

dsPIC33CK256MP508 Motor Control Plug-In Module (PIM) Information Sheet for External Op Amp Configuration

The dsPIC33CK256MP508 External Op Amp Motor Control PIM (P/N: MA330041-1) is designed to demonstrate the motor control capabilities of the dsPIC33CK256MP508 device using external on-board op amps.

The dsPIC33CK256MP508 device is a high-performance, 16-bit Digital Signal Controller (DSC). This Motor Control PIM is designed to take advantage of the high-resolution PWM (with fine edge placement) peripheral in the device. The PWM, along with other peripherals, such as the ADC, enable motor control applications.

The PIM can be used to demonstrate and develop motor control applications by inserting it in the 100-pin PIM interface header provided on the compatible motor control development boards (see [Table 1](#)). The PIM is designed to run a single motor with all the compatible development boards. When operating this PIM on the dsPICDEM™ MCLV-2 Development Board, insert an external op amp configuration matrix board (see [Figure 2](#)) on the J14 header provided on the board. In the case of dsPICDEM MCHV-2/ MCHV-3 Development Boards, insert an external op amp configuration matrix board on to the J4 header (as shown in [Figure 2](#)) on the board. The PIM design also supports dual motor control on the Low-Voltage Motor Control Bundle (DV330100).

For additional information regarding development boards, refer to the respective user's guides available on the Microchip website (www.microchip.com).

[Table 1](#) provides information on the hardware versions of the motor control boards that are compatible with this PIM. Refer to the specific motor control board user's guide for the hardware version identification information.

FIGURE 1: dsPIC33CK256MP508 EXTERNAL OP AMP MOTOR CONTROL PIM (MA330041-1)



FIGURE 2: EXTERNAL OP AMP CONFIGURATION BOARD



TABLE 1: HARDWARE COMPATIBILITY

Development Board	Part Number	Compatible Hardware Version(s)
dsPICDEM™ MCHV Development Board	DM330023	Not Compatible
dsPICDEM MCLV Development Board	DM330021	Not Compatible
dsPICDEM MCSM Development Board	DM330022	Not Compatible
dsPICDEM MCHV-3 Development Board	DM330023-3	All Revisions
dsPICDEM MCHV-2 Development Board	DM330023-2	All Revisions
dsPICDEM MCLV-2 Development Board	DM330021-2	All Revisions
Low-Voltage Motor Control Development Bundle	DV330100	All Revisions

Warning: Do not connect non-isolated oscilloscope probes to the test points on the PIM while using with the dsPICDEM MCHV-2 or MCHV-3 Development Board. Failure to heed this warning could result in hardware damage.

dsPIC33CK256MP508

Table 2 provides the mapping between the 80-pin device pinout and the 100-pin PIM.

TABLE 2: DEVICE TO PIM MAPPING (SORTED BY DEVICE PIN NUMBER)

Device Pin #	dsPIC33CK256MP508 Device Functional Description	PIM Pin #	Remarks
1	RP46/PWM1H/PMD5/RB14	PIM:94	Direct Connection
2	AN20/RE0	PIM:22	Direct Connection
3	RP47/PWM1L/PMD6/RB15	PIM:93	Direct Connection
4	AN21/RE1	PIM:21	Direct Connection
5	RP60/PWM8H/PMD7/RC12	PIM:09	Direct Connection
6	RP61/PWM8L/PMA5/RC13	PIM:08	Direct Connection
7	RP62/PWM6H/PMA4/RC14	PIM:04	Direct Connection
8	RP63/PWM6L/PMA3/RC15	PIM:05	Direct Connection
9	MCLR	PIM:13	MCLR
10	RP79/PCI22/PMA2/RD15	PIM:19	Direct Connection
11	Vss	PIM:15, 36, 65, 75 ⁽⁴⁾	Digital Ground (DGND)
12	VDD	PIM:02, 16, 37, 62, 86 ⁽³⁾	Digital Power (DVDD)
13	RP78/PCI21/RD14	PIM:92	Direct Connection
14	ANN2/RP77/RD13	PIM:89	Direct Connection
15	AN12/ANN0/RP48/RC0	PIM:55	Direct Connection
16	OA1OUT/AN0/CMP1A/IBIAS0/RA0	PIM:25 ⁽¹⁾	Connected via 0 Ohm Resistor
16	OA1OUT/AN0/CMP1A/IBIAS0/RA0	PIM:57 ⁽²⁾	Can be Connected via 0 Ohm Resistor
17	AN22/RE2	PIM:20	Direct Connection
18	OA1IN-/ANA1/RA1	PIM:24 ⁽¹⁾	Connected via 0 Ohm Resistor
18	OA1IN-/ANA1/RA1	PIM:56 ⁽²⁾	Can be Connected via 0 Ohm Resistor
18	OA1IN-/ANA1/RA1	—	—
19	AN23/RE3	PIM:33	Direct Connection
20	OA1IN+/AN9/PMA6/RA2	—	—
21	DACOUT1/AN3/CMP1C/RA3	PIM:12	Direct Connection
22	RE4	PIM:69	Direct Connection
23	OA3OUT/AN4/CMP3B/IBIAS3/RA4	PIM:21 ⁽²⁾	Connected via 0 Ohm Resistor
24	RE5	PIM:68	Direct Connection
25	AVDD	PIM:30	Analog Power (AVDD)
26	AVss	PIM:31 ⁽⁵⁾	Analog Ground (AGND)
27	RP76/RD12	PIM:85	Direct Connection
28	OA3IN-/AN13/CMP1B/ISRC0/RP49/PMA7/RC1	—	—
29	OA3IN+/AN14/CMP2B/ISRC1/RP50/PMD13/PMA13/RC2	—	—
30	AN17/ANN1/IBIAS1/RP54/PMD12/PMA12/RC6	PIM:43	Direct Connection
31	VDD	PIM:02, 16, 37, 62, 86 ⁽³⁾	Digital Power (DVDD)
32	Vss	PIM:15, 36, 65, 75 ⁽⁴⁾	Digital Ground (DGND)
33	AN15/CMP2A/IBIAS2/RP51/PMD11/PMA11/RC3	PIM:23	Direct Connection
34	OSCI/CLKI/AN5/RP32/PMD10/PMA10/RB0	PIM:63	Direct Connection
35	OSCO/CLKO/AN6/RP33/PMA1/PMALH/PSA1/RB1	PIM:64	Direct Connection
36	AN19/CMP2C/RP75/PMA0/PMALL/PSA0/RD11	PIM:32	Direct Connection

- Note 1:** The PIM pin is directly connected to the device pin through a 0 Ohm resistor (default), which can be removed if desired.
- Note 2:** The PIM pin can be connected to a device pin through a 0 Ohm resistor if required. For proper operation, ensure that other 0 Ohm resistors connecting to the same device pin are removed.
- Note 3:** Digital Power (DVDD) pins are shorted together on the PIM.
- Note 4:** Digital Ground (DGND) pins are shorted together on the PIM.
- Note 5:** Analog Ground (AGND) connection via PIM:31 is shorted with Digital Ground (DGND) through 0 Ohm resistor, R27, on the PIM.

dsPIC33CK256MP508

TABLE 2: DEVICE TO PIM MAPPING (SORTED BY DEVICE PIN NUMBER) (CONTINUED)

Device Pin #	dsPIC33CK256MP508 Device Functional Description	PIM Pin #	Remarks
37	RE6	PIM:11	Direct Connection
38	AN18/CMP3C/ISRC3/RP74/PMD9/PMA9/RD10	PIM:35	Direct Connection
39	RE7	PIM:84	Direct Connection
40	AN16/ISRC2/RP55/PMD8/PMA8/RC7	PIM:79	Direct Connection
41	OA2OUT/AN1/AN7/ANA0/CMP1D/CMP2D/CMP3D/RP34/SCL3/INT0/RB2	PIM:22 ⁽¹⁾	Connected via 0 Ohm Resistor
42	RE8	PIM:60	Direct Connection
43	PGD2/OA2IN-/AN8/RP35/RB3	—	—
44	RE9	PIM:1	Direct Connection
45	PGC2/OA2IN+/RP36/RB4	—	—
46	RP56/ASDA1/SCK2/RC8	PIM:95	Direct Connection
47	RP57/ASCL1/SDI2/RC9	PIM:96	Direct Connection
48	RP73/PCI20/RD9	PIM:10	Direct Connection
49	RP72/SDO2/PCI19/RD8	PIM:18	Direct Connection
50	Vss	PIM:15, 36, 65, 75 ⁽⁴⁾	Digital Ground (DGND)
51	VDD	PIM:02, 16, 37, 62, 86 ⁽³⁾	Digital Power (DVDD)
52	RP71/PMD15/RD7	PIM:49	Direct Connection
53	RP70/PMD14/RD6	PIM:50	Direct Connection
54	RP69/PMA15/PMCS2/RD5	PIM:83	Direct Connection
55	PGD3/RP37/SDA2/PMA14/PMCS1/PSCS/RB5	PIM:27	Direct Connection
56	PGC3/RP38/SCL2/RB6	PIM:26	Direct Connection
57	RE10	PIM:40	Direct Connection
58	TDO/AN2/CMP3A/RP39/SDA3/RB7	PIM:14	Direct Connection
59	RE11	PIM:41	Direct Connection
60	PGD1/AN10/RP40/SCL1/RB8	PIM:17	Direct Connection
61	PGC1/AN11/RP41/SDA1/RB9	PIM:25	Direct Connection
62	RE12	PIM:59	Direct Connection
63	RP52/PWM5H/ASDA2/RC4	PIM:76	Direct Connection
64	RE13	PIM:34	Direct Connection
65	RP53/PWM5L/ASCL2/PMWR/PMENB/PSWR/RC5	PIM:54	Direct Connection
66	RP58/PWM7H/PMRD/PMWR/PSRD/RC10	PIM:07	Direct Connection
67	RP59/PWM7L/RC11	PIM:06	Direct Connection
68	RP68/ASDA3/RD4	PIM:61	Direct Connection
69	RP67/ASCL3/RD3	PIM:48	Direct Connection
70	Vss	PIM:15, 36, 65, 75 ⁽⁴⁾	Digital Ground (DGND)
71	VDD	PIM:02, 16, 37, 62, 86 ⁽³⁾	Digital Power (DVDD)
72	RP66/RD2	PIM:47	Direct Connection
73	RP65/PWM4H/RD1	PIM:80	Direct Connection
74	RP64/PWM4L/PMD0/RD0	PIM:78	Direct Connection
75	TMS/RP42/PWM3H/PMD1/RB10	PIM:03	Direct Connection
76	TCK/RP43/PWM3L/PMD2/RB11	PIM:100	Direct Connection
77	RE14	PIM:82	Direct Connection

- Note 1:** The PIM pin is directly connected to the device pin through a 0 Ohm resistor (default), which can be removed if desired.
- Note 2:** The PIM pin can be connected to a device pin through a 0 Ohm resistor if required. For proper operation, ensure that other 0 Ohm resistors connecting to the same device pin are removed.
- Note 3:** Digital Power (DVDD) pins are shorted together on the PIM.
- Note 4:** Digital Ground (DGND) pins are shorted together on the PIM.
- Note 5:** Analog Ground (AGND) connection via PIM:31 is shorted with Digital Ground (DGND) through 0 Ohm resistor, R27, on the PIM.

dsPIC33CK256MP508

TABLE 2: DEVICE TO PIM MAPPING (SORTED BY DEVICE PIN NUMBER) (CONTINUED)

Device Pin #	dsPIC33CK256MP508 Device Functional Description	PIM Pin #	Remarks
78	TDI/RP44/PWM2H/PMD3/RB12	PIM:99	Direct Connection
79	RE15	PIM:90	Direct Connection
80	RP45/PWM2L/PMD4/RB13	PIM:98	Direct Connection

- Note 1:** The PIM pin is directly connected to the device pin through a 0 Ohm resistor (default), which can be removed if desired.
- 2:** The PIM pin can be connected to a device pin through a 0 Ohm resistor if required. For proper operation, ensure that other 0 Ohm resistors connecting to the same device pin are removed.
- 3:** Digital Power (DVDD) pins are shorted together on the PIM.
- 4:** Digital Ground (DGND) pins are shorted together on the PIM.
- 5:** Analog Ground (AGND) connection via PIM:31 is shorted with Digital Ground (DGND) through 0 Ohm resistor, R27, on the PIM.

dsPIC33CK256MP508

Table 3 provides the mapping between the 80-pin device pinout and the 100-pin PIM.

TABLE 3: DEVICE TO PIM MAPPING (SORTED BY PIM PIN NUMBER)

PIM Pin #	Device Pin #	dsPIC33CK256MP508 Device Functional Description	Remarks
PIM:01	44	RE9	Direct Connection
PIM:02 ⁽³⁾	12, 31, 51, 71	VDD	Digital Power (DVDD)
PIM:03	75	TMS/RP42/PWM3H/PMD1/RB10	Direct Connection
PIM:04	7	RP62/PWM6H/PMA4/RC14	Direct Connection
PIM:05	8	RP63/PWM6L/PMA3/RC15	Direct Connection
PIM:06	67	RP59/PWM7L/RC11	Direct Connection
PIM:07	66	RP58/PWM7H/PMRD/PMWR/PSRD/RC10	Direct Connection
PIM:08	6	RP61/PWM8L/PMA5/RC13	Direct Connection
PIM:09	5	RP60/PWM8H/PMD7/RC12	Direct Connection
PIM:10	48	RP73/PCI20/RD9	Direct Connection
PIM:11	37	RE6	Direct Connection
PIM:12	21	DACOUT1/AN3/CMP1C/RA3	Direct Connection
PIM:13	9	MCLR	MCLR
PIM:14	58	TDO/AN2/CMP3A/RP39/SDA3/RB7	Direct Connection
PIM:15 ⁽⁴⁾	11, 32, 50, 70	VSS	Digital Ground (DGND)
PIM:16 ⁽³⁾	12, 31, 51, 71	VDD	Digital Power (DVDD)
PIM:17	60	PGD1/AN10/RP40/SCL1/RB8	Direct Connection
PIM:18	49	RP72/SDO2/PCI19/RD8	Direct Connection
PIM:19	10	RP79/PCI22/PMA2/RD15	Direct Connection
PIM:20	17	AN22/RE2	Direct Connection
PIM:21	4	AN21/RE1	Direct Connection
PIM:21 ⁽¹⁾	23	OA3OUT/AN4/CMP3B/IBIAS3/RA4	Connected via 0 Ohm Resistor
PIM:22	2	AN20/RE0	Direct Connection
PIM:22 ⁽¹⁾	41	OA2OUT/AN1/AN7/ANA0/CMP1D/CMP2D/CMP3D/RP34/SCL3/INT0/RB2	Connected via 0 Ohm Resistor
PIM:23	33	AN15/CMP2A/IBIAS2/RP51/PMD11/PMA11/RC3	Direct Connection
PIM:24 ⁽¹⁾	18	OA1IN-/ANA1/RA1	Connected via 0 Ohm Resistor
PIM:25	61	PGC1/AN11/RP41/SDA1/RB9	Direct Connection
PIM:25 ⁽¹⁾	16	OA1OUT/AN0/CMP1A/IBIAS0/RA0	Connected via 0 Ohm Resistor
PIM:26	56	PGC3/RP38/SCL2/RB6	Direct Connection
PIM:27	55	PGD3/RP37/SDA2/PMA14/PMCS1/PSCS/RB5	Direct Connection
PIM:28	—	—	Not Connected
PIM:29	—	—	Not Connected
PIM:30	25	AVDD	Analog Power (AVDD)
PIM:31 ⁽⁵⁾	26	AVSS	Analog Ground (AGND)
PIM:32	36	AN19/CMP2C/RP75/PMA0/PMALL/PSA0/RD11	Direct Connection
PIM:33	19	AN23/RE3	Direct Connection
PIM:34	64	RE13	Direct Connection
PIM:35	38	AN18/CMP3C/ISRC3/RP74/PMD9/PMA9/RD10	Direct Connection

- Note 1:** The PIM pin is directly connected to the device pin through a 0 Ohm resistor (default), which can be removed if desired.
- Note 2:** The PIM pin can be connected to a device pin through a 0 Ohm resistor if required. For proper operation, ensure that other 0 Ohm resistors connecting to the same device pin are removed.
- Note 3:** Digital Power (DVDD) pins are shorted together on the PIM.
- Note 4:** Digital Ground (DGND) pins are shorted together on the PIM.
- Note 5:** Analog Ground (AGND) connection via PIM:31 is shorted with Digital Ground (DGND) through 0 Ohm resistor, R27, on the PIM.

dsPIC33CK256MP508

TABLE 3: DEVICE TO PIM MAPPING (SORTED BY PIM PIN NUMBER) (CONTINUED)

PIM Pin #	Device Pin #	dsPIC33CK256MP508 Device Functional Description	Remarks
PIM:36 ⁽⁴⁾	11, 32, 50, 70	Vss	Digital Ground (DGND)
PIM:37 ⁽³⁾	12, 31, 51, 71	VDD	Digital Power (DVDD)
PIM:38	—	—	Not Connected
PIM:39	—	—	Not Connected
PIM:40	57	RE10	Direct Connection
PIM:41	59	RE11	Direct Connection
PIM:42	—	—	Not Connected
PIM:43	30	AN17/ANN1/IBIAS1/RP54/PMD12/PMA12/RC6	Direct Connection
PIM:44	—	—	Not Connected
PIM:45	—	—	Not Connected
PIM:46	—	—	Not Connected
PIM:47	72	RP66/RD2	Direct Connection
PIM:48	69	RP67/ASCL3/RD3	Direct Connection
PIM:49	52	RP71/PMD15/RD7	Direct Connection
PIM:50	53	RP70/PMD14/RD6	Direct Connection
PIM:51	—	—	Not Connected
PIM:52	—	—	Not Connected
PIM:53	—	—	Not Connected
PIM:54	65	RP53/PWM5L/ASCL2/PMWR/PMENB/PSWR/RC5	Direct Connection
PIM:55	15	AN12/ANN0/RP48/RC0	Direct Connection
PIM:56 ⁽²⁾	18	OA1IN-/ANA1/RA1	Can be Connected via 0 Ohm Resistor
PIM:57 ⁽²⁾	16	OA1OUT/AN0/CMP1A/IBIAS0/RA0	Can be Connected via 0 Ohm Resistor
PIM:58	—	—	Not Connected
PIM:59	62	RE12	Direct Connection
PIM:60	42	RE8	Direct Connection
PIM:61	68	RP68/ASDA3/RD4	Direct Connection
PIM:62 ⁽³⁾	12, 31, 51, 71	VDD	Digital Power (DVDD)
PIM:63	34	OSCI/CLKI/AN5/RP32/PMD10/PMA10/RB0	Direct Connection
PIM:64	35	OSCO/CLKO/AN6/RP33/PMA1/PMALH/PSA1/RB1	Direct Connection
PIM:65 ⁽⁴⁾	11, 32, 50, 70	Vss	Digital Ground (DGND)
PIM:66	—	—	Not Connected
PIM:67	—	—	Not Connected
PIM:68	24	RE5	Direct Connection
PIM:69	22	RE4	Direct Connection
PIM:70	—	—	Not Connected
PIM:71	—	—	Not Connected
PIM:72	—	—	Not Connected
PIM:73	—	—	Not Connected
PIM:74	—	—	Not Connected
PIM:75 ⁽⁴⁾	11, 32, 50, 70	Vss	Digital Ground (DGND)
PIM:76	63	RP52/PWM5H/ASDA2/RC4	Direct Connection
PIM:77	—	—	Not Connected

- Note 1:** The PIM pin is directly connected to the device pin through a 0 Ohm resistor (default), which can be removed if desired.
- 2:** The PIM pin can be connected to a device pin through a 0 Ohm resistor if required. For proper operation, ensure that other 0 Ohm resistors connecting to the same device pin are removed.
- 3:** Digital Power (DVDD) pins are shorted together on the PIM.
- 4:** Digital Ground (DGND) pins are shorted together on the PIM.
- 5:** Analog Ground (AGND) connection via PIM:31 is shorted with Digital Ground (DGND) through 0 Ohm resistor, R27, on the PIM.

dsPIC33CK256MP508

TABLE 3: DEVICE TO PIM MAPPING (SORTED BY PIM PIN NUMBER) (CONTINUED)

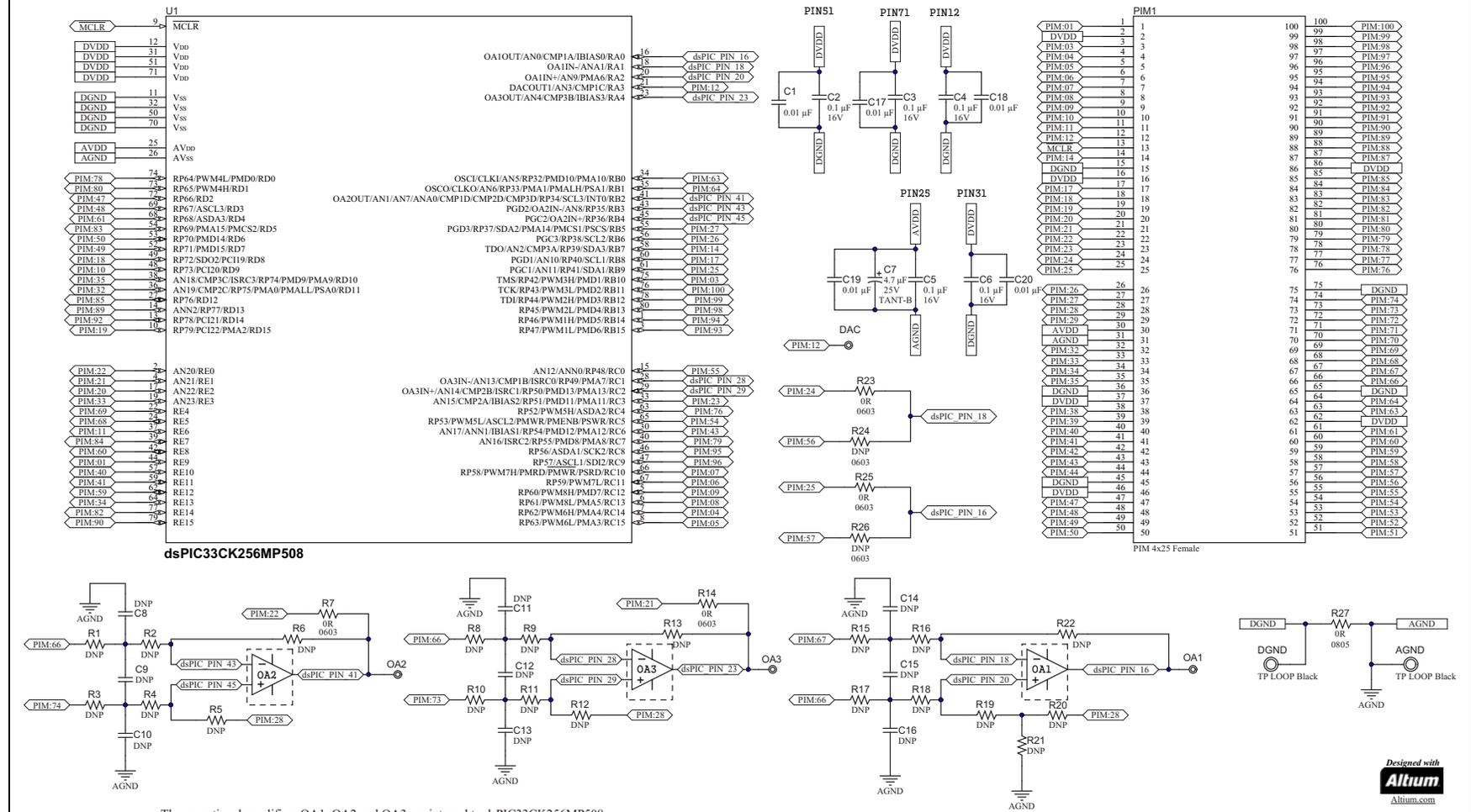
PIM Pin #	Device Pin #	dsPIC33CK256MP508 Device Functional Description	Remarks
PIM:78	74	RP64/PWM4L/PMD0/RD0	Direct Connection
PIM:79	40	AN16/ISRC2/RP55/PMD8/PMA8/RC7	Direct Connection
PIM:80	73	RP65/PWM4H/RD1	Direct Connection
PIM:81	—	—	Not Connected
PIM:82	77	RE14	Direct Connection
PIM:83	54	RP69/PMA15/PMCS2/RD5	Direct Connection
PIM:84	39	RE7	Direct Connection
PIM:85	27	RP76/RD12	Direct Connection
PIM:86 ⁽³⁾	12, 31, 51, 71	VDD	Digital Power (DVDD)
PIM:87	—	—	Not Connected
PIM:88	—	—	Not Connected
PIM:89	14	ANN2/RP77/RD13	Direct Connection
PIM:90	79	RE15	Direct Connection
PIM:91	—	—	Not Connected
PIM:92	13	RP78/PCI21/RD14	Direct Connection
PIM:93	3	RP47/PWM1L/PMD6/RB15	Direct Connection
PIM:94	1	RP46/PWM1H/PMD5/RB14	Direct Connection
PIM:95	46	RP56/ASDA1/SCK2/RC8	Direct Connection
PIM:96	47	RP57/ASCL1/SDI2/RC9	Direct Connection
PIM:97	—	—	Not Connected
PIM:98	80	RP45/PWM2L/PMD4/RB13	Direct Connection
PIM:99	78	TDI/RP44/PWM2H/PMD3/RB12	Direct Connection
PIM:100	76	TCK/RP43/PWM3L/PMD2/RB11	Direct Connection

- Note 1:** The PIM pin is directly connected to the device pin through a 0 Ohm resistor (default), which can be removed if desired.
- 2:** The PIM pin can be connected to a device pin through a 0 Ohm resistor if required. For proper operation, ensure that other 0 Ohm resistors connecting to the same device pin are removed.
- 3:** Digital Power (DVDD) pins are shorted together on the PIM.
- 4:** Digital Ground (DGND) pins are shorted together on the PIM.
- 5:** Analog Ground (AGND) connection via PIM:31 is shorted with Digital Ground (DGND) through 0 Ohm resistor, R27, on the PIM.

dsPIC33CK256MP508 Motor Control Plug-In Module (PIM) for External Op Amp Configuration

Schematic Revision 1.0

dsPIC33CK256MP508 External Op Amp Motor Control PIM



The operational amplifiers OA1, OA2 and OA3 are internal to dsPIC33CK256MP508



Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as “unbreakable.”

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELoC® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

**QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
= ISO/TS 16949 =**

Trademarks

The Microchip name and logo, the Microchip logo, AnyRate, AVR, AVR logo, AVR Freaks, BitCloud, chipKIT, chipKIT logo, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, Helder, JukeBlox, KeeLoq, Klear, LANCheck, LINK MD, maXStylus, maXTouch, MediaLB, megaAVR, MOST, MOST logo, MPLAB, OptoLyzer, PIC, picoPower, PICSTART, PIC32 logo, Prochip Designer, QTouch, SAM-BA, SpyNIC, SST, SST Logo, SuperFlash, tinyAVR, UNI/O, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

ClockWorks, The Embedded Control Solutions Company, EtherSynch, Hyper Speed Control, HyperLight Load, IntelliMOS, mTouch, Precision Edge, and Quiet-Wire are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, BodyCom, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, EtherGREEN, In-Circuit Serial Programming, ICSP, INICnet, Inter-Chip Connectivity, JitterBlocker, KlearNet, KlearNet logo, memBrain, Mindi, MiWi, motorBench, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICKit, PICtail, PowerSmart, PureSilicon, QMatrix, REAL ICE, Ripple Blocker, SAM-ICE, Serial Quad I/O, SMART-I.S., SQI, SuperSwitcher, SuperSwitcher II, Total Endurance, TSHARC, USBCheck, VariSense, ViewSpan, WiperLock, Wireless DNA, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2018, Microchip Technology Incorporated, All Rights Reserved.
ISBN: 978-1-5224-3284-5



MICROCHIP

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
<http://www.microchip.com/support>
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453
Tel: 317-536-2380

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608
Tel: 951-273-7800

Raleigh, NC
Tel: 919-844-7510

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110
Tel: 408-436-4270

Canada - Toronto
Tel: 905-695-1980
Fax: 905-695-2078

ASIA/PACIFIC

Australia - Sydney
Tel: 61-2-9868-6733

China - Beijing
Tel: 86-10-8569-7000

China - Chengdu
Tel: 86-28-8665-5511

China - Chongqing
Tel: 86-23-8980-9588

China - Dongguan
Tel: 86-769-8702-9880

China - Guangzhou
Tel: 86-20-8755-8029

China - Hangzhou
Tel: 86-571-8792-8115

China - Hong Kong SAR
Tel: 852-2943-5100

China - Nanjing
Tel: 86-25-8473-2460

China - Qingdao
Tel: 86-532-8502-7355

China - Shanghai
Tel: 86-21-3326-8000

China - Shenyang
Tel: 86-24-2334-2829

China - Shenzhen
Tel: 86-755-8864-2200

China - Suzhou
Tel: 86-186-6233-1526

China - Wuhan
Tel: 86-27-5980-5300

China - Xian
Tel: 86-29-8833-7252

China - Xiamen
Tel: 86-592-2388138

China - Zhuhai
Tel: 86-756-3210040

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-3090-4444

India - New Delhi
Tel: 91-11-4160-8631

India - Pune
Tel: 91-20-4121-0141

Japan - Osaka
Tel: 81-6-6152-7160

Japan - Tokyo
Tel: 81-3-6880-3770

Korea - Daegu
Tel: 82-53-744-4301

Korea - Seoul
Tel: 82-2-554-7200

Malaysia - Kuala Lumpur
Tel: 60-3-7651-7906

Malaysia - Penang
Tel: 60-4-227-8870

Philippines - Manila
Tel: 63-2-634-9065

Singapore
Tel: 65-6334-8870

Taiwan - Hsin Chu
Tel: 886-3-577-8366

Taiwan - Kaohsiung
Tel: 886-7-213-7830

Taiwan - Taipei
Tel: 886-2-2508-8600

Thailand - Bangkok
Tel: 66-2-694-1351

Vietnam - Ho Chi Minh
Tel: 84-28-5448-2100

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

Finland - Espoo
Tel: 358-9-4520-820

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Garching
Tel: 49-8931-9700

Germany - Haan
Tel: 49-2129-3766400

Germany - Heilbronn
Tel: 49-7131-67-3636

Germany - Karlsruhe
Tel: 49-721-625370

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Germany - Rosenheim
Tel: 49-8031-354-560

Israel - Ra'anana
Tel: 972-9-744-7705

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Padova
Tel: 39-049-7625286

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Norway - Trondheim
Tel: 47-7289-7561

Poland - Warsaw
Tel: 48-22-3325737

Romania - Bucharest
Tel: 40-21-407-87-50

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Gothenberg
Tel: 46-31-704-60-40

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820