SWITCHERGEAR
GEAR TO CONTROL YOUR POWER SWITCHES

Micro MC28377D1

Dual 200 MHz Delfino™ CPU + CLA
16 channel ADC, 16 MB SDRAM

REFERENCE MANUAL

Features

Standard MCU card for SwitcherGear

Texas Instruments TMS320F28377D microcontroller

- *2x 200 MHz CPU with FPU and trigonometric maths unit*
- *2x 200 MHz CLA processor with FPU*
- *Quad 12/16-bit ADC*

16 MB SDRAM for user data storage

- *Capture of real-time data at the control rate*

16 analogue input pins

- *Precision 3 V ADC reference*

53 digital I/O pins

20 MHz crystal oscillator

Compatible with DIMM 100-pin controlCARD

Applications

University research

Rapid prototyping of power converter systems

SwitcherGear rapid-prototyping controller

Custom development boards with DIMM 100-pin MCU connector

General Description

The MC28377D1 is a complete microcontroller system on a compact, plug-in board. It can be used as the host MCU in SwitcherGear controllers, or as a microcontroller resource in your own development systems.

The MC28377D1 features the Texas Instruments TMS320F28377D dual-core 200 MHz microcontroller. A DIMM 100-pin connector provides connections for a 5 V supply input, analogue inputs, digital I/O and JTAG debug probe signals.

An on-board 16 MB SDRAM is ideal for buffering large amounts of real-time data in product development or university research applications.

The MC28377D1 is compatible with TI's controlCARD format and can be used with TI's 100-pin experimenter boards.

Ordering Information

Order Code	*Description*
MC28377D1	*SwitcherGear microcontroller card with TMS320F28377D dual 200 MHz CPU + CLA, 16 channel ADC, 16 MB SDRAM.*

Interfaces

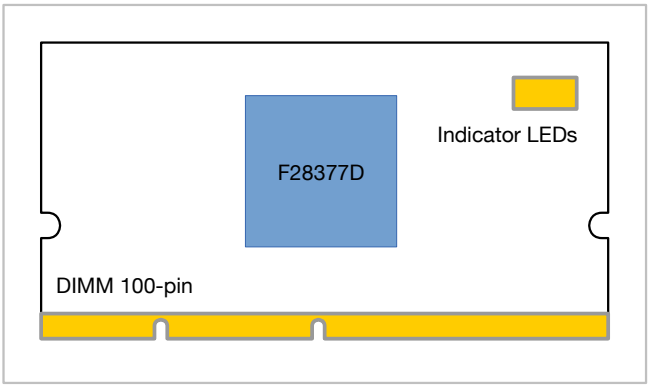

Figure 1: Interfaces of the MC28377D1 micro card.

100-pin DIMM Connector

This is a DIMM style edge connector that provides the power and signal connection to the external system. Table 2 and Table 3 show the pin-out of this connector.

The edge connector is polarised and can be installed only one way into the mating connector.

To install the micro card, first open the ejector tabs of the DIMM connector on the target board. Hold the micro card by the upper corners. Align the micro card and press down firmly until the ejector tabs engage with the sides of the micro card.

To remove the micro card, gently pull apart the ejector tabs until the card disengages from the connector.

Indicator LEDs

The miniature indicator LEDs show the power status of the MC28377D1 and allow for user indication. Refer to Table 1 for details.

Table 1: Indicator LEDs

Designator	Colour	Description
D1	Green	Power
D2	Red	Driven by GPIO67
D3	Red	Driven by GPIO68

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contact@denki.com.au

Table 2: Pin-out for DIMM 100-pin connector – pins 1 to 50.

GPIO Index ►	0,4,8,12	1	2	3	5	6	7	15
GPyGMUXn.GPIOz ►	0,1,2,3	0	0	0	1	1	1	3
GPyMUXn.GPIOz ►	0	1	2	3	1	2	3	3
DIMM100 Pin ▼								
1	ISO 3.3V							
2	RS-232 RX at GPIO85.5 (SCIRXDA)							
3	GPIO100			EM2A2	EQEP2A	SPISIMOC		
4	GPIO102			EM2A4	EQEP2S	SPICLKC		
5	GPIO104	SDAA		EM2A6	EQEP3A	SCITXDD		
6	ISO 0V							
7	ADCINB0							
8	0V							
9	ADCINB1							
10	0V							
11	ADCINB2							
12	0V							
13	ADCINB3							
14	0V							
15	ADCIND0							
16	0V							
17	ADCIND1							
18	GPIO58	MCLKRA	EM1D26	EM2D10	OXBAR1	SPICLKB	SD2-D2	SPISIMOA
19	ADCIND2							
20	GPIO54	SPISIMOA	EM1D30	EM2D14	EQEP2A	SCITXDB	SD1-D4	
21	ADCIND3							
22	GPIO56	SPICLKA	EM1D28	EM2D12	EQEP2S	SCITXDC	SD2-D1	
23	GPIO00	EPWM1A				SDAA		
24	GPIO02	EPWM2A			OXBAR1	SDAB		
25	GPIO04	EPWM3A			OXBAR3	CANTXA		
26	GPIO06	EPWM4A	OXBAR4	EPWMSYNCO	EQEP3A	CANTXB		
27	0V							
28	GPIO08	EPWM5A	CANTXB	ADCSOCAO	EQEP3S	SCITXDA		
29	GPIO10	EPWM6A	CANRXB	ADCSOCBO	EQEP1A	SCITXDB		UPP_WAIT
30	GPIO60	MCLKRB	EM1D24	EM2D8	OXBAR3	SPISIMOB	SD2-D3	SPICLKA
31	GPIO64		EM1D20	EM2D4	EQEP3S	SCIRXDA		SPISOMIB
32	GPIO66		EM1D18	EM2D2		SDAB		SPISTEB
33	GPIO12	EPWM7A	CANTXB	MDXB	EQEP1S	SCITXDC		UPP-ENA
34	GPIO15	EPWM8B	SCIRXDB	MFSXB		OXBAR4		UPP-D5
35	GPIO24	OXBAR1	EQEP2A	MDXB		SPISIMOB	SD2-D1	
36	GPIO26	OXBAR2	EQEP2I	MCLKXB	OXBAR3	SPICLKB	SD2-D2	
37	0V							
38	GPIO16	SPISIMOA	CANTXB	OXBAR7	EPWM9A		SD1-D1	UPP-D4
39	GPIO18	SPICLKA	SCITXDB	CANRXA	EPWM10A		SD1-D2	UPP-D2
40	GPIO20	EQEP1A	MDXA	CANTXB	EPWM11A		SD1-D3	UPP-D0
41	GPIO22	EQEP1S	MCLKXA	SCITXDB	EPWM12A	SPICLKB	SD1-D4	
42	GPIO35	SCIRXDA	EM1CS3			SCLB		
43	GPIO85		EM1D0		SCIRXDA	MDRB		MDRA
44	GPIO62	SCIRXDC	EM1D22	EM2D6	EQEP3A	CANRXA	SD2-D4	
45	GPIO42					SDAA		SCITXDA
46	GPIO34	OXBAR1	EM1CS2			SDAB		
47	0V							
48	JTAG TCK							
49	JTAG TMS							
50	-							

Table 3: Pin-out for DIMM 100-pin connector – pins 51 to 100.

GPIO Index ►	0,4,8,12	1	2	3	5	6	7	15
GPyGMUXn.GPIOz ►	0,1,2,3	0	0	0	1	1	1	3
GPyMUXn.GPIOz ►	0	1	2	3	1	2	3	3
DIMM100 Pin ▼								
51	ISO 3.3V							
52	RS-232 TX at GPIO84.5 (SCITXDA)							
53	GPIO101			EM2A3	EQEP2B	SPISOMIC		
54	GPIO103			EM2A5	EQEP2I	SPISTEC		
55	GPIO105	SCLA		EM2A7	EQEP3B	SCIRXD		
56	ISO 0V							
57	ADCINA0							
58	0V							
59	ADCINA1							
60	0V							
61	ADCINA2							
62	0V							
63	ADCINA3							
64	0V							
65	ADCINC2							
66	VREFHI							
67	ADCINC3							
68	GPIO59	MFSRA	EM1D25	EM2D9	OXBAR2	SPISTEB	SD2-C2	SPISOMIA
69	ADCIN14							
70	GPIO55	SPISOMIA	EM1D29	EM2D13	EQEP2B	SCIRXDB	SD1-C4	
71	ADCIN15							
72	GPIO57	SPISTEA	EM1D27	EM2D11	EQEP2I	SCIRXDC	SD2-C1	
73	GPIO01	EPWM1B		MFSRB		SCLA		
74	GPIO03	EPWM2B	OXBAR2	MCLKRB	OXBAR2	SCLB		
75	GPIO05	EPWM3B	MFSRA	OXBAR3		CANRXA		
76	GPIO07	EPWM4B	MCLKRA	OXBAR5	EQEP3B	CANRXB		
77	+5V							
78	GPIO09	EPWM5B	SCITXDB	OXBAR6	EQEP3I	SCIRXDA		
79	GPIO11	EPWM6B	SCIRXDB	OXBAR7	EQEP1B	SCIRXDB		UPP-STRT
80	GPIO61	MFSRB	EM1D23	EM2D7	OXBAR4	SPISOMIB	SD2-C3	SPOISTEA
81	GPIO65		EM1D19	DM2D3	EQEP3I	SCITXDA		SPICLKB
82	+5V							
83	GPIO13	EPWM7B	CANRXB	MDRB	EQEP1I	SCIRXDC		UPP-D7
84	GPIO14	EPWM8A	SCITXDB	MCLKXB		OXBAR3		UPP-D6
85	GPIO25	OXBAR2	EQEP2B	MDRB		SPISOMIB	SD2-C1	
86	GPIO27	OXBAR4	EQEP2S	MFSXB	OXBAR4	SPISTEB	SD2-C2	
87	+5V							
88	GPIO17	SPISOMIA	CANRXB	OXBAR8	EPWM9B		SD1-C1	UPP-D3
89	GPIO19	SPISTEA	SCIRXDC	CANTXA	EPWM10B		SD1-C2	UPP-D1
90	GPIO21	EQEP1B	MDRA	CANRXB	EPWM11B		SD1-C3	IPP-CLK
91	GPIO23	EQEP1I	MFSXA	SCIRXDB	EPWM12B	SPISTEB	SD1-C4	
92	+5V							
93	GPIO84				SCITXDA	MDXB		MDXA
94	GPIO63	SCITXDC	EM1D21	EM2D5	EQEP3B	CANTXA	SD2-C4	SPISIMOB
95	GPIO43					SCLA		SCIRXDA
96	+5V							
97	JTAG TDI							
98	JTAG TDO							
99	JTAG TRST							
100	-							

Configuration

Boot Mode

The boot mode of the F28377D can be configured using the solder jumpers on the reverse side of the card. The settings are shown in Table 4.

Table 4: Configuration of boot mode

Boot Mode	Solder Jumpers	
	BOOT1	BOOT0
Parallel I/O	Short	Short
SCIBOOT0	Short	Open
Wait	Open	Short
Get (Default)	Open	Open

VREFHI Source

The VREFHI reference voltage for the ADC can be derived from either an on-board precision voltage reference, or the voltage applied to the VREFHI pin of the DIMM 100-pin connector. See Table 5 for settings.

The MC28377D1 is supplied with a zero-Ohm resistor fitted at location R33, which selects the on-board voltage reference as the ADC VREFHI voltage. To modify the setting, de-solder the resistor and replace in the required location – see warnings that apply to solder jumpers, below.

Table 5: Configuration of ADC VREFHI source

ADC VREFHI Source	Jumpers	
	R33	R34
On-board reference (default)	Short	Not fitted
Module VREFHI pin	Not fitted	Short

RS-232 Interface Isolation

Pins 1 to 6 and 51 to 56 implement an interface that includes a RS-232 serial interface with RX and TX lines. The interface has its own ground system that is accessible on the ISO 0V pins. The ground system can be connected to the ground of the main circuitry or can be isolated from it.

Table 6: Configuration of RS232 interface isolation

RS232 Interface Ground	Jumper
	R36
Common ground (default)	Fitted
Isolated	Not fitted

The interface also requires a 3.3 V supply, that can be sourced either from the on-board circuitry, or externally using the ISO 3.3V pins. The R35 jumper must be removed when using an external supply.

Table 7: Configuration of RS232 interface supply

RS232 Interface 3.3V Supply	Jumper
	R35
On-board 3.3 V (default)	Fitted
External 3.3 V	Not fitted

Solder Jumpers

Modules are supplied with all solder jumpers in the open state. These default feature settings are highlighted in grey in the configuration tables.

If a different configuration is required for your application, you must change the solder jumper settings before using the SwitcherGear.

Solder jumpers allow configuration of SwitcherGear modules. They function like a switch to control the features of the module. Jumpers consist of two adjacent pads on the rear side of the module circuit board. The jumper can be shorted (switch closed) by making a solder bridge across the pads. The jumper can be opened (switch open) by removing the solder bridge.

The solder jumpers are intended for one-time-only configuration. No warranty is provided for damage to solder jumpers. Only skilled personnel who are trained in correct soldering technique should undertake the configuration of the solder jumpers. Incorrect technique or excessive temperature can result in the pads of the solder jumper detaching from the circuit board, rendering the jumper permanently open-circuit.

Observe the following precautions when configuring solder jumpers:

- Anti-static handling procedures.
- Turn off power before removing or inserting modules.
- Use a fine-tip soldering iron with adjustable temperature.
- Use only lead free solder and compatible tools.
- Use the minimum temperature required to perform the task.
- Do not heat the jumper for more than 5 seconds. Allow to cool before re-applying heat.
- To remove solder from a jumper, use a narrow (e.g. 1.5 mm) fluxed solder wicking braid.

Functional Description

Crystal Oscillator

A 20 MHz crystal oscillator is connected between the X1 and X2 oscillator pins of the F28377D.

SDRAM

The MC28377D1 micro card features a 16M x 16-bit SDRAM connected to external memory interface EMIF1, which is accessible from CPU1 or CPU2. The memory is on chip-select zone EM1CS0, which is mapped to data memory space.

The memory is mapped to the address range 0x8000 0000 to 0x80FF FFFF.

Digital Input/Output Pin 85

Digital I/O pin 85 (DIO85) of the MCU is connected to three separate resources, as shown in Figure 2. The pin must be used with only one resource at a time and you must ensure there are no conflicts in operation.

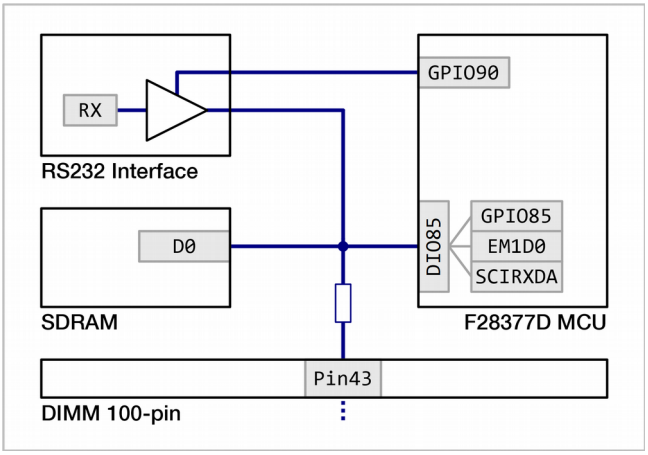

Figure 2: Multiple resources connected to digital I/O pin 85.

RS-232 serial interface

DIO85 is connected to the RX channel of the RS-232 serial interface. For this use case, the RX output must be enabled. And the DIO85 pin's GPIO index should be set to 5, which selects it as a SCIRXDA input pin. You must also disable any drivers connected to pin 43 of the DIMM 100-pin connector.

The RX channel has a tri-state output buffer that is controlled using GPIO90. When the output buffer is active, the receiver output is enabled and the RX signal is passed to DIO85. When the output buffer is Hi-Z, the receiver output is put into a high-impedance state that effectively disconnects it from DIO85.

To enable the RX signal, digital I/O pin 90 must be configured as a GPIO output with the output logic level set high.

To disable the RX signal, digital I/O pin 90 can be configured as a GPIO output with the output logic level set low. You should use this approach if you need to enable and disable the RX signal in your application.

The RX signal will also be disabled if digital I/O pin 90 is left in its power-on reset state, i.e. a GPIO input. If you intend to never use the RS-232 interface RX signal you can ignore any configuration of digital I/O pin 90.

SDRAM

DIO85 is connected to the data bit 0 pin of the on-board SDRAM. If you intend to use the SDRAM, the DIO85 pin's GPIO index should be set to 2, which configures the it as a EM1D0 input/output pin. This is a standard part of the DIO pin configuration that is required to configure the external memory interface. You must also disable the RX channel of the RS-232 serial interface.

If you do not use the SDRAM, its D0 pin will be configured as an input with a high-impedance state that effectively disconnects it from DIO85.

DIMM 100-pin edge connector

DIO85 is connected to pin 43 of the DIMM 100-pin edge connector. This enables you to connect external circuits to DIO85. The connection is made through a 10 kΩ resistor.

By setting the mux for digital I/O pin 85, you can use the pin as a general purpose digital input or output (GPIO), or as a serial RX input for various serial peripherals. You must also disable the RX channel of the RS-232 serial interface and not use the SDRAM on external memory interface EM1.

VREFHI Buffer

The voltage selected as the ADC VREFHI source is buffered by a precision op-amp. One buffer drives the VREFHI pin of each ADC.

Isolated Interface

Pins 1 to 6 and 51 to 56 implement an interface that includes a RS-232 serial interface with RX and TX lines and digital GPIO pins. The interface has its own ground system that can be connected to the ground of the main circuitry or can be isolated from it.

By default, the interface ground is connected to the ground of the main circuitry of the MC28377D1. In this configuration, the power for the interface can also be derived from the main circuitry.

The interface can be optionally isolated from the ground of the main circuitry. In this case, you must supply

Applications Information

SDRAM

The SwitcherWare Library from Denkinetic provides classes to configure the SDRAM.

ADC Peripherals

The Texas Instruments TMS320F28377D MCU contains 4 high-speed analogue-to-digital converter (ADC) peripherals. Each ADC peripheral can be operated in either 12-bit mode or 16-bit mode. For PWM controller applications, the higher speed and resolution of 12-bit mode is preferred. The effective sample rate can be increased by operating the ADC peripherals in parallel.

They are well suited to capturing the values of voltages, currents, etc. in the physical system for use as inputs to the digital controller. The analogue input pins of the MC28377D1 micro module are shared between the 4 ADC peripherals, as shown in Table 2 and Table 3.

The ADC peripherals include hardware to automatically convert multiple analogue signals. The conversions can be time synchronised to PWM signals, which is ideal for switch-mode converter applications.

The purpose of ADC conversion is to convert the analogue input voltage, V_{ADCIN}, of the ADC to a proportional integer result value, $ADCINT$. The active range for the analogue input voltage is from 0 V to V_{REFHI} (essentially 0 V to 3 V).

In 12-bit mode, the ideal conversion characteristic is

$$ADCINT = \frac{V_{ADCIN}}{V_{REFHI}} \times 4096$$

and $ADCINT$ is limited to the range 0 to 4095, inclusive.
In 16-bit mode, the ideal conversion characteristic is

$$ADCINT = \frac{V_{ADCIN}}{V_{REFHI}} \times 65536$$

and $ADCINT$ is limited to the range 0 to 65535, inclusive.

The SwitcherWare Library from Denkinetic provides various classes to handle ADC conversions, including the mapping of conversion results to sensor values.

Absolute Maximum Ratings

Stresses above these ratings may cause permanent damage. These are stress ratings only – functional operation is not implied. Exposure to absolute maximum conditions for extended periods may affect reliability.

Parameter	Conditions	Min	Max	Unit
Voltage Input Range		-0.3	7	V

Electrical Characteristics

The following specifications apply for V_{DC} = 5 V, T_A = 25 °C, unless otherwise noted.

Parameter	Conditions	Min	Typ	Max	Unit
POWER SUPPLY					
Voltage Input Range		4.5		5.5	V
Operating Current	Idle		TBA		mA
ON-BOARD VREFHI REFERENCE					
Voltage			3.000		V
Accuracy		-0.003		0.003	V
Temperature Coefficient	-40 °C ≤ T_A ≤ 85 °C		10	25	µV/°C
VREFHI BUFFER					
Offset Voltage		-250		250	µV
Temperature Coefficient		-5		5	µV/°C
CRYSTAL OSCILLATOR					
Frequency			20.0000		MHz
Accuracy		-400		400	Hz
Stability over temperature	-40 °C ≤ T_A ≤ 85 °C	600		600	Hz
SDRAM					
Clock Frequency				100	MHz

Revision History

Revision	Date	Changes From Previous Release
1	21 Sep 2017	▪ Original release.