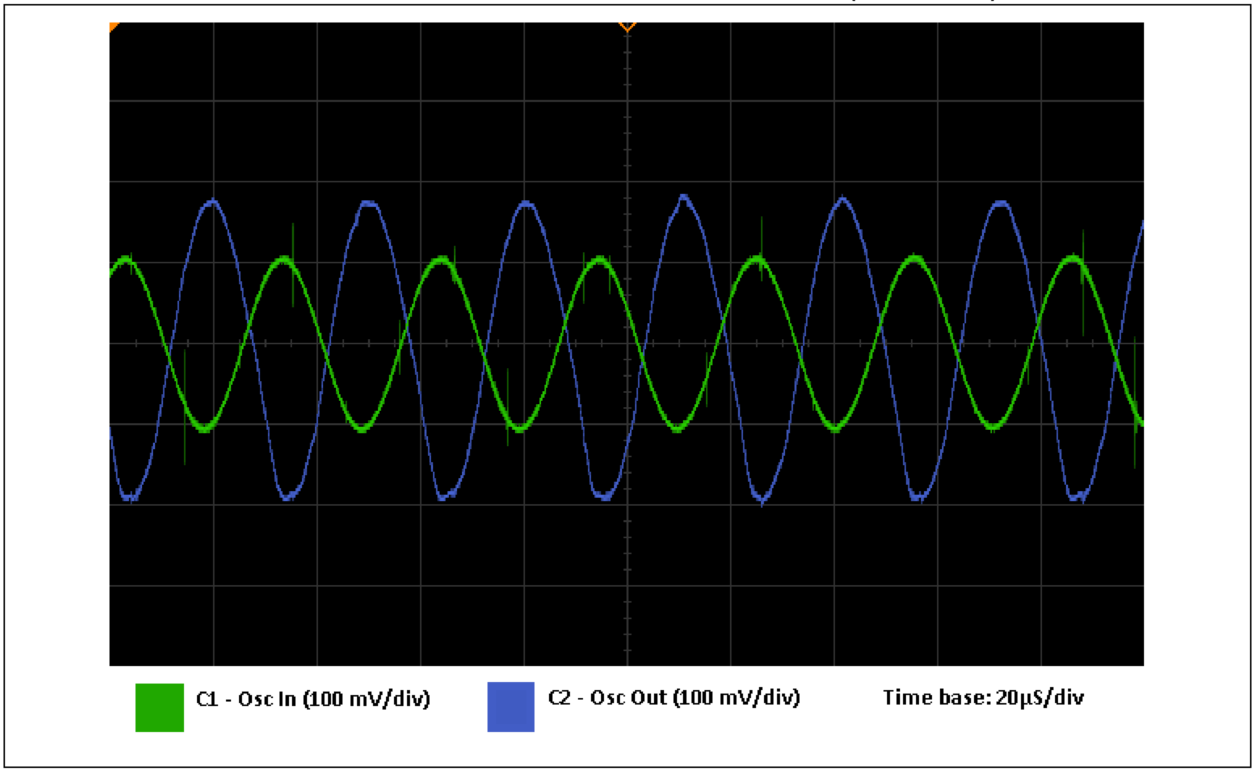


FIGURE 54: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 5.0V)

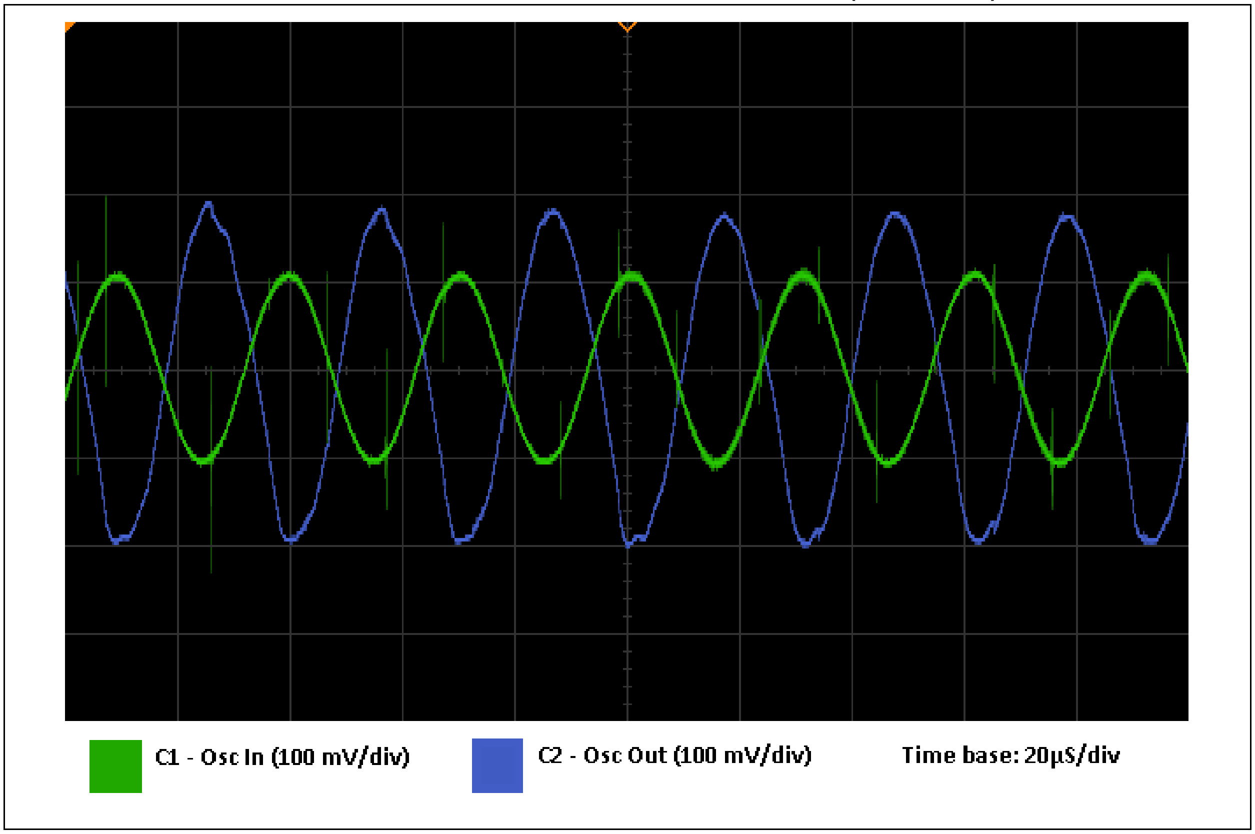


FIGURE 55: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 5.5V)

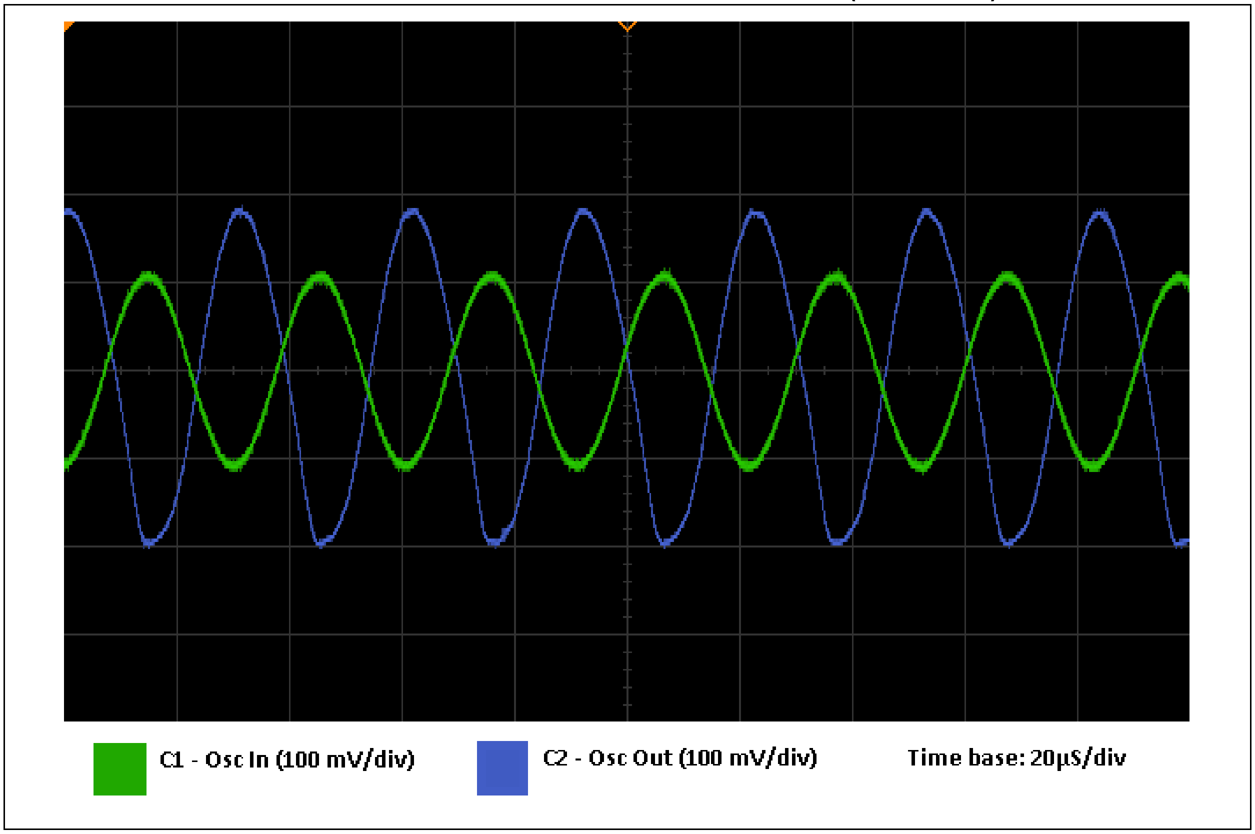


FIGURE 56: OSCILLATOR START-UP WAVEFORM (VCC = 3.3V)

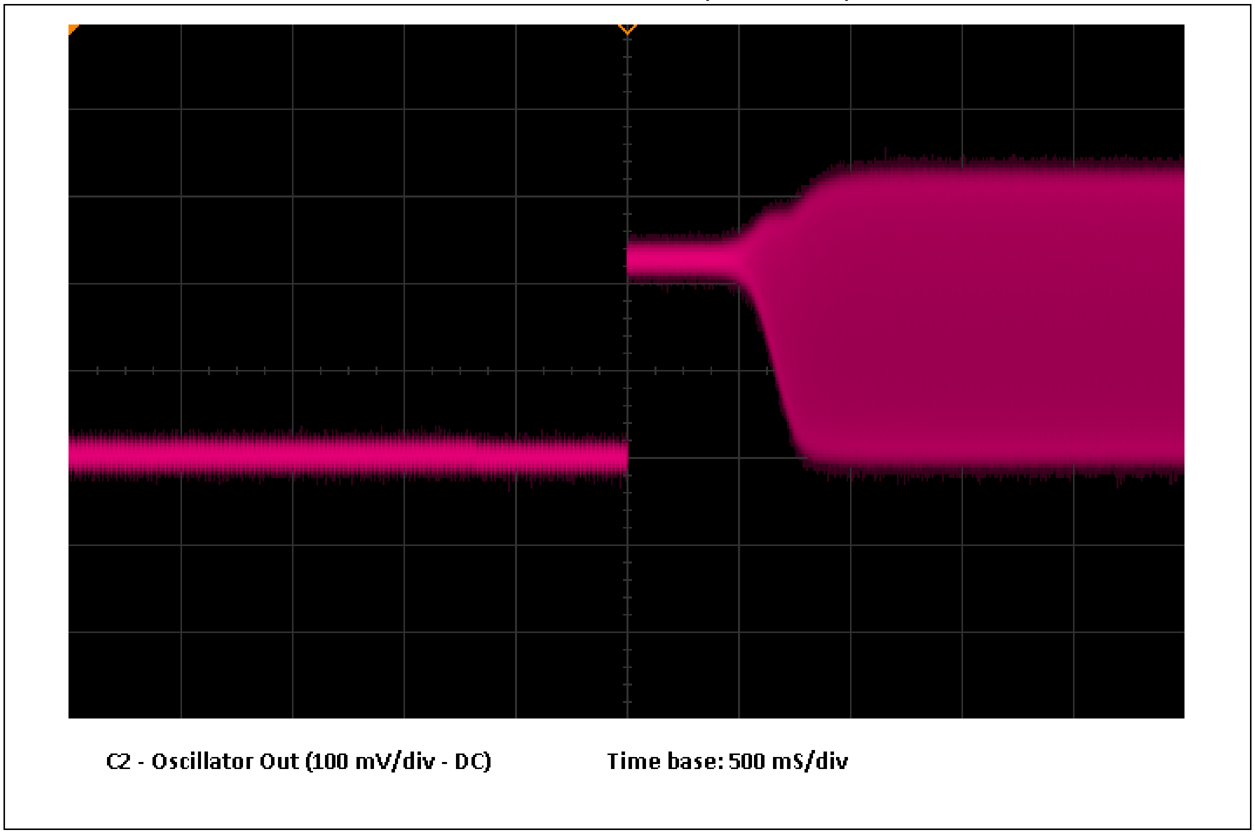


FIGURE 57: OSCILLATOR START-UP WAVEFORM (VCC = 5.0V)

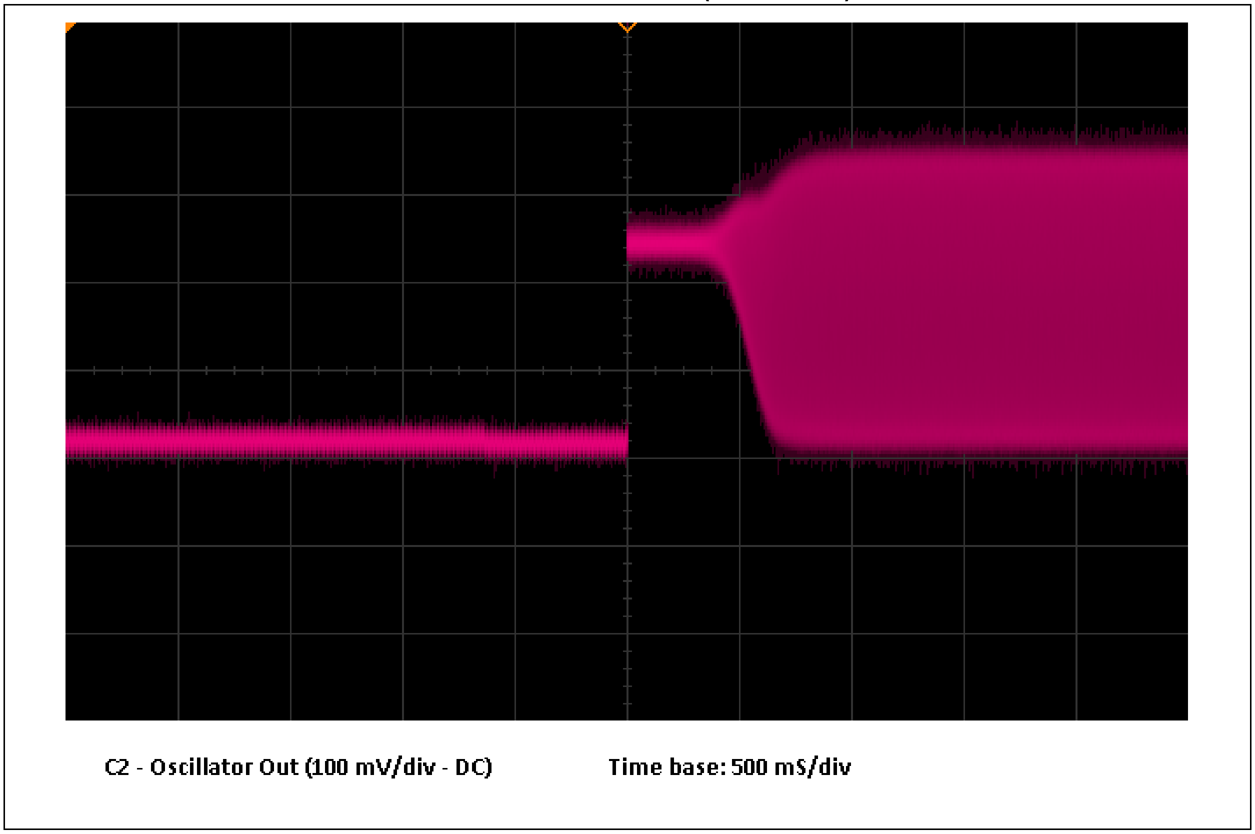


FIGURE 58: OSCILLATOR START-UP WAVEFORM (VCC = 5.5V)

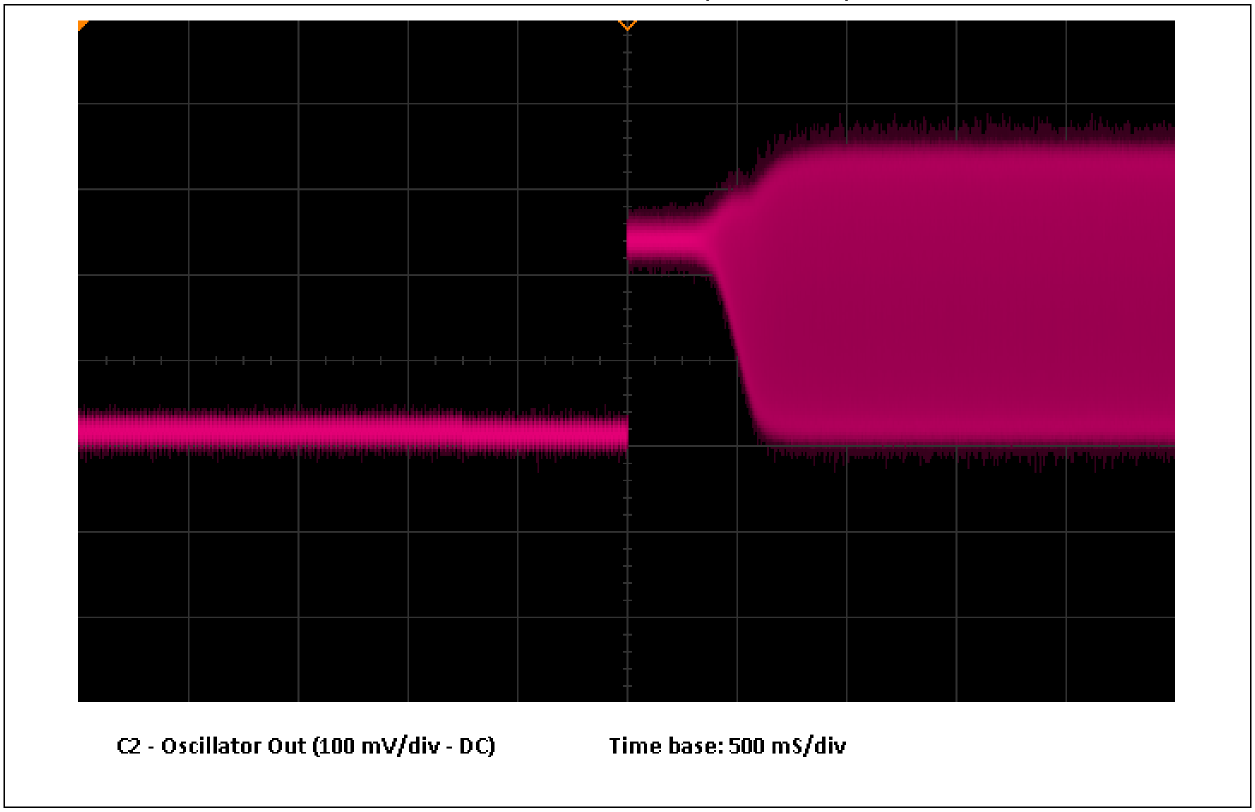
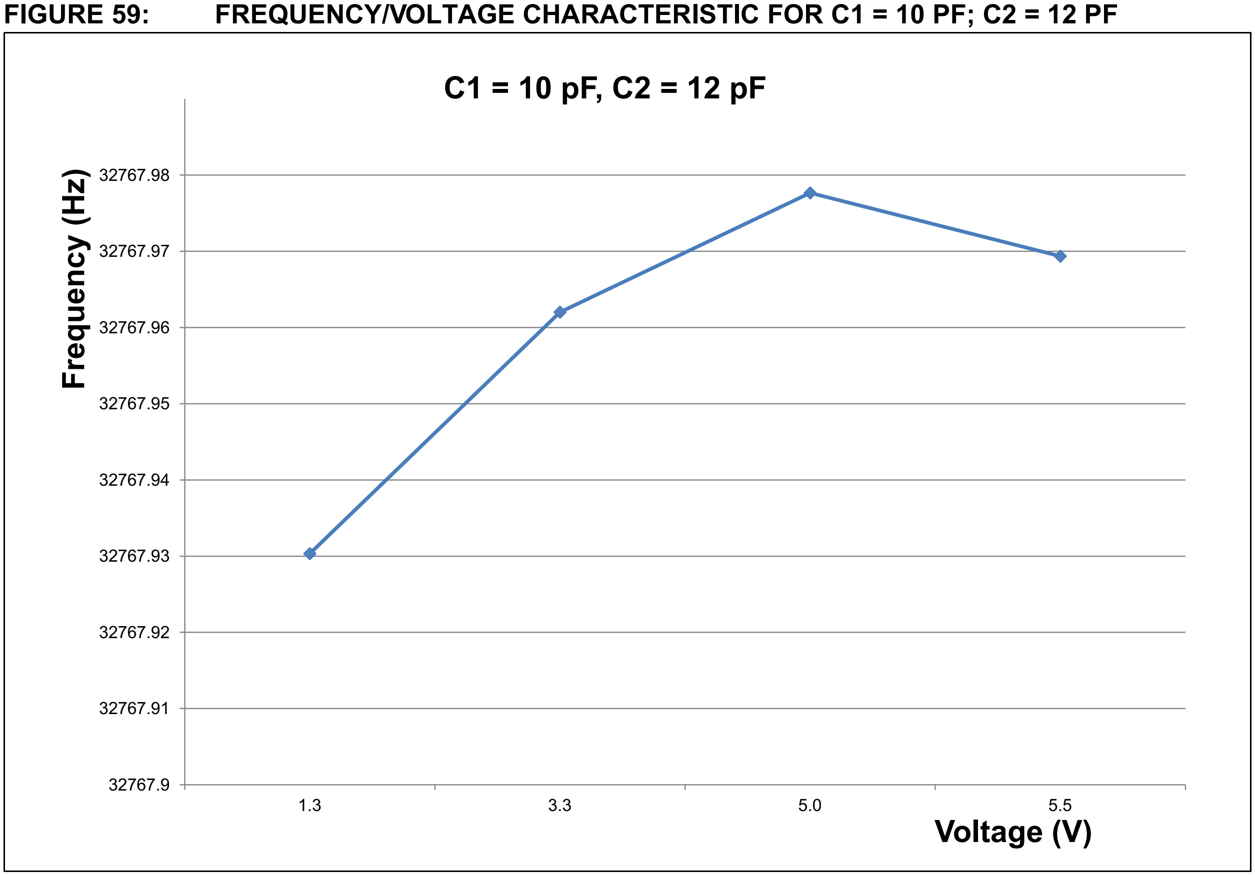


FIGURE 59: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 10 PF; C2 = 12 PF



APPENDIX H: FOX NC38LF-32.768KHZ

FIGURE 60: OSCILLATOR INPUT AND OUTPUT WAVEFORM (V_{BAT} = 1.3V, V_{CC} = 1.3V)

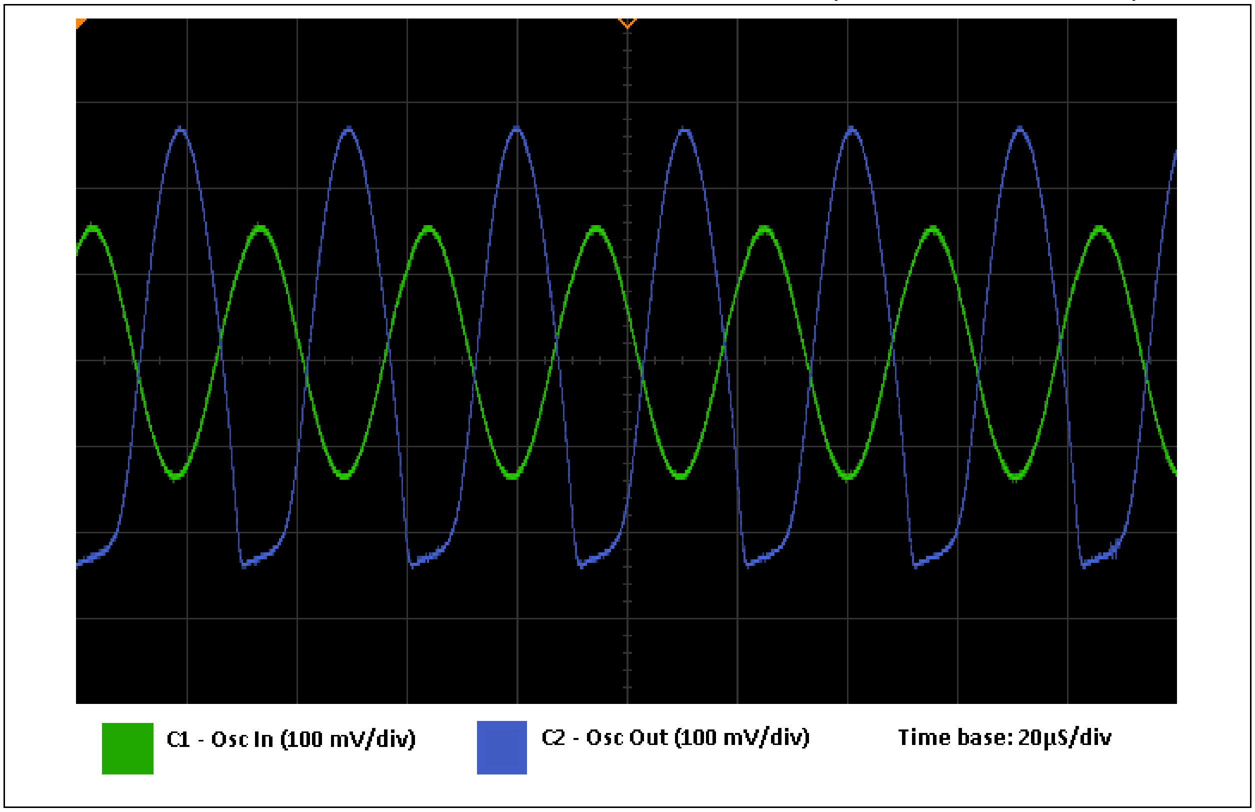


FIGURE 61: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 3.3V)

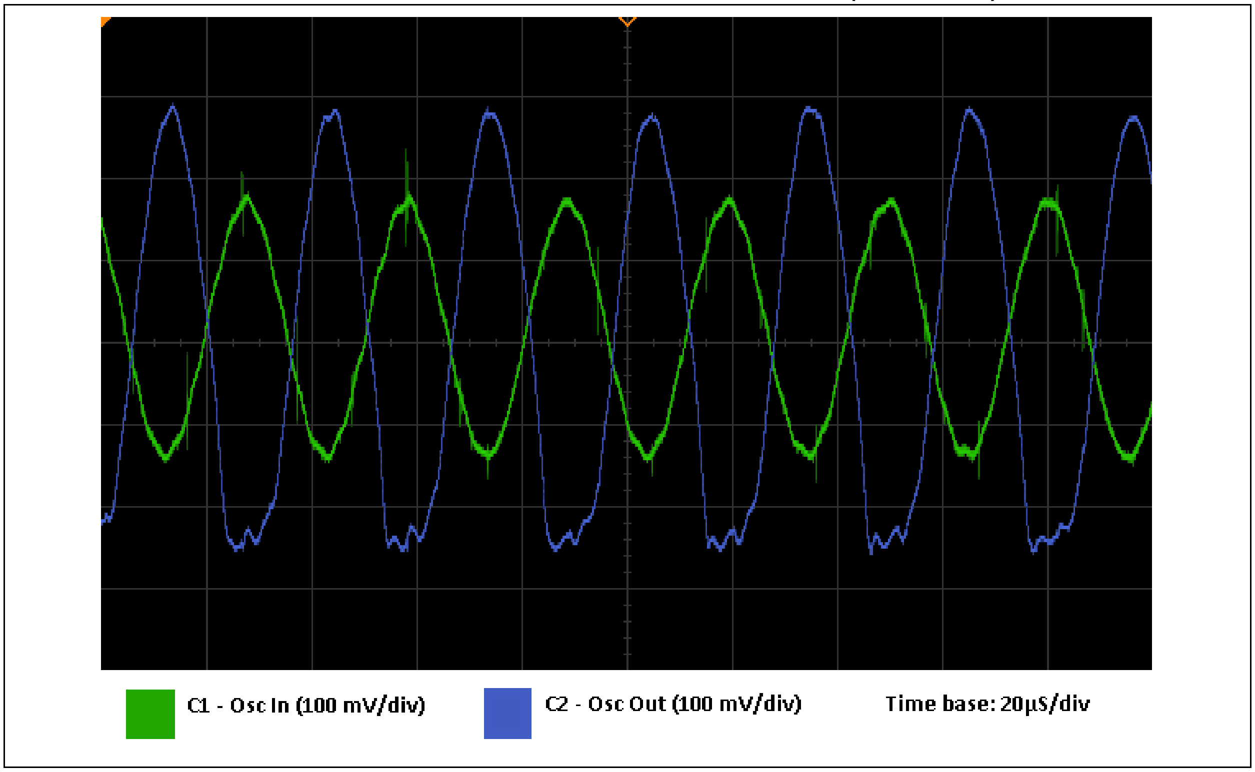


FIGURE 62: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 5.0V)

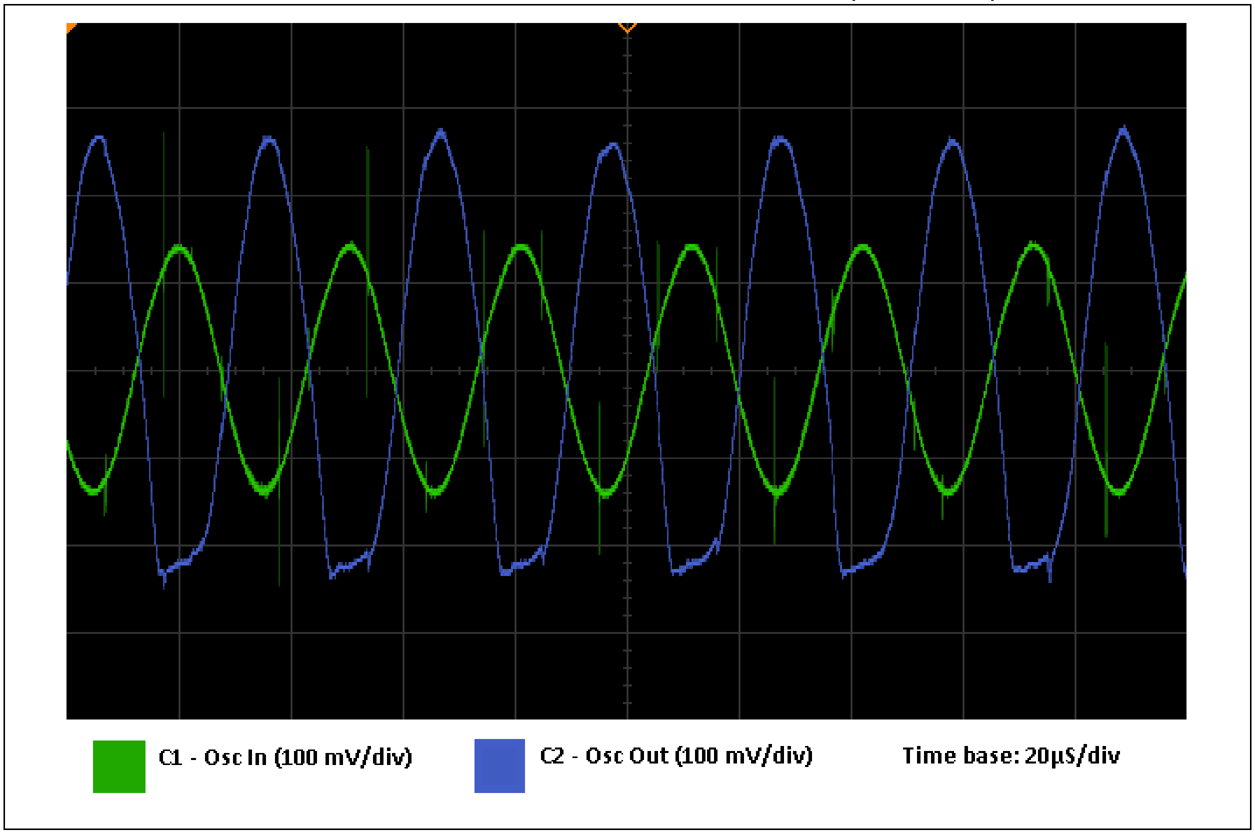


FIGURE 63: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 5.5V)

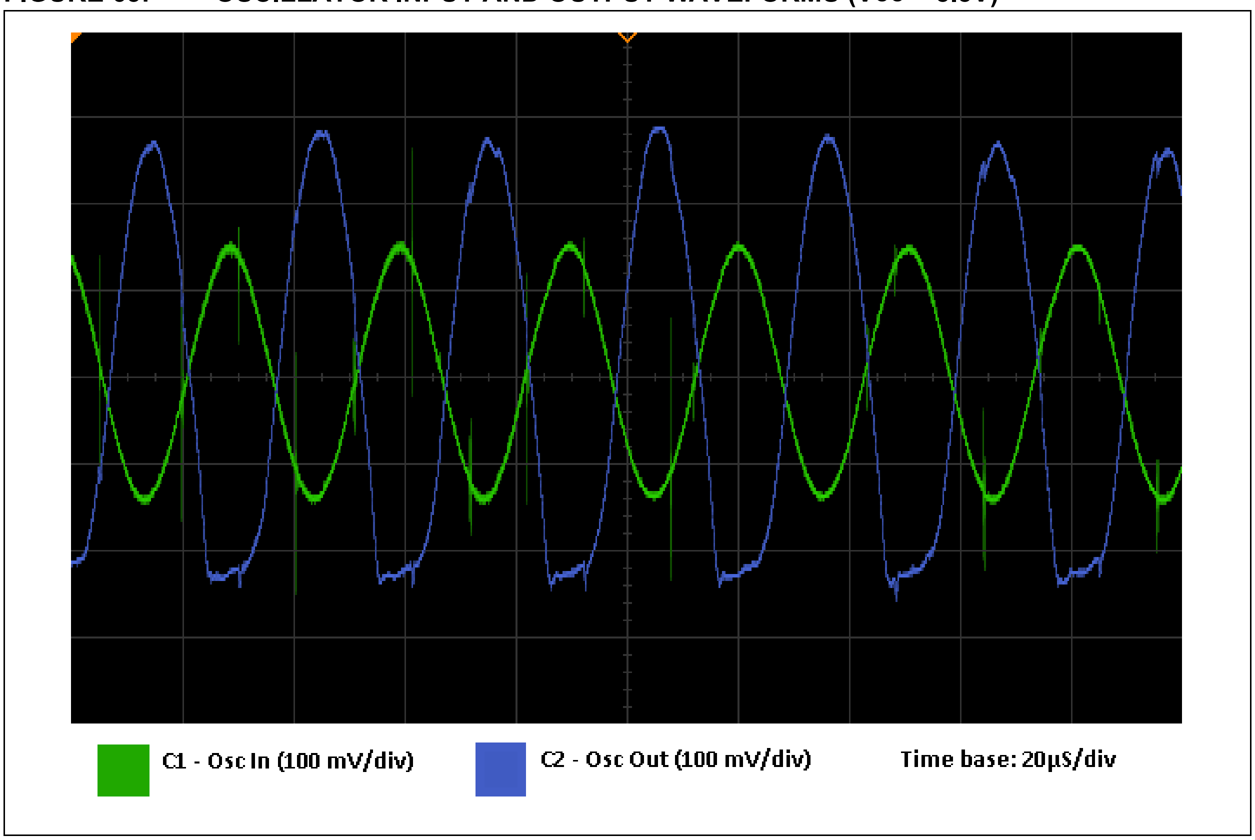


FIGURE 64: OSCILLATOR START-UP WAVEFORM (Vcc = 3.3V)

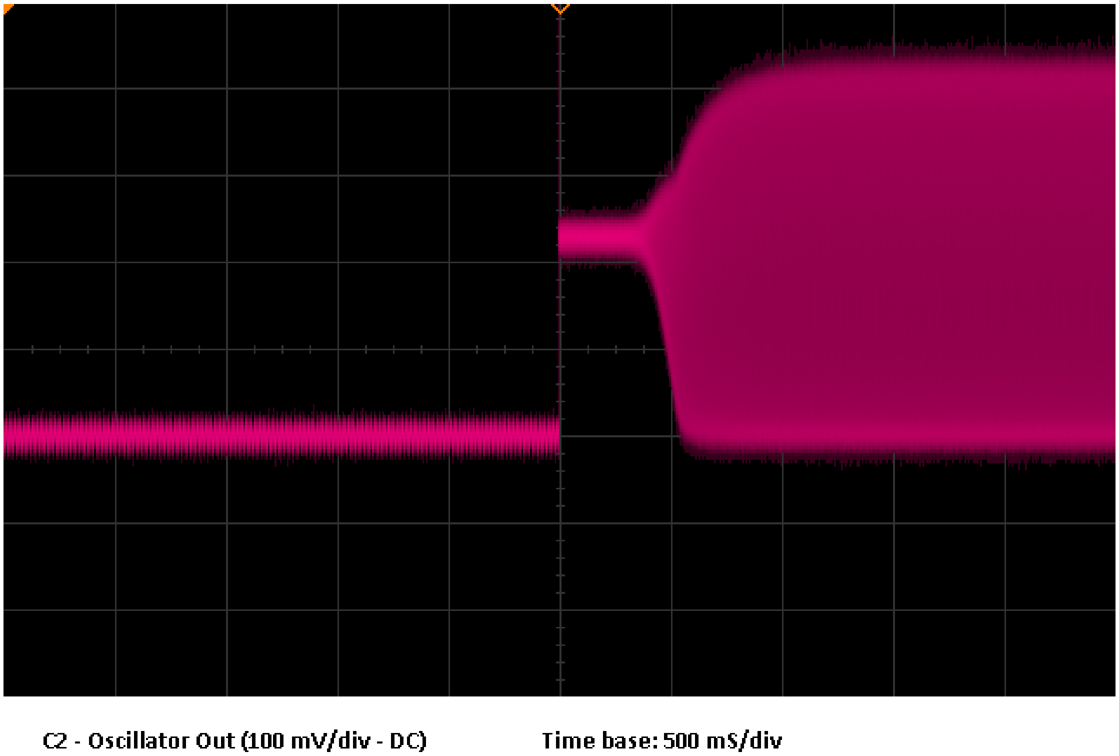


FIGURE 65: OSCILLATOR START-UP WAVEFORM (Vcc = 5.0V)

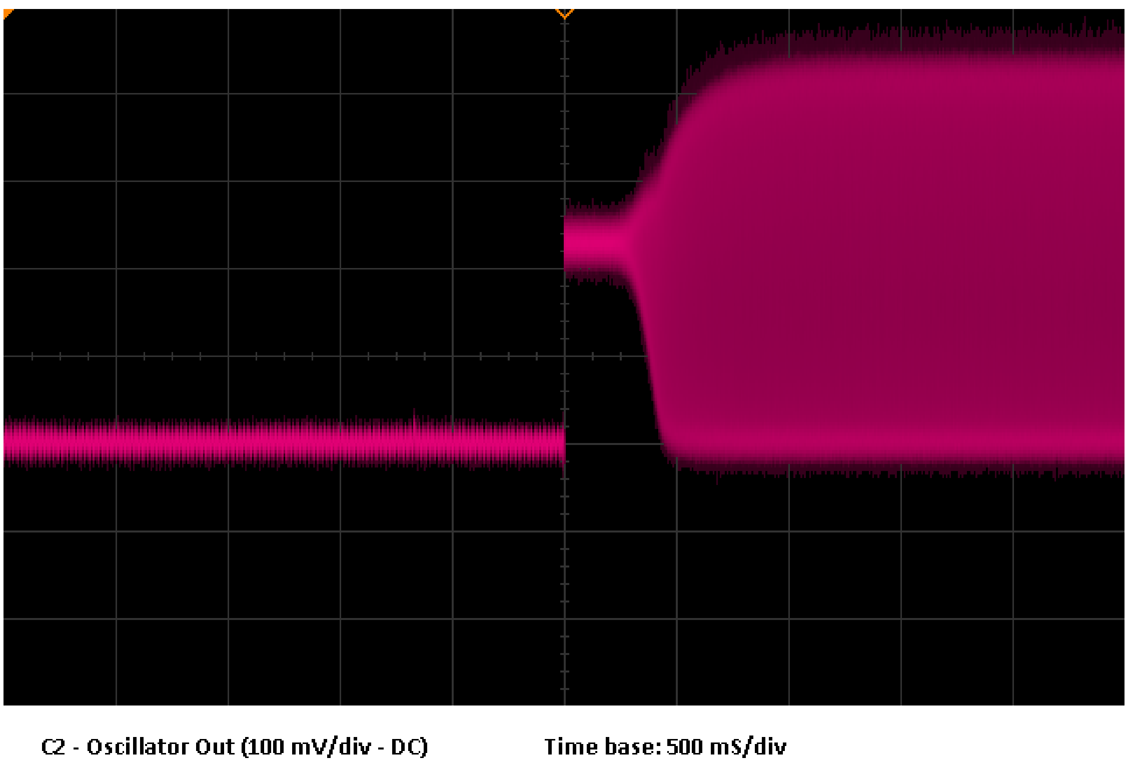


FIGURE 66: OSCILLATOR START-UP WAVEFORM (VCC = 5.5V)

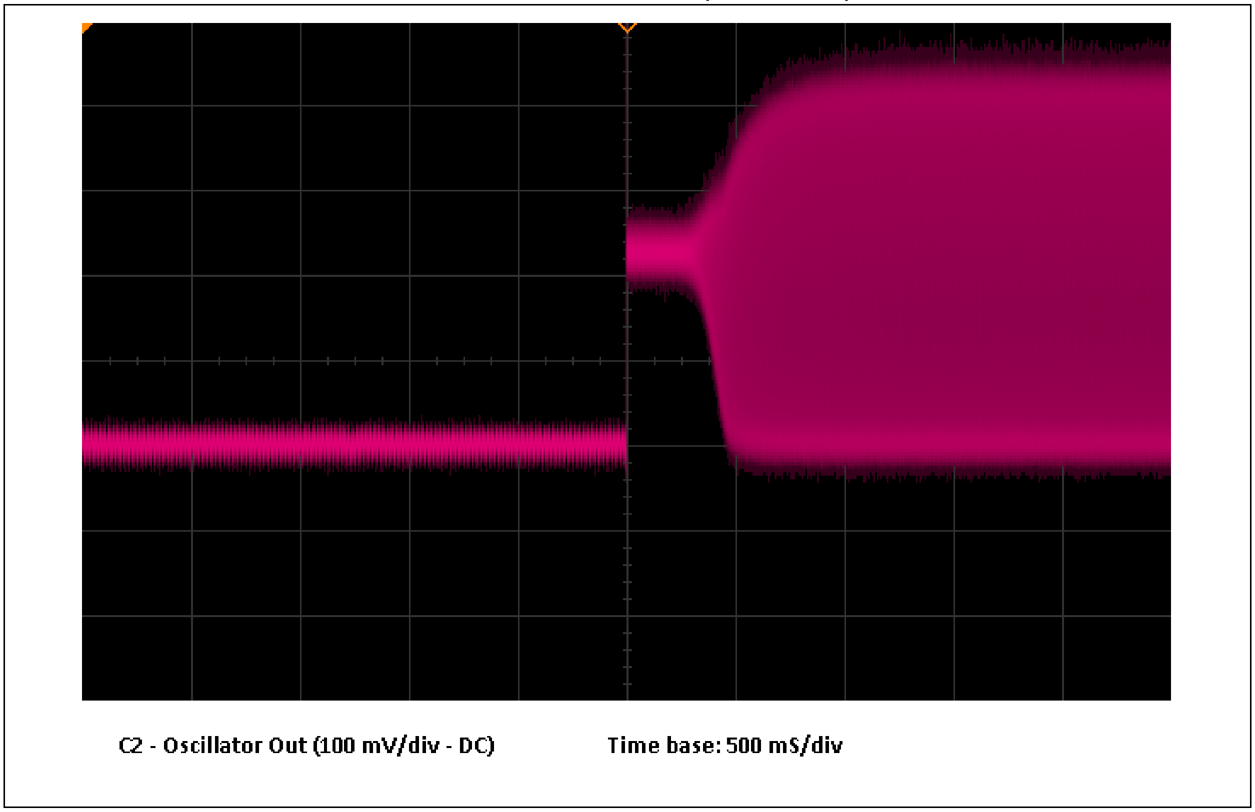
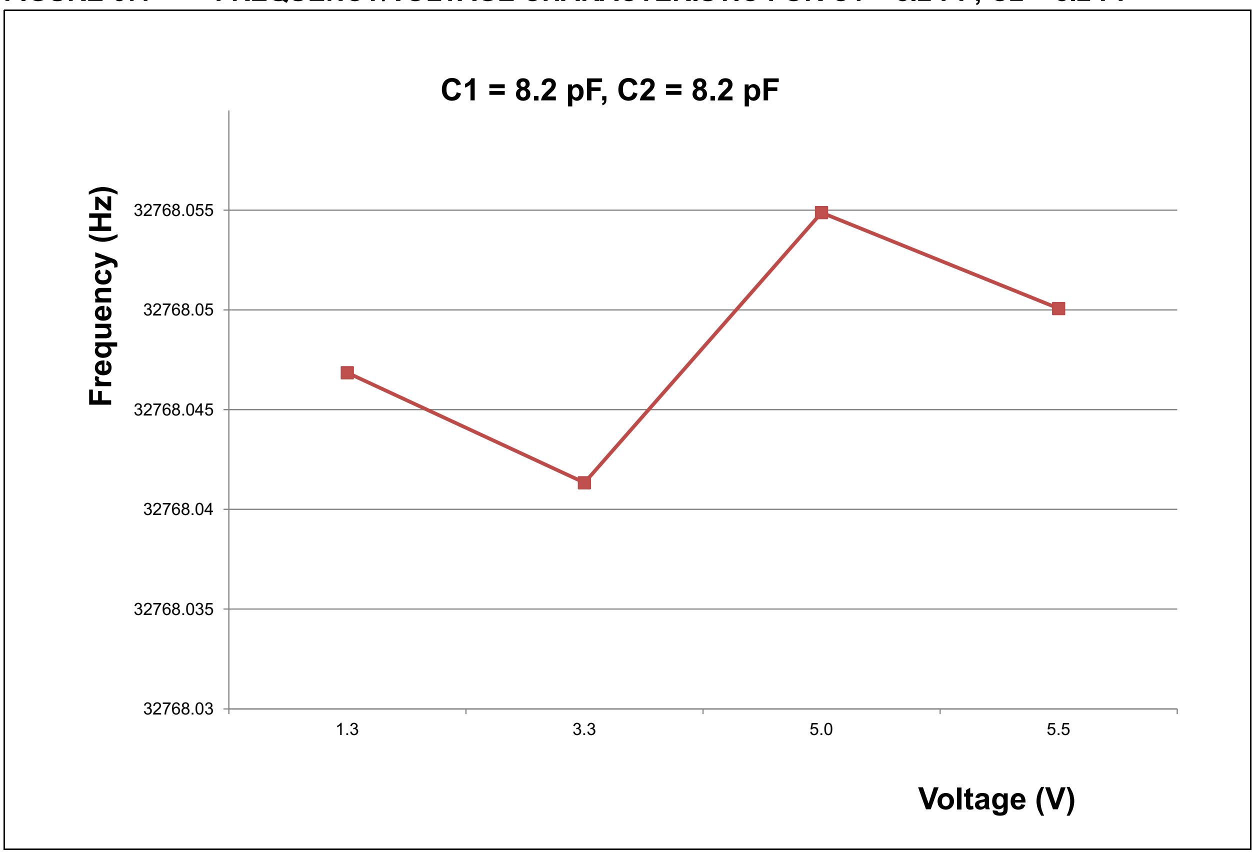


FIGURE 67: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 8.2 PF; C2 = 8.2 PF



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