

## PIC32MK MCM 100-pin Motor Control Plug-In Module (PIM) Information Sheet

The PIC32MK MCM 100-pin Motor Control Plug-in Module (PIM) (MA320211) is designed to demonstrate the capabilities of the PIC32MK MCM 100-pin Motor Control device, PIC32MK1024MCM100, using external or internal on-chip op amps with the following hardware:

- dsPICDEM™ MCLV-2 development board (DM330021-2)
- dsPICDEM™ MCHV-2 development board (DM330023-2)
- dsPICDEM™ MCHV-3 development board (DM330023-3)

All above development boards support 100-pin PIM interfaces.

### Selecting the External On-board Op Amp Configuration

To operate the PIC32MK MCM 100-pin Motor Control PIM using external on-board op amps, insert the External Op amp Configuration Board, which is included with the development board, into the appropriate header for the hardware in use:

- J14 (dsPICDEM™ MCLV-2 development board)
- J4 (dsPICDEM™ MCHV-2/MCHV-3 development board). In addition, for MCHV-2/MCHV-3, ensure that jumpers are set at position 1-2 for J12, J13, J14, and position 5-6 for J11.

Figure 1 shows the connection location for the external on-board op amp on the dsPICDEM MCLV-2 development board.

**FIGURE 1: EXTERNAL OP AMP CONFIGURATION BOARD**



### Selecting the Internal On-board Op Amp Configuration

To operate the PIC32MK MCM 100-pin Motor Control PIM using internal on-chip op amps, insert the Internal Op Amp Configuration Board, which is included with the development board, into the appropriate header for the hardware in use:

- J14 (dsPICDEM MCLV-2 development board)
- J4 (dsPICDEM MCHV-2/MCHV-3 development board)

Figure 2 shows the connection locations for the internal on-board op amp on the dsPICDEM MCLV-2 development board.

**FIGURE 2: INTERNAL OP AMP CONFIGURATION BOARD**



**WARNING:** Do not connect non-isolated oscilloscope probes to probe any traces while using the PIM with the dsPICDEM MCHV-2 or dsPICDEM MCHV-3 development boards. Instead, use a high-voltage differential probe, rate in excess of 600 VRMS (Common mode). Failure to heed this warning could result in hardware damage.

Table 1 provides the static mapping between the 100-pin PIM pins and the 100-pin device pins.

Figure 3 shows the 100-pin PIM header schematic.

Figure 4 shows the 100-pin PIM device schematic.

**TABLE 1: PIN MAP**

| PIM Pin Number | PIC32MK MCM |                          | dsPICDEM MCLV2 Board 100-pin PIM Header |   | dsPICDEM MCM             |
|----------------|-------------|--------------------------|---|---|--------------------------|
|                | Pin Number  | Pin Name                 | Pin Name                                | Pin Functionality                               | Pin Name                 |
| 1              | 1           | RG15                     | DBG_LED2                                | Debug LED 2                                     | DBG_LED1                 |
| 2              | 2           | VDD                      | VDD                                     | VDD   | +3.3V_DIG                |
| 3              | 93          | PWM3H                    | PWM1H3                                  | Phase M3 High-Side PWM                          | PWM1H3                   |
| 4              | 6           | PWM5L                    | N/A                                     | N/A   | N/A                      |
| 5              | N/A         | N/A                      | N/A                                     | N/A   | N/A                      |
| 6              | 8           | PWM6L                    | N/A                                     | N/A   | N/A                      |
| 7              | 9           | PWM6H                    | N/A                                     | N/A   | N/A                      |
| 8              | 17          | AN22                     | N/A                                     | N/A   | N/A                      |
| 9              | 18          | AN21                     | N/A                                     | N/A   | N/A                      |
| 10             | N/A         | N/A                      | N/A                                     | N/A   | N/A                      |
| 11             | N/A         | N/A                      | N/A                                     | N/A   | N/A                      |
| 12             | N/A         | N/A                      | N/A                                     | N/A   | N/A                      |
| 13             | 13          | $\overline{\text{MCLR}}$ | $\overline{\text{MCLR}}$                | Master Clear Reset ( $\overline{\text{MCLR}}$ ) | $\overline{\text{MCLR}}$ |
| 14             | N/A         | N/A                      | N/A                                     | N/A   | N/A                      |
| 15             | 15          | VSS                      | VSS                                     | VSS   | GND_DIG                  |
| 16             | 16          | VDD                      | VDD                                     | VDD   | +3.3V_DIG                |
| 17             | N/A         | N/A                      | N/A                                     | N/A   | N/A                      |
| 18             | 50          | FLT15                    | FAULT_MC                                | Motor Fault                                     | FAULT                    |
| 19             | 42          | FLT6                     | N/A                                     | N/A   | PFC_FAULT                |
| 20             | 23          | AN1/RPA1                 | PIM_V_M3                                | Phase M3 Voltage Feedback Signal                | PIM_INDX/POT/<br>V_M3    |

**TABLE 1: PIN MAP (CONTINUED)**

| PIM Pin Number | PIC32MK MCM |          | dsPICDEM MCLV2 Board 100-pin PIM Header |                                  | dsPICDEM MCM    |
|----------------|-------------|----------|---|----------------------------------|-----------------|
|                | Pin Number  | Pin Name | Pin Name                                | Pin Functionality                | Pin Name        |
| 21             | 26          | AN4/RPB2 | PIM_V_M2                                | Phase M2 Voltage Feedback Signal | PIM_QEB/IB/V_M2 |
| 22             | 34          | AN8/RPC2 | PIM_V_M1                                | Phase M1 Voltage Feedback Signal | PIM_QEA/IA/V_M1 |
| 23             | 72          | AN25     | PIM_IMOTOR_SUM                          | DC Bus Current Signal            | PIM_IBUS/VBUS   |
| 24             | 21          | AN9      | PIM_IMOTOR2                             | Phase B Current Signal           | PIM_IB/POT      |
| 25             | 51          | AN24     | PIM_IMOTOR1                             | Phase A Current Signal           | PIM_IA/IPFC     |
| 26             | 70          | PGEC2    | PGC                                     | Device Programming Clock Line    | PGD             |
| 27             | 69          | PGED2    | PGD                                     | Device Programming Clock Line    | PGC             |
| 28             | N/A         | N/A      | VREF                                    | AVDD/2                           | AVDD/2          |
| 29             | 11          | AN18     | PIM_REC_NEUTR                           | Recreated Motor Neutral Voltage  | PIM_REC_NEUTR   |
| 30             | 30          | AVDD     | AVDD                                    | AVDD                             | AVDD            |
| 31             | 31          | AVSS     | AVSS                                    | AVSS                             | AVSS            |
| 32             | 44          | AN15     | PIM_POT                                 | Potentiometer Signal             | PIM_POT         |
| 33             | 35          | AN11     | N/A                                     | N/A                              | PIM_POT         |
| 34             | 38          | RG11     | PIM_GEN2                                | General I/O                      | PIM_GEN2        |
| 35             | 20          | AN10     | PIM_VBUS                                | DC Bus Voltage Signal            | PIM_DC_BUS      |

**TABLE 1: PIN MAP (CONTINUED)**

| PIM Pin Number | PIC32MK MCM |           | dsPICDEM MCLV2 Board 100-pin PIM Header |   | dsPICDEM MCM    |
|----------------|-------------|-----------|---|---|-----------------|
|                | Pin Number  | Pin Name  | Pin Name                                | Pin Functionality   | Pin Name        |
| 36             | 36          | VSS       | VSS                                     | VSS   | GND_DIG         |
| 37             | 37          | VDD       | VDD                                     | VDD   | +3.3V_DIG       |
| 38             | 39          | RF13      | N/A                                     | N/A   | PIM_VAC_VOL2    |
| 39             | 40          | RF12      | N/A                                     | N/A   | PIM_IPFC_C_SHUT |
| 40             | 41          | RE12      | N/A                                     | N/A   | PIM_PFC_L       |
| 41             | 14          | RPG9/AN16 | PIM_MONITOR_1                           | Hall sensor A/Phase A<br>Current signal/Phase M1<br>Voltage feedback signal | PIM_V_M1/POT    |
| 42             | 12          | RPG8/AN17 | PIM_MONITOR_2                           | Hall sensor B/Phase B<br>Current signal/Phase M2<br>Voltage feedback signal | PIM_V_M2        |
| 43             | 53          | RPE1/AN41 | PIM_MONITOR_3                           | Hall sensor C/DC Bus<br>Current signal/Phase M3<br>Voltage feedback signal  | PIM_V_M3/IBUS   |
| 44             | 47          | RD14      | N/A                                     | N/A   | N/A             |
| 45             | 45          | VSS       | VSS                                     | VSS   | GND_DIG         |
| 46             | 46          | VDD       | VDD                                     | VDD   | +3.3V_DIG       |
| 47             | 43          | RPE14     | HALLB                                   | Hall Sensor B/QEI - B Input   | HALLB/QEB       |

**TABLE 1: PIN MAP (CONTINUED)**

| PIM Pin Number | PIC32MK MCM |          | dsPICDEM MCLV2 Board 100-pin PIM Header |                                 | dsPICDEM MCM |
|----------------|-------------|----------|---|---------------------------------|--------------|
|                | Pin Number  | Pin Name | Pin Name                                | Pin Functionality               | Pin Name     |
| 48             | 66          | RPA14    | HALLC                                   | Hall Sensor C/QEI - INDX Input  | HALLC/INDX   |
| 49             | 81          | RPC8     | RX                                      | UART Rx                         | RX           |
| 50             | 76          | RPB9     | TX                                      | UART Tx                         | TX           |
| 51             | 3           | RPA7     | USB_TX                                  | USB - UART Bridge Tx            | N/A          |
| 52             | 67          | RPA15    | USB_RX                                  | USB - UART Bridge Rx            | N/A          |
| 53             | 58          | VBUS2    | N/A                                     | N/A                             | N/A          |
| 54             | 59          | D2-      | N/A                                     | N/A                             | N/A          |
| 55             | 60          | D2+      | N/A                                     | N/A                             | N/A          |
| 56             | 77          | USBID2   | N/A                                     | N/A                             | N/A          |
| 57             | 71          | DAC2     | N/A                                     | N/A                             | N/A          |
| 58             | 80          | RD13     | PIM_FLT_OUT2                            | General I/O                     | PIM_FLT_OUT2 |
| 59             | 91          | RF6      | PIM_FLT_OUT1                            | General I/O                     | PIM_FLT_OUT1 |
| 60             | 61          | RF5      | DBG_LED1                                | Debug LED 1                     | DBG_LED2     |
| 61             | 10          | RPG6     | HOME                                    | Quadrature Encoder Home Input   | HOME         |
| 62             | 62          | VDD      | VDD                                     | VDD                             | +3.3V_DIG    |
| 63             | 63          | CLKI     | OSCI/CLKI                               | Oscillator Clock In             | OSCI         |
| 64             | 64          | CLKO     | OSCO/CLKO                               | Oscillator Clock Out            | OSCO         |
| 65             | 65          | VSS      | VSS                                     | VSS                             | GND_DIG      |
| 66             | N/A         | N/A      | PIM_IBUS+                               | DC Bus current shunt signal (+) | PIM_IBUS+    |
| 67             | N/A         | N/A      | PIM_IBUS-                               | DC Bus current shunt signal (-) | PIM_IBUS-    |
| 68             | 68          | RD8      | LIN_CS                                  | LIN Chip Select Signal          | BTN          |
| 69             | 79          | RD12     | LIN_FAULT                               | LIN Fault Signal                | N/A          |

**TABLE 1: PIN MAP (CONTINUED)**

| PIM Pin Number | PIC32MK MCM |          | dsPICDEM MCLV2 Board 100-pin PIM Header |                                  | dsPICDEM MCM |
|----------------|-------------|----------|---|----------------------------------|--------------|
|                | Pin Number  | Pin Name | Pin Name                                | Pin Functionality                | Pin Name     |
| 70             | 81          | RPC8     | RX                                      | UART Rx                          | RX           |
| 71             | 7           | PWM5H    | N/A                                     | N/A                              | PIM_PFC_PWM  |
| 72             | 67          | RPA15    | USB_RX                                  | USB - UART Bridge Rx             | N/A          |
| 73             | N/A         | N/A      | PIM_IB+                                 | Phase B current shunt signal (+) | PIM_IB+      |
| 74             | N/A         | N/A      | PIM_IA+                                 | Phase A current shunt signal (+) | PIM_IA+      |
| 75             | 75          | VSS      | VSS                                     | VSS                              | GND_DIG      |
| 76             | 3           | RPA7     | USB_TX                                  | USB - UART Bridge Tx             | N/A          |
| 77             | 52          | RPE0     | CAN_TX                                  | CAN Tx                           | N/A          |
| 78             | 87          | RPF0     | CAN_RX                                  | CAN Rx                           | N/A          |
| 79             | 19          | RE9      | N/A                                     | N/A                              | VACZX        |
| 80             | 84          | RPC9     | HALLA                                   | Hall Sensor A/ QEI - A Input     | HALLA/QEA    |
| 81             | N/A         | N/A      | N/A                                     | N/A                              | N/A          |
| 82             | 82          | RD5      | PIM_GEN1                                | General I/O                      | PIM_GEN1     |
| 83             | 89          | RG1      | BTN_1                                   | Push Button S2 Input             | N/A          |
| 84             | 78          | RC7      | BTN_2                                   | Push Button S3 Input             | N/A          |
| 85             | 49          | DAC3     | N/A                                     | N/A                              | N/A          |
| 86             | 86          | VDD      | VDD                                     | VDD                              | +3.3V_DIG    |
| 87             | 87          | RPF0     | CAN_RX                                  | CAN Rx                           | N/A          |
| 88             | 52          | RPE0     | CAN_TX                                  | CAN Tx                           | N/A          |
| 89             | 88          | RF1      | N/A                                     | N/A                              | N/A          |
| 90             | 90          | RG0      | N/A                                     | N/A                              | N/A          |
| 91             | 73          | SOSCI    | N/A                                     | N/A                              | N/A          |
| 92             | 74          | SOSCO    | N/A                                     | N/A                              | N/A          |

**TABLE 1: PIN MAP (CONTINUED)**

| PIM Pin Number | PIC32MK MCM |          | dsPICDEM MCLV2 Board 100-pin PIM Header |                        | dsPICDEM MCM |
|----------------|-------------|----------|---|------------------------|--------------|
|                | Pin Number  | Pin Name | Pin Name                                | Pin Functionality      | Pin Name     |
| 93             | 5           | PWM1L    | PWM1L1                                  | Phase M1 Low-Side PWM  | PWM1L1       |
| 94             | 4           | PWM1H    | PWM1H1                                  | Phase M1 High-Side PWM | PWM1H1       |
| 95             | 95          | RG14     | N/A                                     | N/A                    | N/A          |
| 96             | 96          | RG12     | N/A                                     | N/A                    | N/A          |
| 97             | 97          | RG13     | N/A                                     | N/A                    | N/A          |
| 98             | 99          | PWM2L    | PWM1L2                                  | Phase M2 Low-Side PWM  | PWM1L2       |
| 99             | 98          | PWM2H    | PWM1H2                                  | Phase M2 High-Side PWM | PWM1H2       |
| 100            | 94          | PWM3L    | PWM1L3                                  | Phase M3 Low-Side PWM  | PWM1L3       |

**FIGURE 3: 100-PIN PIM HEADER SCHEMATIC**

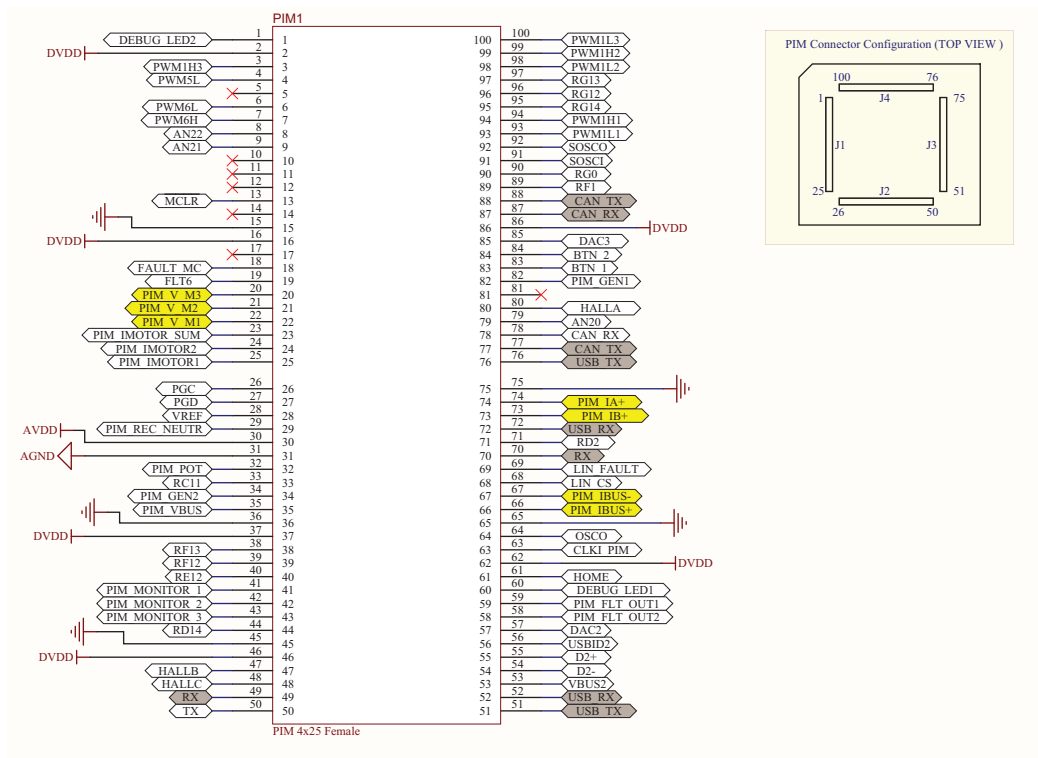
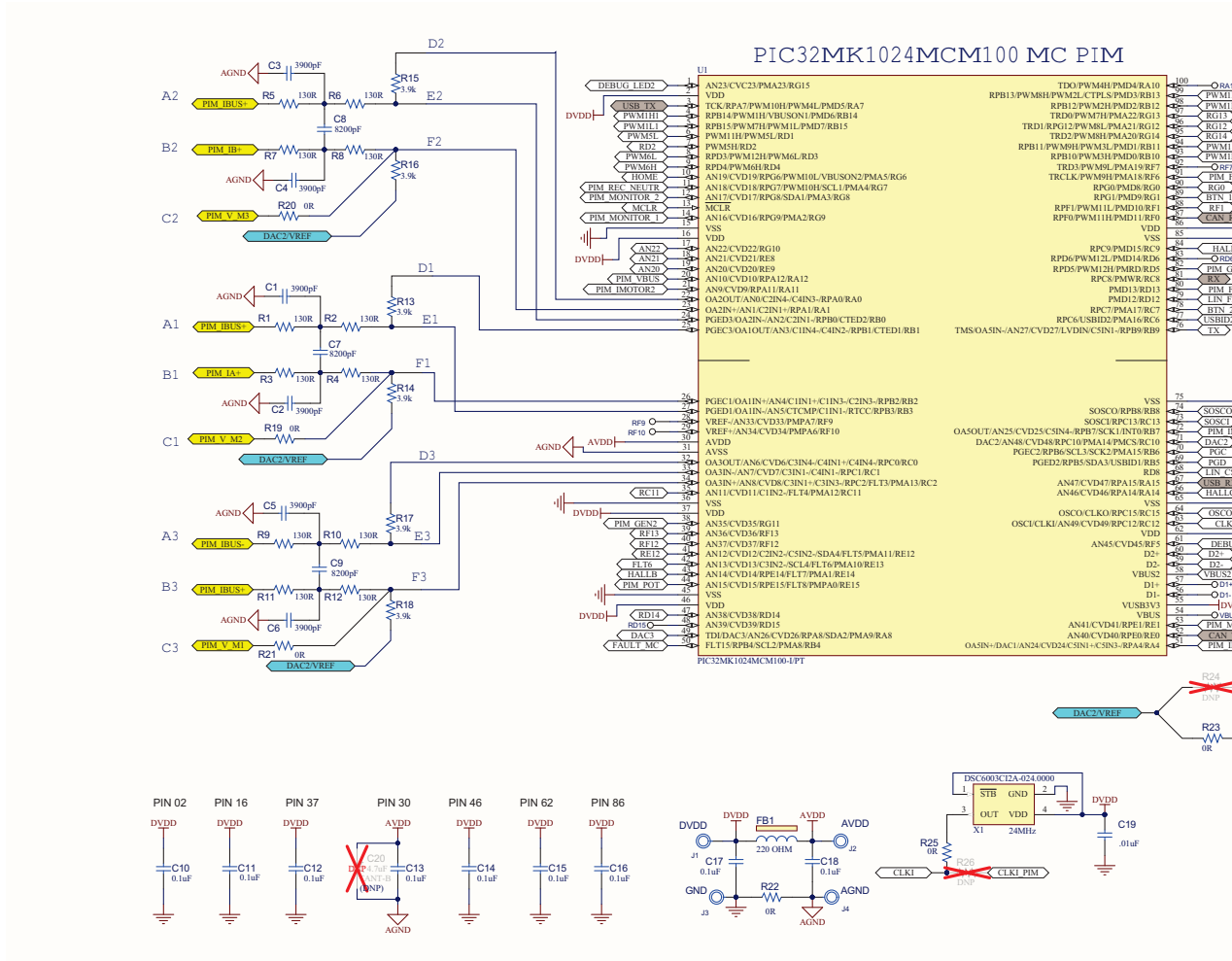




FIGURE 4: 100-PIN PIM DEVICE SCHEMATIC



# PIC32MK MCM

The reference voltage ( $V_{REF}$ ) biases the op amps to  $V_{DD}/2$ , therefore the bidirectional motor phase current can be sensed using unipolar op amps. The source of  $V_{REF}$  can be selected either from the development board or from the internally generated reference voltage using DAC2 and resistors R23/R24, as shown in Figure 4. By default, the PIM is configured to source the reference voltage, internally generated using DAC2 by populating R23 and keeping R24 depopulated.

To source the reference voltage from Motor Control PIM, R23 needs to be depopulated and R24 must be populated with a zero ohm resistor.

The internal op amp configuration and passive resistor-capacitive network configures the filter bandwidth, op amp bias and op amp gain, as shown in Figure 4.

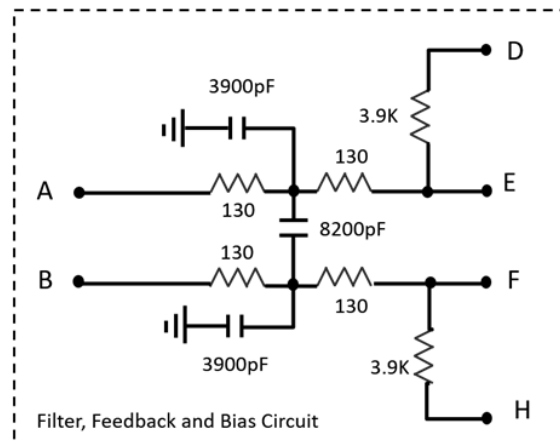
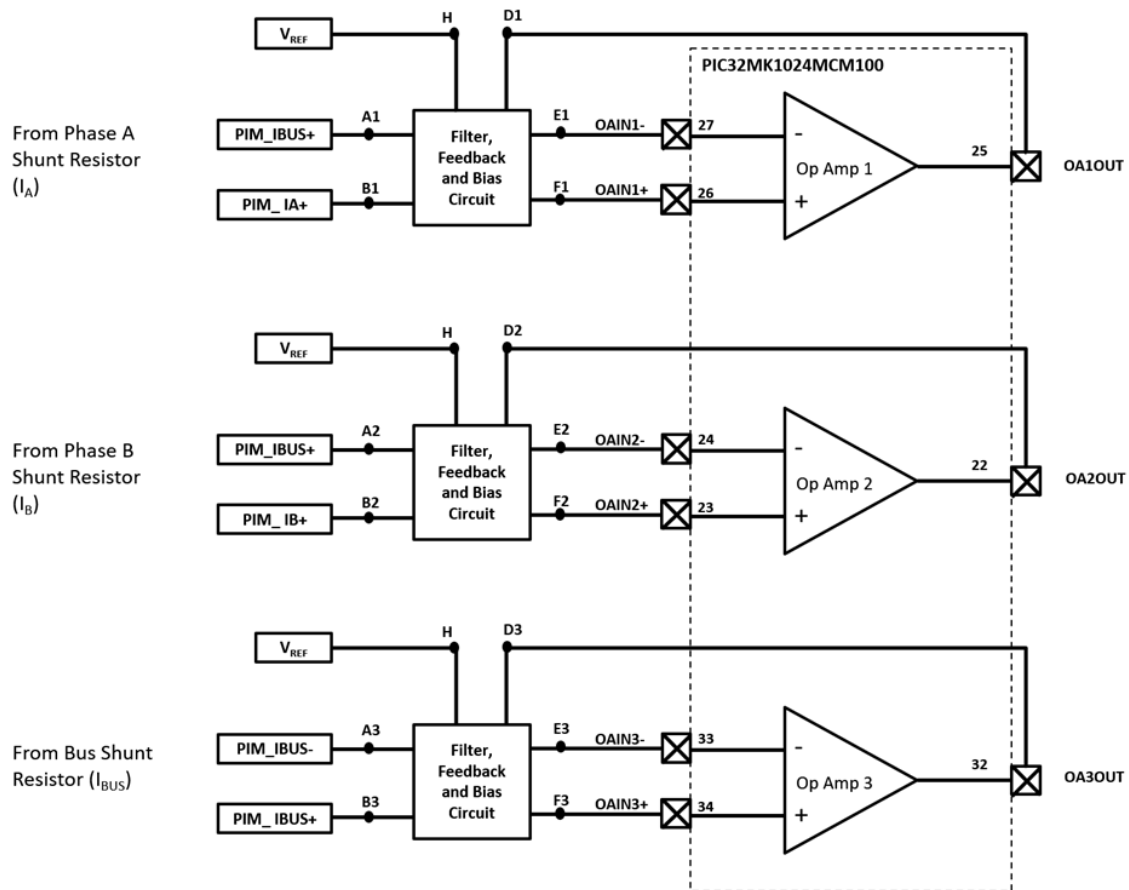
Table 2 classifies the passive components according to their functionality and also specifies the design equations for filter bandwidth and op amp gain.

**TABLE 2: ANALOG FUNCTIONALITY LISTING**

| Op Amp Number | Analog Function                 | Passive Components            | Design Equations  |
|---------------|---------------------------------|-------------------------------|---|
| 1             | Low-Pass Filter                 | R1, R2, R3, R4, C1, C2, C7    | $R1 = R2 = R3 = R4 = R$<br>$C1 = C2 = C$  |
|               | Differential Amplifier Input    | R1, R2, R3, R4                | $\text{Common mode } f_{-3dB} \cong \frac{1}{2\pi RC}$ $\text{Differential mode } f_{-3dB} \cong \frac{1}{2\pi(2R)\left(\frac{C}{2} + C_7\right)}$ $\text{Differential Amplifier Gain} = \frac{R_{13}}{2R}$ |
|               | Differential Amplifier Feedback | R13                           |   |
| 2             | Low-Pass Filter                 | R5, R6, R7, R8, C3, C4, C8    | $R5 = R6 = R7 = R8 = R$<br>$C3 = C4 = C$  |
|               | Differential Amplifier Input    | R5, R6, R7, R8                | $\text{Common mode } f_{-3dB} \cong \frac{1}{2\pi RC}$ $\text{Differential mode } f_{-3dB} \cong \frac{1}{2\pi(2R)\left(\frac{C}{2} + C_8\right)}$ $\text{Differential Amplifier Gain} = \frac{R_{15}}{2R}$ |
|               | Differential Amplifier Feedback | R15                           |   |
| 3             | Low-Pass Filter                 | R9, R10, R11, R12, C5, C6, C9 | $R9 = R10 = R11 = R12 = R$<br>$C5 = C6 = C$   |
|               | Differential Amplifier Input    | R9, R10, R11, R12             | $\text{Common mode } f_{-3dB} \cong \frac{1}{2\pi RC}$ $\text{Differential mode } f_{-3dB} \cong \frac{1}{2\pi(2R)\left(\frac{C}{2} + C_9\right)}$ $\text{Differential Amplifier Gain} = \frac{R_{17}}{2R}$ |
|               | Differential Amplifier Feedback | R17                           |   |

Figure 5 illustrates a typical block diagram of the op amp circuit.

**FIGURE 5: OP AMP CIRCUIT BLOCK DIAGRAM**



$$\text{Differential Amplifier Gain} = \frac{3.9k\Omega}{2 * 130\Omega} = 15$$

$$\text{Differential mode } f_{-3dB} \cong \frac{1}{2\pi(2 * 130\Omega) \left( \frac{3900pF}{2} + 8200pF \right)} \cong 60.3kHz$$

$$\text{Common mode } f_{-3dB} \cong \frac{1}{2\pi(130\Omega)(3900pF)} \cong 313.9kHz$$

# PIC32MK MCM

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NOTES:

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