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DC Performance Comparisons of CMOS vs. Bipolar LDOs when Operating in "Dropout" (V_{IN} = Nominal V_{OUT}) Mode

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INTRODUCTION

More and more, battery operated systems are requiring lower terminal voltages to power internal circuits. Multi-cell designs are rapidly migrating to single-cell architectures to reduce system cost. A prime example of this system type is digital cameras, which often use a single-cell 3.6V Li-Ion battery for their power source. Digital cameras contain high-speed memory ICs, which require tight voltage regulation at moderate loads to meet the required timing parameters of the system. Precision low dropout (LDO) regulator devices can be used to meet these requirements but in doing so, the LDO regulators must be able to successfully operate in the 'dropout' mode as the battery discharges. Dropout mode is entered when the input voltage (from the battery source) is equal to the "nominal output voltage" of the LDO; for example a 3.3V LDO enters dropout mode when its input voltage at the V_{IN} pin is equal to 3.3V. Minimal output voltage droop and minimal LDO power dissipation are critical to meeting various system performance parameters and extending the life of the battery.

This application note compares the performance of Microchip Technology's TC1015 CMOS family of LDOs to two of its bipolar counterparts, the National Semiconductor LP2981 and the Micrel MIC5205. Dropout measurements were taken on three different popular output voltage options (5.0V, 3.3V, and 3.0V) under varying load conditions ranging from 10mA to 150mA. All measurements were made at ambient temperature (T_A = +25°C).

BACKGROUND INFORMATION: CMOS vs. BIPOLAR ARCHITECTURE

Figures 1A and 1B compare the block diagram for a common bipolar regulator with that of an equivalent regulator fabricated in CMOS. The supply current to the bipolar device is composed of the bias current, plus a "ground current" (I_{GND}) component shown in Figure 1A, which is a fraction of the output current (determined by the h_{FE} of the pass transistor) sunk through the output stage of the error amplifier. The "ground current" component of the CMOS regulator shown in Figure 1B is virtually zero, due to the extremely large drain-to-gate impedance of the CMOS pass transistor.

TEST CIRCUIT

The circuit shown in Figure 2 was used to measure output voltage droop and device ground current with loads ranging from 10mA to 100mA (in 10mA increments), 125mA, and 150mA. Both the TC1015 and the MIC5205 have optional reference bypass capacitor connections from pin four to ground. Measurements were made with and without a 470pF bypass capacitor on both of these devices but the output voltage droop and ground current did not vary much with the bypass capacitor connected (only the data taken without a bypass capacitor is shown in this application note).

TEST RESULTS

Tables I, II, and III show the performance of the TC1015, LP2981, and MIC5205 for dropout mode operation. Table I contains the data taken for 5.0V LDOs, Table II contains the data taken for 3.3V LDOs, and Table III contains the data taken for 3V LDOs. Notice that in each case, the ground current and power dissipation for the

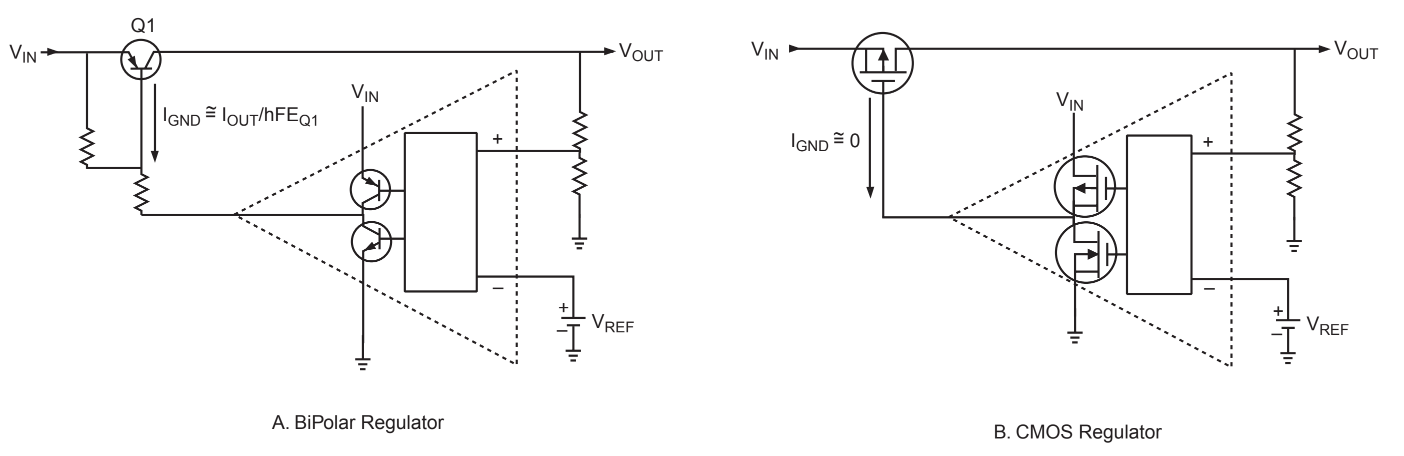

FIGURE 1: *Bipolar vs. CMOS LDO regulator schematics.*

TC1015 CMOS devices is several orders of magnitude better than the bipolar LP2981/MIC5205 devices. The TC1015 has a slightly better output voltage droop in dropout mode than the LP2981 for all load currents and has slightly better droop performance than the MIC5205 for load currents up to 60mA. The TC1015 has similar droop performance compared to the MIC5205 for load currents between 70mA and 100mA and slightly poorer droop performance for load currents greater than 100mA. However, the extremely high power dissipation of the MIC5205 makes it a hazardous liability in systems where extending battery life is critical. The CMOS architecture of the TC1015 family tends to be the best fit for these types of battery powered applications requiring regulators to operate in the dropout mode.

SUMMARY

In battery powered systems requiring lower terminal voltages (such as digital cameras), LDO regulators must often operate in the 'dropout' mode to enhance battery life. The TC1015 series of CMOS LDOs provide superior performance to bipolar LDOs in minimizing device power dissipation (through lower ground currents) when operating in the dropout mode. The TC1015 series has equivalent if not superior performance to bipolar LDOs in minimizing output voltage droop (under most load conditions) when operating in dropout.

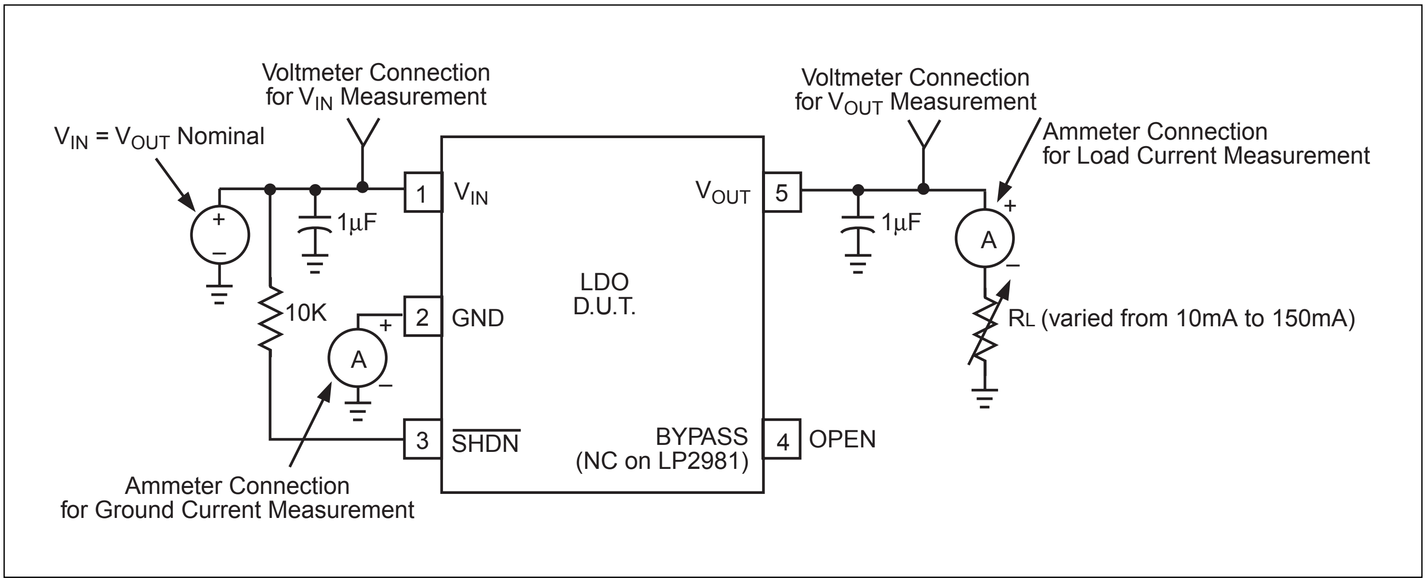

FIGURE 2: *Dropout mode test circuit.*

Test Conditions				Microchip TC1015-5.0VCT				NSC LP2981AIM5-5.0				Micrel MIC5205-5.0BM5			
V_{IN} (V)	C_{IN} (µF)	C_{OUT} (µF)	Load Current (mA)	V_{OUT} (V)	V_{OUT} Droop (mV)	Ground Current (µA)	*Device Power Dissipation (mW)	V_{OUT} (V)	V_{OUT} Droop (mV)	Ground Current (µA)	*Device Power Dissipation (mW)	V_{OUT} (V)	V_{OUT} Droop (mV)	Ground Current (µA)	*Device Power Dissipation (mW)
5.0	1.0	1.0	10	4.98	20	57.4	0.287	4.96	40	439	2.20	4.96	40	790	3.95
5.0	1.0	1.0	20	4.96	40	58.3	0.292	4.94	60	569	2.85	4.93	70	878	4.39
5.0	1.0	1.0	30	4.94	60	59.1	0.296	4.92	80	687	3.44	4.92	80	966	4.83
5.0	1.0	1.0	40	4.93	70	59.9	0.299	4.90	100	808	4.04	4.91	90	1082	5.41
5.0	1.0	1.0	50	4.91	90	60.6	0.303	4.88	120	933	4.66	4.89	110	1213	6.07
5.0	1.0	1.0	60	4.89	110	61.4	0.307	4.87	130	1054	5.27	4.88	120	1358	6.79
5.0	1.0	1.0	70	4.88	120	62.1	0.310	4.85	150	1188	5.94	4.87	130	1517	7.59
5.0	1.0	1.0	80	4.86	140	62.8	0.314	4.83	170	1318	6.59	4.87	130	1695	8.47
5.0	1.0	1.0	90	4.85	150	63.3	0.317	4.81	190	1455	7.27	4.86	140	1874	9.37
5.0	1.0	1.0	100	4.83	170	64.0	0.320	4.79	210	1598	7.99	4.85	150	2058	10.29
5.0	1.0	1.0	125	4.78	220	65.3	0.327	4.75	250	1961	9.80	4.83	170	2546	12.73
5.0	1.0	1.0	150	4.73	270	66.6	0.333	4.70	300	2298	11.49	4.81	190	3087	15.43

Notes: * Does not include power dissipated in pass element.
No reference bypass capacitors were used when measuring TC1015 and MIC5205.

TABLE 1: *5.0V LDO data in device dropout mode (V_{IN} = nominal V_{OUT}).*

Test Conditions				Microchip TC1015-3.3VCT				NSC LP2981AIM5-3.3				Micrel MIC5205-3.3BM5			
V_{IN} (V)	C_{IN} (µF)	C_{OUT} (µF)	Load Current (mA)	V_{OUT} (V)	V_{OUT} Droop (mV)	Ground Current (µA)	*Device Power Dissipation (mW)	V_{OUT} (V)	V_{OUT} Droop (mV)	Ground Current (µA)	*Device Power Dissipation (mW)	V_{OUT} (V)	V_{OUT} Droop (mV)	Ground Current (µA)	*Device Power Dissipation (mW)
3.3	1.0	1.0	10	3.28	20	58.5	0.193	3.27	30	467	1.54	3.27	30	1166	3.85
3.3	1.0	1.0	20	3.27	30	59.6	0.197	3.24	60	582	1.92	3.25	50	1264	4.17
3.3	1.0	1.0	30	3.25	50	60.4	0.199	3.22	80	693	2.29	3.23	70	1376	4.54
3.3	1.0	1.0	40	3.24	60	61.2	0.202	3.21	90	799	2.63	3.22	80	1497	4.94
3.3	1.0	1.0	50	3.22	80	61.8	0.204	3.19	110	917	3.03	3.21	90	1621	5.35
3.3	1.0	1.0	60	3.21	90	62.3	0.206	3.17	130	1050	3.47	3.20	100	1770	5.84
3.3	1.0	1.0	70	3.19	110	62.9	0.208	3.15	150	1173	3.87	3.19	110	1932	6.38
3.3	1.0	1.0	80	3.17	130	63.4	0.209	3.13	170	1304	4.30	3.18	120	2085	6.88
3.3	1.0	1.0	90	3.16	140	64.7	0.213	3.12	180	1452	4.79	3.18	120	2247	7.41
3.3	1.0	1.0	100	3.14	160	65.0	0.215	3.10	200	1597	5.27	3.17	130	2411	7.96
3.3	1.0	1.0	125	3.09	210	65.5	0.216	3.05	250	1955	6.45	3.15	150	2856	9.42
3.3	1.0	1.0	150	3.04	260	66.2	0.219	3.00	300	2293	7.57	3.13	170	3337	11.01

Notes: * Does not include power dissipated in pass element.
No reference bypass capacitors were used when measuring TC1015 and MIC5205.

TABLE 2: *3.3V LDO data in device dropout mode (V_{IN} = nominal V_{OUT}).*

Test Conditions				Microchip TC1015-3.0VCT				NSC LP2981AIM5-3.0				Micrel MIC5205-3.0BM5			
V_{IN} (V)	C_{IN} (µF)	C_{OUT} (µF)	Load Current (mA)	V_{OUT} (V)	V_{OUT} Droop (mV)	Ground Current (µA)	*Device Power Dissipation (mW)	V_{OUT} (V)	V_{OUT} Droop (mV)	Ground Current (µA)	*Device Power Dissipation (mW)	V_{OUT} (V)	V_{OUT} Droop (mV)	Ground Current (µA)	*Device Power Dissipation (mW)
3.0	1.0	1.0	10	2.98	20	60.7	0.182	2.97	30	572	1.72	2.94	60	536	1.61
3.0	1.0	1.0	20	2.97	30	61.5	0.185	2.95	50	685	2.06	2.92	80	619	1.86
3.0	1.0	1.0	30	2.95	50	62.2	0.187	2.93	70	793	2.38	2.90	100	724	2.17
3.0	1.0	1.0	40	2.94	60	62.8	0.189	2.91	90	903	2.71	2.89	110	845	2.53
3.0	1.0	1.0	50	2.92	80	63.4	0.190	2.90	100	1015	3.05	2.88	120	977	2.93
3.0	1.0	1.0	60	2.91	90	63.9	0.192	2.88	120	1137	3.41	2.87	130	1126	3.38
3.0	1.0	1.0	70	2.89	110	65.2	0.196	2.86	140	1253	3.76	2.86	140	1282	3.85
3.0	1.0	1.0	80	2.87	130	65.4	0.196	2.85	150	1379	4.14	2.85	150	1446	4.34
3.0	1.0	1.0	90	2.86	140	65.5	0.196	2.83	170	1504	4.51	2.84	160	1638	4.91
3.0	1.0	1.0	100	2.84	160	65.5	0.197	2.81	190	1639	4.92	2.83	170	1818	5.45
3.0	1.0	1.0	125	2.80	200	65.7	0.197	2.77	230	1969	5.91	2.81	190	2323	6.97
3.0	1.0	1.0	150	2.75	250	66.2	0.198	2.73	270	2251	6.75	2.79	210	2884	8.65

Notes: * Does not include power dissipated in pass element.
No reference bypass capacitors were used when measuring TC1015 and MIC5205.

TABLE 3: *3.0V LDO data in device dropout mode (V_{IN} = nominal V_{OUT}).*

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