AN813

Applying the TC1219/TC1220 Inverting Charge Pumps with Small External Capacitor Values

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INTRODUCTION

Microchip Technology Inc.'s TC1219 (switching frequency at 12 kHz) and TC1220 (switching frequency at 35 kHz) are inverting charge pump voltage converters that are specified using rather large capacitors (10 µF for the TC1219 and 3.3 µF for the TC1220). These capacitor sizes allow the designer the luxury of a reasonably low output resistance (25Ω typical) capable of driving load currents up to 25 mA. However, these larger-value external capacitors are more expensive and require additional printed circuit board (PCB) space than their smaller-valued counterparts. Additionally, the time required to shutdown these charge pump converters becomes longer with larger-value external capacitors and in certain higher-speed applications, this unfortunate feature can be devastating.

In many cases where a negative DC bias source is required, lower output load currents (15 mA or less) and faster shutdown times are what the design engineer optimally needs. For applications such as these, the TC1219 and TC1220 can be applied with lower value external capacitors than those recommended in the device data sheet. The data in this Application Note shows measurements taken on both the TC1219 and TC1220 using five different, smaller-value external capacitors: a) 2.2 µF, b) 1 µF, c) 0.47 µF, d) 0.22 µF and e) 0.1 µF. All measurements were made with a 5V input (at the V_{IN} pin) and at ambient temperature T_A = +25°C.

APPLICATION TEST CIRCUIT

Figure 1 shows the circuit configuration for measuring the output performance of the TC1219 and TC1220 under varying load currents. Two external capacitors (flying capacitor C_1 and output capacitor C_2) and a resistive load (comprised of R_{L1} and R_{L2}) are required to measure the output voltage droop, output voltage ripple and shutdown response times under different output loading conditions.

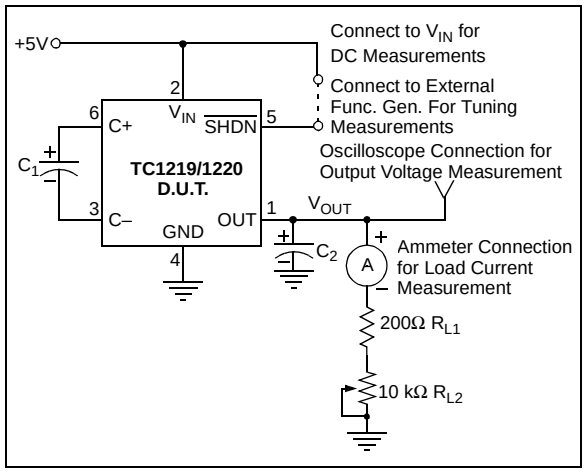

FIGURE 1: *TC1219/20 Application Circuit.*

TEST RESULTS

Table 1 contains typical TC1219 data for varying load currents with these five different values of external capacitors. Note that output voltage droop and the output voltage ripple both increase with higher load currents and smaller external capacitors. Table 2 contains similar data for the TC1220.

Figure 2 is a plot of the TC1219 output voltage droop versus load current, Figure 3 is a plot of the TC1219 Output Voltage Droop versus Capacitance, Figure 4 is a plot of the TC1219 Output Voltage Ripple versus Load Current, and Figure 5 is a plot of the TC1219 Output Voltage Ripple versus Capacitance. Figure 6 is a plot of the TC1220 Output Voltage Droop versus Load Current, Figure 7 is a plot of the TC1220 Output Voltage Droop versus Capacitance, Figure 8 is a plot of the TC1220 Output Voltage Ripple versus Load Current and Figure 9 is a plot of the TC1220 Output Voltage Ripple versus Capacitance.

Figure 10 shows the shutdown response time for the TC1219 using 2.2 µF external capacitors for C_1 and C_2 driving a 10 mA load current. The top trace is the output signal (V_{OUT}) and the bottom trace is the shutdown input. Note that the shutdown time for this condition measured 2.259 msec. Similarly, Figure 11 shows the shutdown response time for the TC1219 using 0.47 µF external capacitors for C_1 and C_2 driving a 10 mA load current. As before, the top trace is the output signal

(V_{OUT}) and the bottom trace is the shutdown input. Note that the shutdown time for this condition measured only 225.9 µsec at the expense of significantly higher output voltage ripple at the V_{OUT} pin.

Figure 12 shows the shutdown response time for the TC1220, using 0.47 µF external capacitors for C_1 and C_2 driving a 10 mA load current. The top trace is the output signal (V_{OUT}) and the bottom trace is the shutdown input. Note that the shutdown time for this condition measured 482 µsec. Similarly, Figure 13 shows the shutdown response time for the TC1220 using 0.22 µF external capacitors for C_1 and C_2 driving a 10 mA load current. As before, the top trace is the output signal (V_{OUT}) and the bottom trace is the shutdown input. Note that the shutdown time for this condition measured only 225.9 µsec at the expense of significantly higher output voltage ripple at the V_{OUT} pin.

Figure 14 is a plot of the TC1219 Shutdown Time versus Load Current, Figure 15 is a plot of the TC1219 Shutdown Time versus Capacitance, Figure 16 is a plot of the TC1220 Shutdown Time versus Load Current, and Figure 17 is a plot of the TC1220 Shutdown Time versus Capacitance.

TABLE 1: TC1219 DATA SUMMARY AT VARIOUS LOAD CURRENTS

V_{IN} Voltage (V)	Flying Capacitor C_1 (µF)	Output Capacitor C_2 (µF)	Load Current (mA)	V_{OUT} Voltage (V)	V_{OUT} Droop (V)	Osc. Freq. (kHz)	Output Ripple (mVp-p)
5.0	2.2	2.2	0	-4.99	0.01	12	0
5.0	2.2	2.2	0.5	-4.97	0.03	12	19
5.0	2.2	2.2	1	-4.94	0.06	12	38
5.0	2.2	2.2	2	-4.89	0.11	12	76
5.0	2.2	2.2	3	-4.84	0.16	12	114
5.0	2.2	2.2	4	-4.78	0.22	12	152
5.0	2.2	2.2	5	-4.73	0.27	12	190
5.0	2.2	2.2	6	-4.68	0.32	12	228
5.0	2.2	2.2	7	-4.63	0.37	12	267
5.0	2.2	2.2	8	-4.58	0.42	12	305
5.0	2.2	2.2	9	-4.53	0.47	12	343
5.0	2.2	2.2	10	-4.47	0.53	12	381
5.0	2.2	2.2	12	-4.37	0.63	12	457
5.0	2.2	2.2	15	-4.19	0.81	12	571
5.0	1	1	0	-4.99	0.01	12	0
5.0	1	1	0.5	-4.94	0.06	12	42
5.0	1	1	1	-4.88	0.12	12	84
5.0	1	1	2	-4.78	0.22	12	167
5.0	1	1	3	-4.67	0.33	12	251
5.0	1	1	4	-4.56	0.44	12	334
5.0	1	1	5	-4.45	0.55	12	418
5.0	1	1	6	-4.34	0.66	12	501
5.0	1	1	7	-4.24	0.76	12	585
5.0	1	1	8	-4.13	0.87	12	668
5.0	1	1	9	-4.02	0.98	12	752
5.0	1	1	10	-3.91	1.09	12	835
5.0	1	1	12	-3.70	1.30	12	1002
5.0	1	1	15	-3.37	1.63	12	1253
5.0	0.47	0.47	0	-4.99	0.01	12	0
5.0	0.47	0.47	0.5	-4.89	0.11	12	89
5.0	0.47	0.47	1	-4.79	0.21	12	178
5.0	0.47	0.47	2	-4.58	0.42	12	355
5.0	0.47	0.47	3	-4.38	0.62	12	533
5.0	0.47	0.47	4	-4.17	0.83	12	710
5.0	0.47	0.47	5	-3.97	1.03	12	888
5.0	0.47	0.47	6	-3.76	1.24	12	1065
5.0	0.47	0.47	7	-3.56	1.44	12	1243
5.0	0.47	0.47	8	-3.36	1.64	12	1420
5.0	0.47	0.47	9	-3.15	1.85	12	1598
5.0	0.47	0.47	10	-2.93	2.07	12	1775
5.0	0.22	0.22	0	-4.99	0.01	12	0
5.0	0.22	0.22	0.5	-4.78	0.22	12	189
5.0	0.22	0.22	1	-4.57	0.43	12	379

TABLE 1: TC1219 DATA SUMMARY AT VARIOUS LOAD CURRENTS (CONTINUED)

V_{IN} Voltage (V)	Flying Capacitor C_1 (µF)	Output Capacitor C_2 (µF)	Load Current (mA)	V_{OUT} Voltage (V)	V_{OUT} Droop (V)	Osc. Freq. (kHz)	Output Ripple (mVp-p)
5.0	0.22	0.22	2	-4.15	0.85	12	758
5.0	0.22	0.22	3	-3.74	1.26	12	1137
5.0	0.22	0.22	4	-3.32	1.68	12	1516
5.0	0.22	0.22	5	-2.91	2.09	12	1895
5.0	0.1	0.1	0	-4.98	0.02	12	0
5.0	0.1	0.1	0.5	-4.46	0.54	12	417
5.0	0.1	0.1	1	-3.95	1.05	12	834
5.0	0.1	0.1	2	-2.94	2.06	12	1667
5.0	0.1	0.1	3	-2.03	2.97	12	2501

TABLE 2: TC1220 DATA SUMMARY AT VARIOUS LOAD CURRENTS

V_{IN} Voltage (V)	Flying Capacitor C_1 (µF)	Output Capacitor C_2 (µF)	Load Current (mA)	V_{OUT} Voltage (V)	V_{OUT} Droop (V)	Osc. Freq. (kHz)	Output Ripple (mVp-p)
5.0	2.2	2.2	0	-4.99	0.01	35	0
5.0	2.2	2.2	0.5	-4.98	0.03	35	7
5.0	2.2	2.2	1	-4.96	0.04	35	13
5.0	2.2	2.2	2	-4.93	0.07	35	26
5.0	2.2	2.2	3	-4.90	0.10	35	40
5.0	2.2	2.2	4	-4.87	0.13	35	53
5.0	2.2	2.2	5	-4.83	0.17	35	66
5.0	2.2	2.2	6	-4.80	0.20	35	79
5.0	2.2	2.2	7	-4.77	0.23	35	92
5.0	2.2	2.2	8	-4.74	0.26	35	105
5.0	2.2	2.2	9	-4.71	0.29	35	119
5.0	2.2	2.2	10	-4.68	0.32	35	132
5.0	2.2	2.2	12	-4.62	0.38	35	158
5.0	2.2	2.2	15	-4.52	0.48	35	198
5.0	2.2	2.2	20	-4.36	0.64	35	264
5.0	1	1	0	-4.99	0.01	35	0
5.0	1	1	0.5	-4.97	0.03	35	14
5.0	1	1	1	-4.95	0.05	35	29
5.0	1	1	2	-4.90	0.10	35	58
5.0	1	1	3	-4.86	0.14	35	86
5.0	1	1	4	-4.82	0.18	35	115
5.0	1	1	5	-4.78	0.22	35	144
5.0	1	1	6	-4.73	0.27	35	173
5.0	1	1	7	-4.69	0.31	35	201
5.0	1	1	8	-4.65	0.35	35	230
5.0	1	1	9	-4.61	0.39	35	259
5.0	1	1	10	-4.56	0.44	35	288
5.0	1	1	12	-4.48	0.52	35	345
5.0	1	1	15	-4.35	0.65	35	432

TABLE 2: TC1220 DATA SUMMARY AT VARIOUS LOAD CURRENTS (CONTINUED)

V_{IN} Voltage (V)	Flying Capacitor C_1 (µF)	Output Capacitor C_2 (µF)	Load Current (mA)	V_{OUT} Voltage (V)	V_{OUT} Droop (V)	Osc. Freq. (kHz)	Output Ripple (mVp-p)
5.0	1	1	20	-4.15	0.85	35	575
5.0	0.47	0.47	0	-4.99	0.01	35	0
5.0	0.47	0.47	0.5	-4.95	0.05	35	30
5.0	0.47	0.47	1	-4.92	0.08	35	61
5.0	0.47	0.47	2	-4.85	0.15	35	122
5.0	0.47	0.47	3	-4.78	0.22	35	183
5.0	0.47	0.47	4	-4.72	0.28	35	244
5.0	0.47	0.47	5	-4.65	0.35	35	305
5.0	0.47	0.47	6	-4.58	0.42	35	366
5.0	0.47	0.47	7	-4.51	0.49	35	427
5.0	0.47	0.47	8	-4.44	0.56	35	488
5.0	0.47	0.47	9	-4.37	0.63	35	549
5.0	0.47	0.47	10	-4.30	0.70	35	610
5.0	0.47	0.47	12	-4.17	0.83	35	732
5.0	0.47	0.47	15	-3.96	1.04	35	915
5.0	0.22	0.22	0	-4.99	0.01	35	0
5.0	0.22	0.22	0.5	-4.92	0.08	35	65
5.0	0.22	0.22	1	-4.86	0.14	35	130
5.0	0.22	0.22	2	-4.73	0.27	35	260
5.0	0.22	0.22	3	-4.59	0.41	35	390
5.0	0.22	0.22	4	-4.46	0.54	35	520
5.0	0.22	0.22	5	-4.33	0.67	35	650
5.0	0.22	0.22	6	-4.20	0.80	35	780
5.0	0.22	0.22	7	-4.07	0.93	35	910
5.0	0.22	0.22	8	-3.93	1.07	35	1041
5.0	0.22	0.22	9	-3.80	1.20	35	1171
5.0	0.22	0.22	10	-3.67	1.33	35	1301
5.0	0.1	0.1	0	-4.98	0.02	35	0
5.0	0.1	0.1	0.5	-4.82	0.18	35	143
5.0	0.1	0.1	1	-4.66	0.34	35	286
5.0	0.1	0.1	2	-4.33	0.67	35	572
5.0	0.1	0.1	3	-4.01	0.99	35	858
5.0	0.1	0.1	4	-3.69	1.31	35	1144
5.0	0.1	0.1	5	-3.37	1.63	35	1430

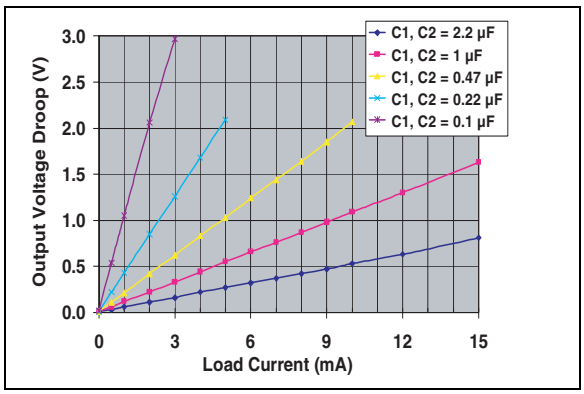

FIGURE 2: *TC1219 Output Voltage Droop vs. Load Current (V_{IN} = +5V).*

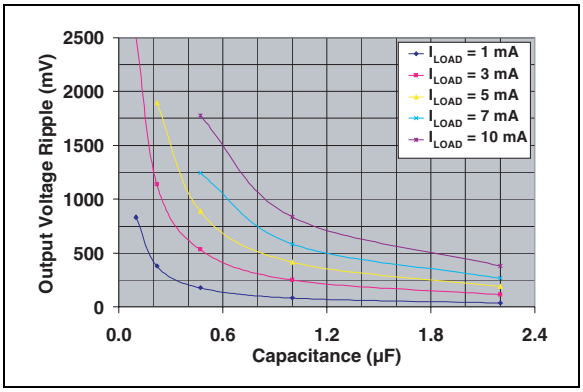

FIGURE 5: *TC1219 Output Voltage Ripple vs. Capacitance (V_{IN} = +5V).*

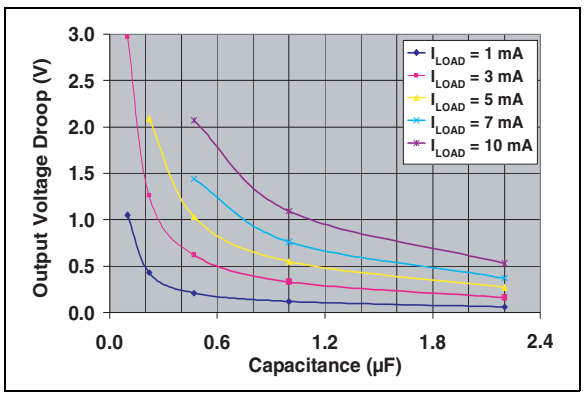

FIGURE 3: *TC1219 Output Voltage Droop vs. Capacitance (V_{IN} = +5V).*

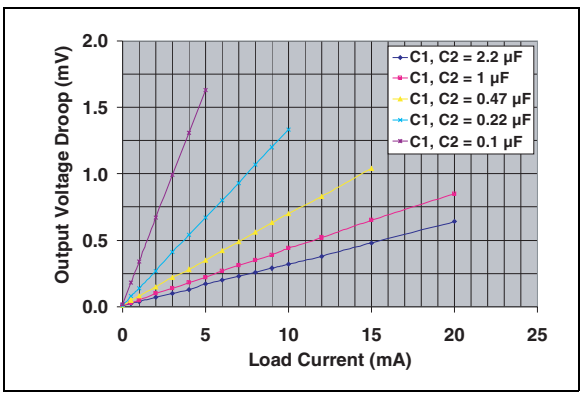

FIGURE 6: *TC1220 Output Voltage Droop vs. Load Current (V_{IN} = +5V).*

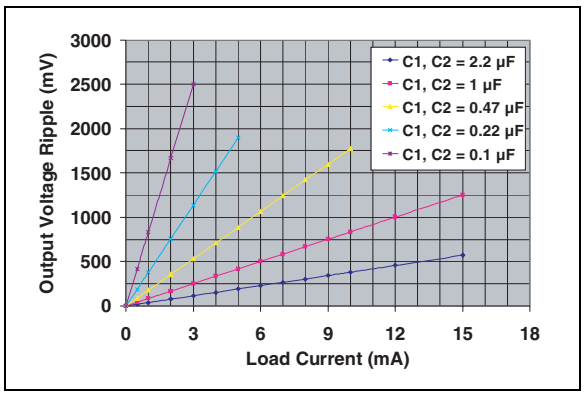

FIGURE 4: *TC1219 Output Voltage Ripple vs. Load Current (V_{IN} = +5V).*

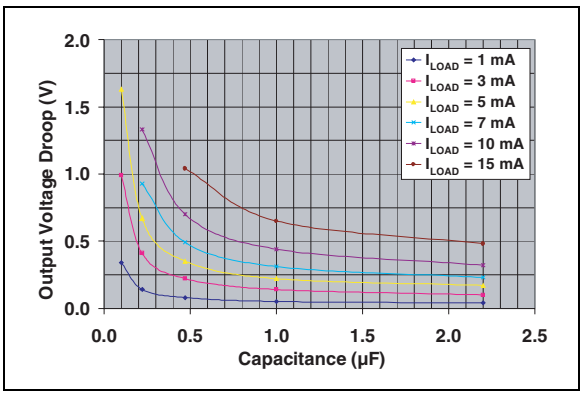

FIGURE 7: *TC1220 Output Voltage Droop vs. Capacitance (V_{IN} = +5V).*

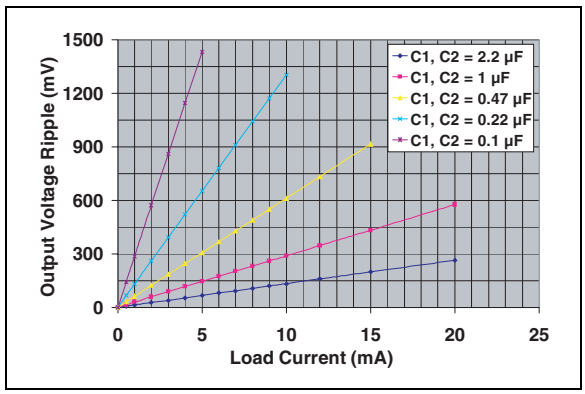

FIGURE 8: *TC1220 Output Voltage Ripple vs. Load Current (V_{IN} = +5V).*

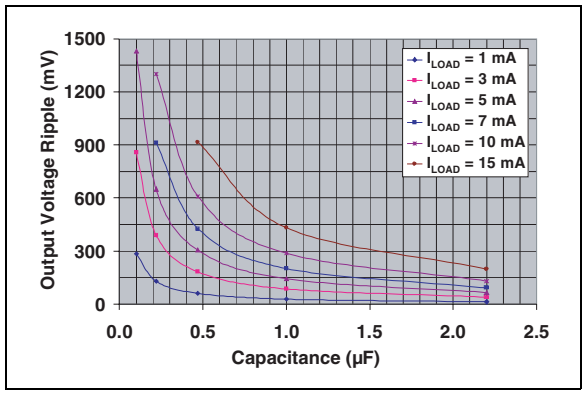

FIGURE 9: *TC1220 Output Voltage Ripple vs. Capacitance (V_{IN} = +5V).*

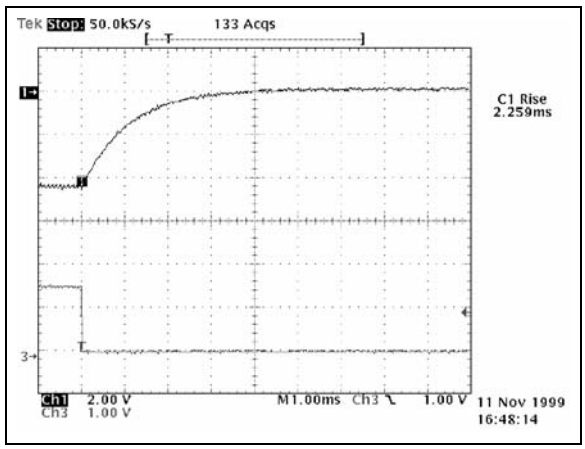

FIGURE 10: *TC1219 Shutdown Time with 2.2 µF External Capacitors and 10 mA Load Current. The top trace is the V_{OUT} signal and the bottom trace is the shutdown input.*

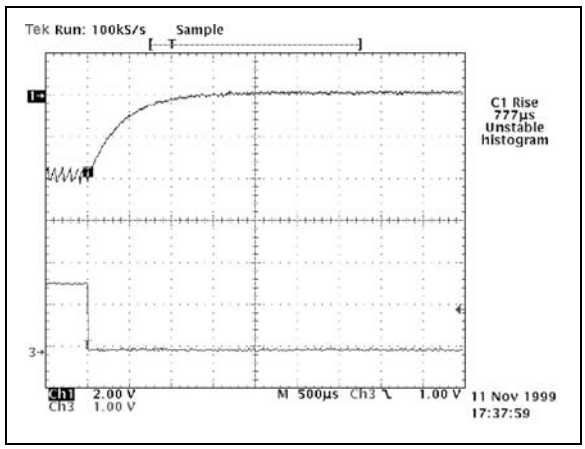

FIGURE 11: *TC1219 Shutdown Time with 1 µF External Capacitors and 10 mA Load Current. The top trace is the V_{OUT} signal and the bottom trace is the shutdown input.*

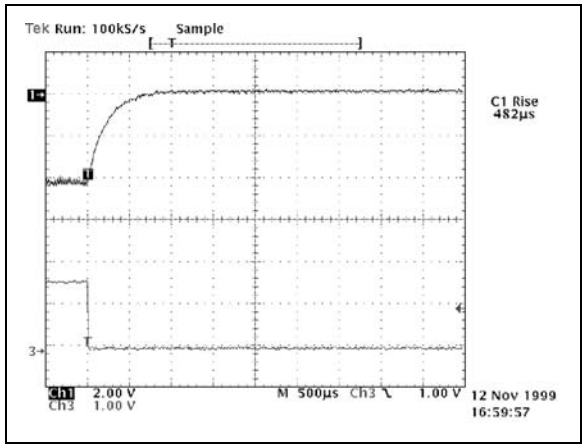

FIGURE 12: *TC1220 Shutdown Time with 0.47 µF External Capacitors and 10 mA Load Current. The top trace is the V_{OUT} signal and the bottom trace is the shutdown input.*

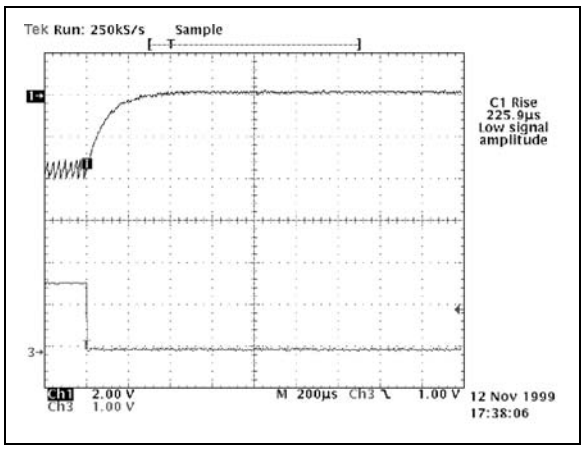

FIGURE 13: *TC1220 Shutdown Time with 0.22 µF External Capacitors and 10 mA Load Current. The top trace is the V_{OUT} signal and the bottom trace is the shutdown input.*

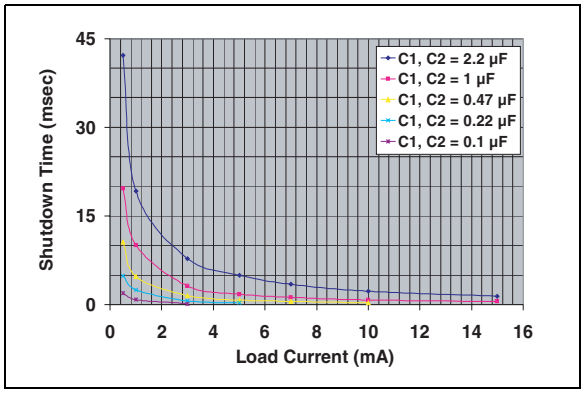

FIGURE 14: *TC1219 Shutdown Time vs. Load Current (V_{IN} = +5V).*

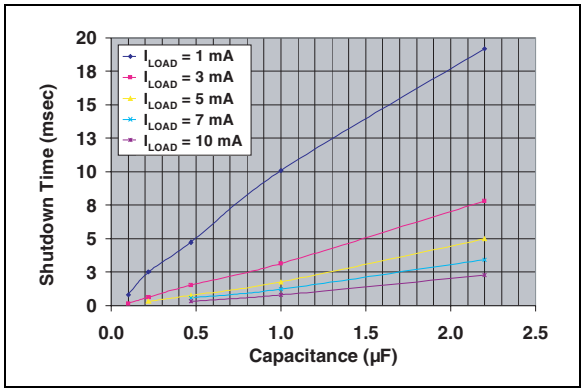

FIGURE 15: *TC1219 Shutdown Time vs. Capacitance (V_{IN} = +5V).*

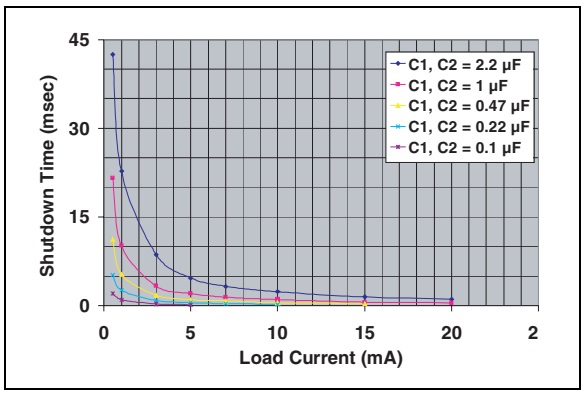

FIGURE 16: *TC1220 Shutdown Time vs. Load Current (V_{IN} = +5V).*

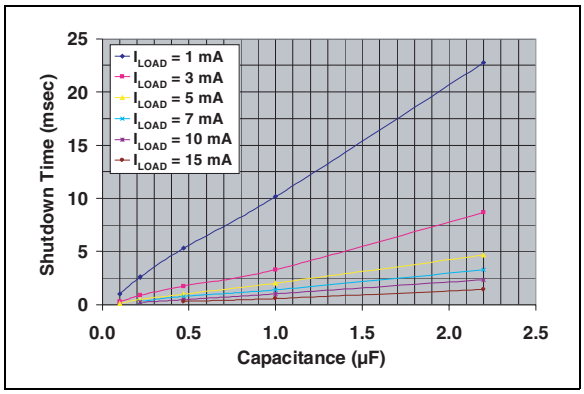

FIGURE 17: *TC1220 Shutdown Time vs. Capacitance (V_{IN} = +5V).*

SUMMARY

Microchip Technology Inc.'s TC1219 and TC1220 inverting charge pumps can be applied with lower value and lower cost external capacitors in circuit designs requiring lower output load currents that can also afford to have increased output voltage ripple. Using these devices with lower power external capacitors significantly quickens the shutdown response time, which is important in applications requiring higher speeds.

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