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The semiconductor operations of Hitachi and Mitsubishi Electric were transferred to Renesas Technology Corporation on April 1st 2003. These operations include microcomputer, logic, analog and discrete devices, and memory chips other than DRAMs (flash memory, SRAMs etc.) Accordingly, although Mitsubishi Electric, Mitsubishi Electric Corporation, Mitsubishi Semiconductors, and other Mitsubishi brand names are mentioned in the document, these names have in fact all been changed to Renesas Technology Corp. Thank you for your understanding. Except for our corporate trademark, logo and corporate statement, no changes whatsoever have been made to the contents of the document, and these changes do not constitute any alteration to the contents of the document itself.

Note : Mitsubishi Electric will continue the business operations of high frequency & optical devices and power devices.

Renesas Technology Corp.
Customer Support Dept.
April 1, 2003

Smart battery protection and monitoring IC M61040FP

DESCRIPTION

The M61040FP is intended to be used as SB: Smart Battery.

All functions needed for SB are packed to this M61040FP. The combination use with Microcomputer such as M37515 will give various functions such as a detection or calculation of SB Remaining Capacity.

Over Current detection circuit dedicated in M61040FP will give safety FET on/off control independent from microcomputer control.

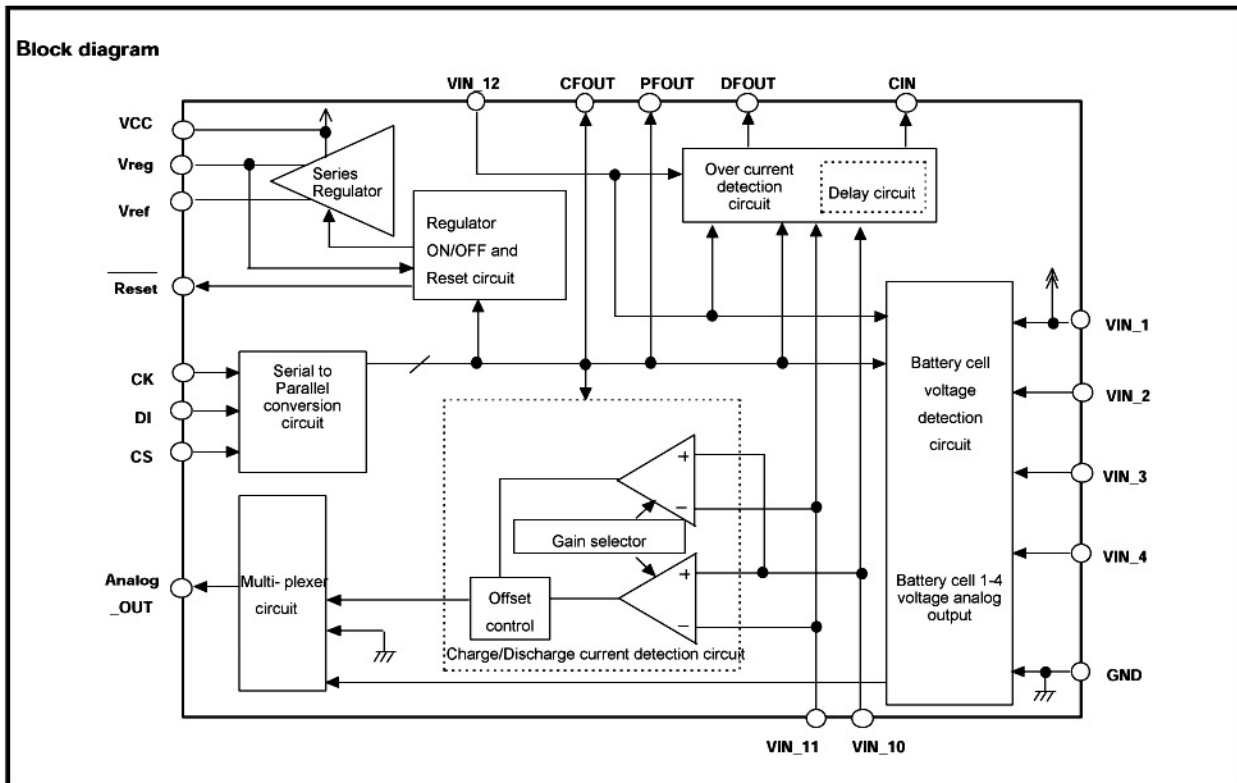
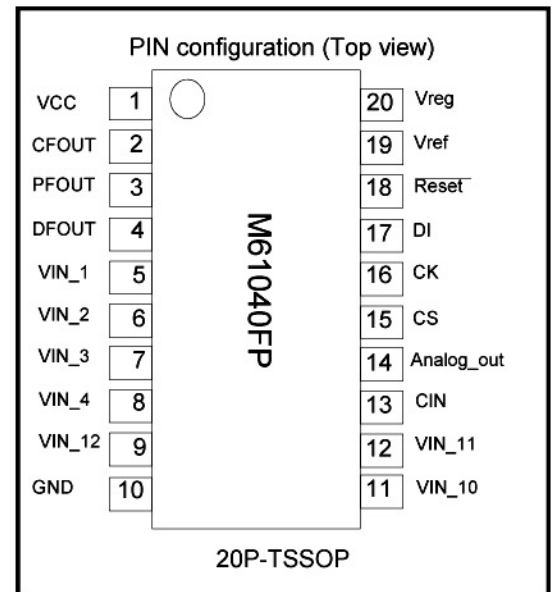
The amp gain of charge/discharge current detection circuit is controlled by microcomputer, therefore the accuracy of SB's Remaining Capacity Detection becomes better than before. The reset circuit and The linear regulator for Vcc / Vref of microcomputer are dedicated in M61040FP. So this will help easy design of power circuit design of SB.

FEATURE

- Built-in high gain op-amps for monitoring charge/discharge current
- Built-in over current detection circuit for FET protection
- All FETs are controlled by microcomputer
- Various powers saving function to reduce total power dissipation
- High Input Voltage Device(Absolute Maximum Rating:33V)

APPLICATION

- Smart Battery System



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1. Explanation of terminals

Table 1.

PIN	Symbol	Functions
5	V _{IN} 1	Battery 1 + voltage input
6	V _{IN} 2	Battery 1 – voltage and Battery 2 + voltage input
7	V _{IN} 3	Battery 2 – voltage and Battery 3 + voltage input
8	V _{IN} 4	Battery 3 – voltage and Battery 4 + voltage input
9	V _{IN} 12	Monitoring charger is connected or not
13	CIN	Connect capacitor for over current detection delay
11	V _{IN} 10	Charge / discharge current monitor input and connects charge / discharge current Sense resistor
12	V _{IN} 11	Charge / discharge current monitor input and connects charge / discharge current Sense resistor
1	V _{CC}	Power source pin. Power from charger or battery
10	GND	Ground
20	Vreg	Linear-Regulator output for microcomputer
19	Vref	Vreg voltage output for Vreg of Microcomputer, Max 200uA / 5V
18	RESET	Reset signal output to RESET of Microcomputer
14	Analog OUT	Various Analog signal outputs to AD-input of Microcomputer
4	DFOUT	Discharge FET-Drive Output. The Driver is turned off when over current detected.
2	CFOUT	Charge FET-Drive Output. The Driver is turned off by Microcomputer.
17	DI	Input of 6 bit length serial data from Microcomputer
16	CK	Input of shift clock from Microcomputer. DI's input data is latched by low-to-high edge of this CK
15	CS	During low signal input to this CS, data input to DI is enabled.
3	PFOUT	Pre-charge FET-Drive Output. The Driver is turned off by Microcomputer.

2. Operation description

M61040 is developed for intelligent Li-ion battery pack such as SB in SBS. M61040 is suitable for Smart Battery.

*SBS: Smart Battery System introduced by Intel and Duracell

*SB: Smart Battery which contains 3 or 4 series Li-ion battery cells.

All analog circuits are included to M61040. Therefore pair using with Microcomputer such as M37515 and small additional parts will give various functions such as battery remaining capacity detection. All functions are described as follows:

1) Voltage Detection circuit of each Li-ion battery cells

M61040 can output each battery cell's voltage of 3 or 4 series connection. Built-in buffer amplifier is monitoring each battery voltage. Microcomputer can adjust the offset voltage.

2) Charge / discharge current detection circuit

In SBS, remaining capacity check function (Gas-gage function) is necessary. To calculate accurate remaining capacity, microcomputer must get charge / discharge current periodically. Accurate charge / discharge current of external sense register is monitored by built-in amp. The charger/ discharge current is converted to Voltage value through the accurate sense resistor.

Output gain can be controlled by Microcomputer. Off-set voltage can be set lower by external parts, therefore dynamic range of Microcomputer's A to D converter will widen.

3) Over current detection circuit

M61040 contains over current detection circuit. The discharging FET is turned off to stop discharging and it continues for the over current detection delay time (tIOV1) or longer, if the discharging current becomes equal to or higher than a specified value. It is necessary for safety of Li-ion battery pack. Delay time is set by external capacity connected to CIN. Also the voltage of CIN shows detection or NOT detection of over current. Over current detection is controlled independently by this M61040's built-in hardware NOT by Microcomputer's software control.

4) Series regulator, reference voltage

M61040 contains Low drop out series regulator. Microcomputer in SB does not need any additional voltage regulator, MAX 20mA/5V. Also M61040 gives very accurate reference voltage as 4.85V for Vref voltage for Microcomputer's A to D converter.

5) Reset circuit for Microcomputer

Vreg output voltage is checked by Reset circuit of M61040. Therefore, lower voltage of Vreg issues RESET signal to stop multi-function of Microcomputer. Also, lower voltage after long time's left issues RESET signal to stop multi-function of Microcomputer. This function is useful for safety of long time's left battery.

When charger is connected to SB, this circuit will check Vreg voltage, so if Vreg voltage is NOT enough high, this circuit remains Low as for RESET signal to Microcomputer.

6) Power save function

M61040FP contains power save function to control several supply current.

The function and control method are shown as table 2.

The function of battery voltage detection circuit, Charge/Discharge detection circuit, Over current detection circuit can be stopped as the need arises.

Table 2

Control method	Battery voltage detection circuit	Charge/Discharge detection circuit	Over current detection circuit
Software control (through Serial I/F)	O	O	O
Each function can be ON/OFF separately.			

Enter Power Down Mode

Microcomputer issues shot-down command to M61040 after microcomputer detects that battery voltage is too low. After this command, the DFOUT pin is set to 'high' and the Vin_12pin is pulled down by internal resistor to be set 'low' and series regulator are turned off.

In the power down mode, the M61040 operation is impossible. And CFOUT, DFOUT and PFOUT pins are set to 'high'. (In this situation, both charging and discharging are forbidden.)
At this time, supply current becomes max. $1.0\mu\text{A}$, so drops of battery voltage is prevented.



Figure1. Function after detecting over-discharge

Resume from Power Down Mode

After entering Power Down mode, the series regulator will begin operation when charger is connected(VIN_12 pin is high). The RESET will output low to high signal when Vreg is over reset level voltage. Microcomputer will begin operation and send command to resume M61040 from Power Down mode.

7) Conditioning Circuit

M61040 have a discharge circuit of each cells. It is available for drop of cell voltage for safety purpose. And to shorten the difference voltage among the cells . It can extend the battery pack life.

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3. Absolute Maximum Ratings

Table 3

ITEM	SYMBOL	CONDITION	RATINGS	UNIT
Absolute maximum rating	V _{abs}		33	V
Supply voltage	V _{CC}		30	V
Power dissipation	P _D		750	mW
Operating temperature range	T _{opr} 1		-20 ~ +85	°C
Storage temperature range	T _{stg}		-40 ~ +125	°C

4. Electrical Characteristics

Table 4

(Ta=25°C V_{CC}=14V, unless otherwise noted)

	ITEM	SYMBOL	CONDITION	Min.	Typ.	Max.	UNIT	Circuit
TOTAL	Supply voltage	V _{CC}		—	—	30	V	
	Supply current 1	I _{sup1}	Voltage monitor, V/R, reset ON Current monitor ON	105	200	280	μA	7
	Supply current 2	I _{sup2}	Voltage monitor, V/R, reset ON Current monitor OFF	65	120	165	μA	7
	Supply current (at Power save mode)	I _{ps}	Regulator ON, Non-loading, Reset circuit ON, Others OFF	35	60	85	μA	7
	Supply current (at Power Down mode)	I _{pd}	All operation stop, V _{IN} 12=GND	—	—	0.5	μA	7
REGULATOR	Output voltage	V _{reg}	I _{out} =20mA	5.145	5.2	5.295	V	3
	Input and output voltage Difference	V _{dif0}	I _{out} =20mA	—	0.3	0.8	V	3
	Linear regulation	ΔV _{out10}	V _{CC} =6.2~24V I _{out} =20mA	—	100	200	mV	3
	Load regulation	ΔV _{out20}	V _{CC} =6.2V I _{out} =50μA~20mA	—	30	45	mV	3
	Input voltage	V _{IN 0}	V _{CC} voltage	—	—	30	V	
REFERENCE VOLTAGE	Output voltage	V _{ref}	I _{out} =200μA	4.818	4.85	4.917	V	4
	Load stability	ΔV _{out21}	V _{CC} =6.2V I _{out} =50~200μA	—	5	45	mV	4
OVER CURRENT DETECTION	Over current inhibit Detection voltage 1	V _{cl}		V _{CL} -0.02	0.2	V _{CL} +0.02	V	8
	Over current inhibit detection voltage 2	V _{ch}	Load short detection	$\frac{V_{CC}}{3} \times 0.6$	$\frac{V_{CC}}{3}$	$\frac{V_{CC}}{3} \times 1.4$	V	8
	Over current inhibit detection delay time1	T _{vcl}	C _{ICT} =0.01μF	7	10	15	msec	5
	Over current inhibit detection delay time 2	T _{vch}		150	250	350	μsec	8

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Table 4

(Ta=25°C V_{CC}=14V ,unless otherwise noted)

	ITEM	SYMBOL	CONDITION	Min.	Typ.	Max.	UNIT	Circuit
BATTERY VOLTAGE DETECTION	Input Offset voltage	V _{off1}		31	208	385	mV	5
	Voltage gain 1	G _{amp1}		0.99	1.0	1.01		5
	Output source current	I _{source1}		150	—	—	μA	10
	Output sink current	I _{sink1}		150	—	—	μA	10
	Detection voltage of battery cell	V _{ref} -V _{off1}		4.45	—	—	V	5,6
CHARGE/DISCHARGE CURRENT DETECTION	Input Offset voltage	V _{off2}	Gain=200 selected	0.2	2	3.8	V	5
	Voltage gain21	G _{ain21}		38.4	40	41.6	V	5
	Voltage gain22	G _{ain22}		96	100	104	V	5
	Voltage gain23	G _{ain23}		192	200	208	V	5
	Output source current	I _{source2}		150	—	—	μA	9
	Output sink current	I _{sink2}		150	—	—	μA	9
INTERFACE	DI input H voltage	V _{DIH}		3.5	—	V _{reg}	V	1
	DI input L voltage	V _{DIL}		0	—	0.5	V	1
	CS input H voltage	V _{CSH}		3.5	—	V _{reg}	V	1
	CS input L voltage	V _{CSL}		0	—	0.5	V	1
	CK input H voltage	V _{CKH}		3.5	—	V _{reg}	V	1
	CK input L voltage	V _{CKL}		0	—	0.5	V	1
RESET	Detection voltage1	V _{det-}		3.045	3.25	3.475	V	2
	Release voltage1	V _{det+}		4.16	4.2	4.27	V	2
CONDITIONING CIRCUIT	V _{IN} 1 resistor	R _{INV1}		4.4	12	27	KΩ	6
	V _{IN} 2 resistor	R _{INV2}		4.4	12	27	KΩ	6
	V _{IN} 3 resistor	R _{INV3}		4.4	12	27	KΩ	6
	V _{IN} 4 resistor	R _{INV4}		4.4	12	27	KΩ	6

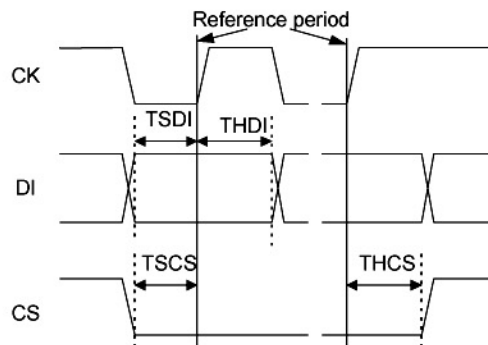
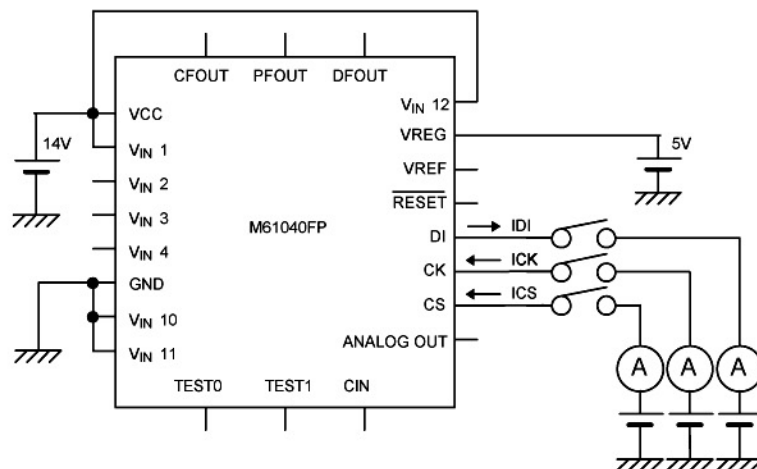
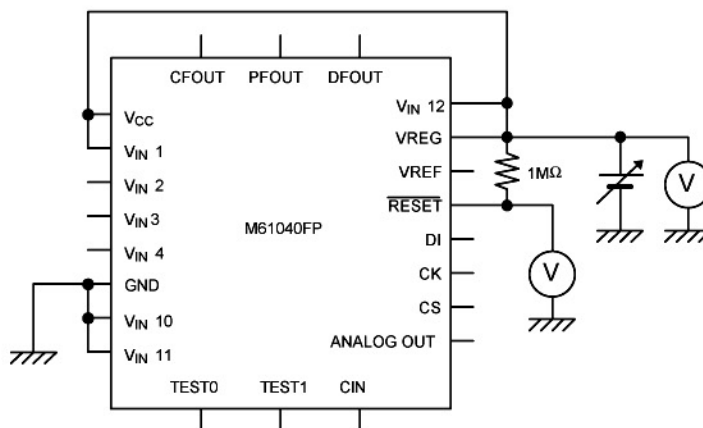


Figure 3 Interface Timing

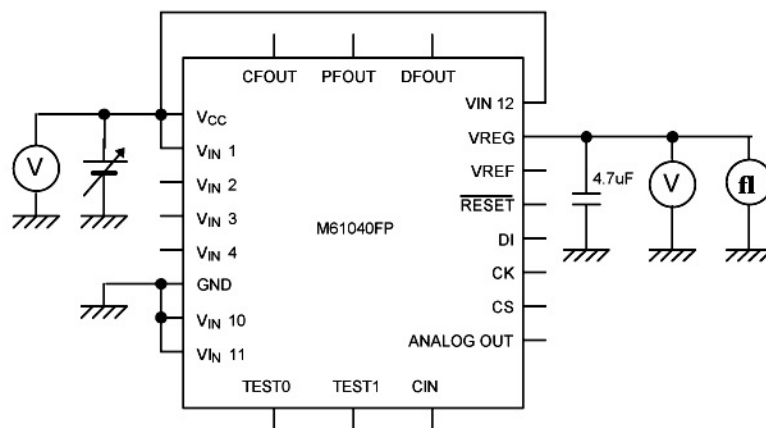
5. Measurement circuit



Circuit 1



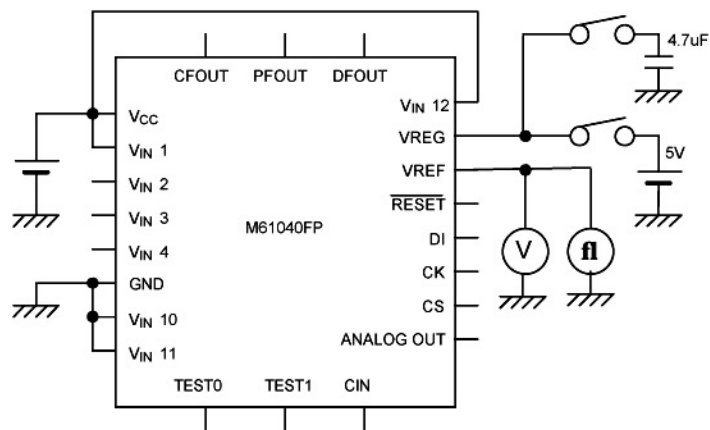
Circuit 2



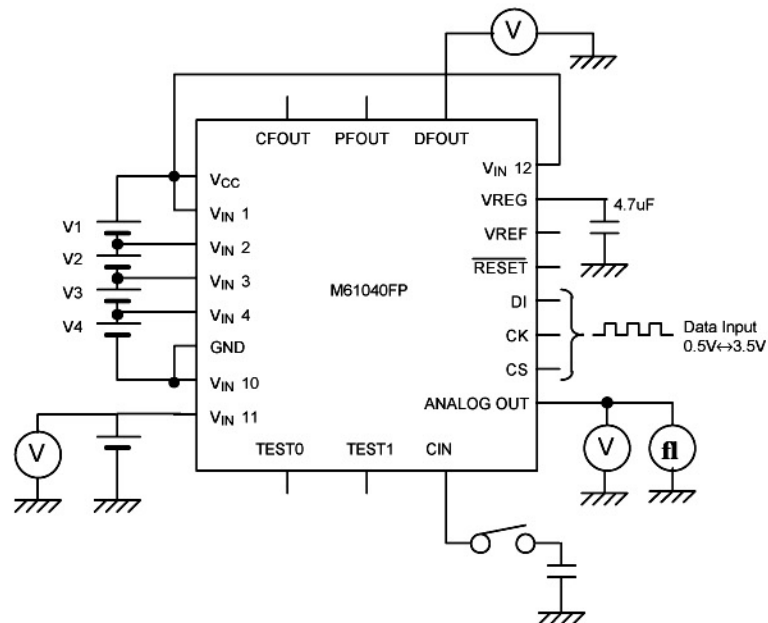
Circuit 3

Figure 4-1

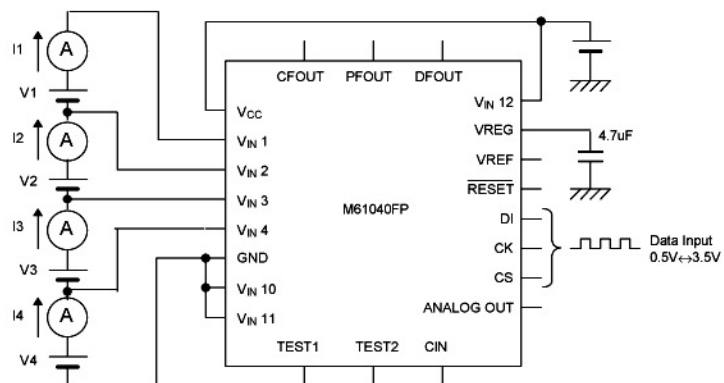
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Circuit 4



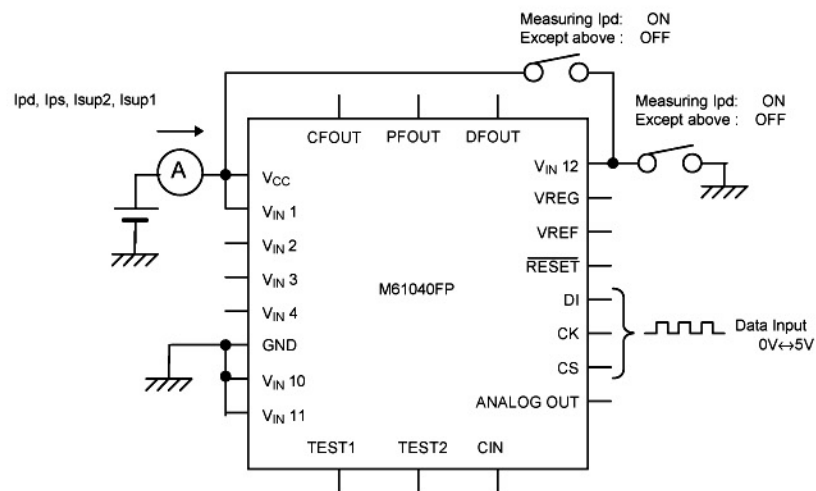
Circuit 5



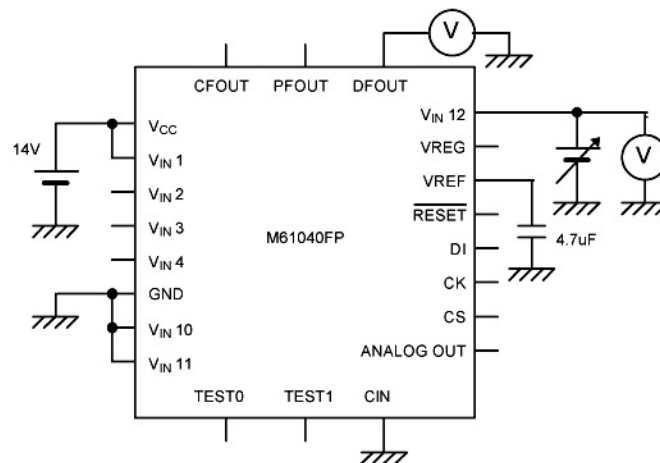
Circuit 6

Figure 4-2

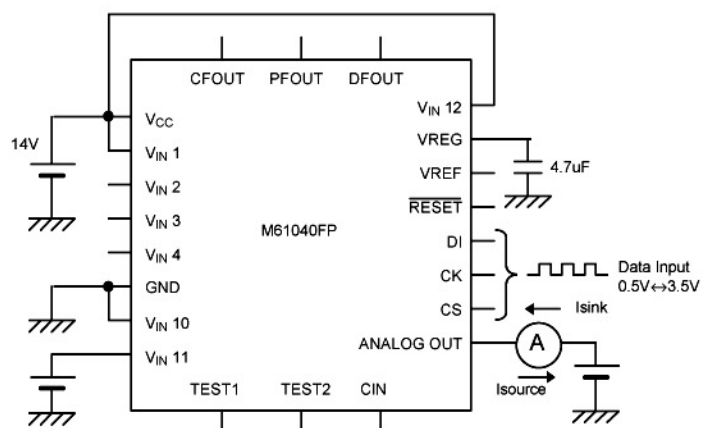
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Circuit 7



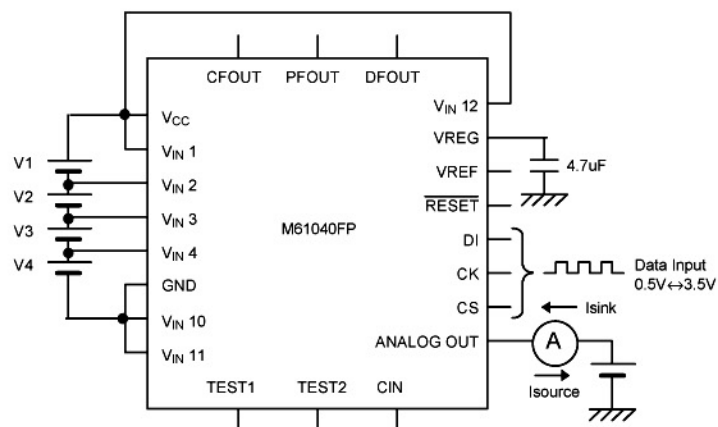
Circuit 8



Circuit 9

Figure 4-3

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Circuit 10

Figure 4-4

6. Block diagram description

(1) Battery voltage detection circuit

The M61040 battery voltage detection circuit is shown in figure 5.

This circuit is composed of switch, buffer amplifier, reference voltage section and logic circuit.

Microcomputer selects detecting voltage before logic circuit controls the connection of switches. This connection decides which cell voltage (V_{bat1} , V_{bat2} , V_{bat3} , V_{bat4}) should be output from Analog out pin. Besides offset voltage can be output.

In Power Down mode, supply current in this block is close to zero because all switches are off.

NOTE:

Regard $50\mu s$ as the standard of settling time by voltage change in this block.

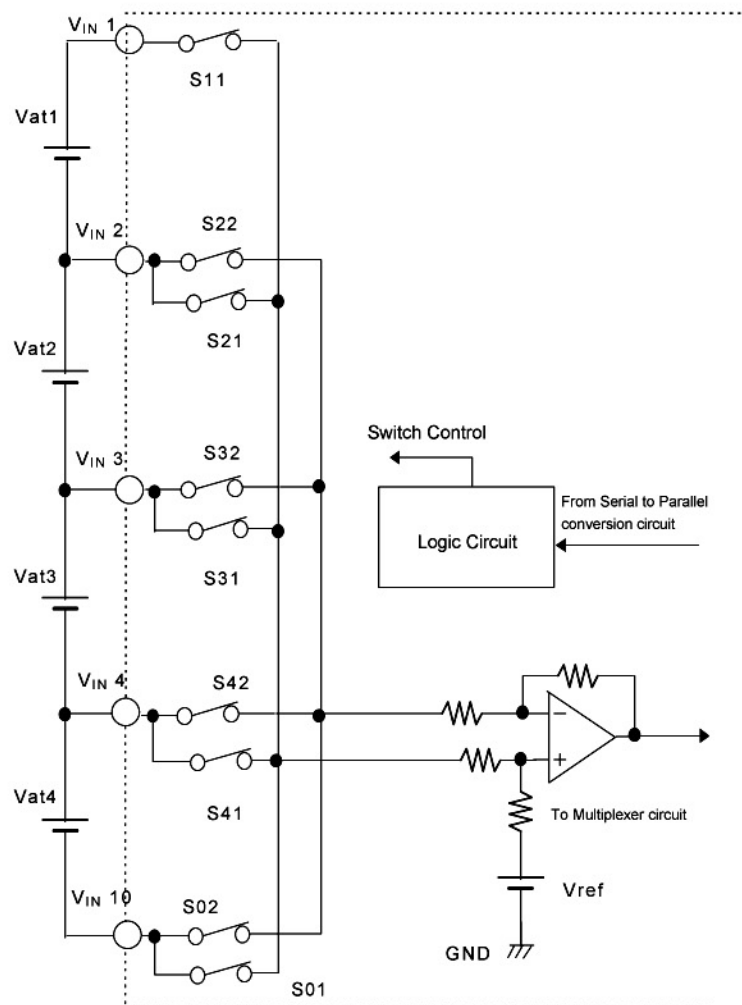


Figure 5. Battery voltage detection circuit

(2) Charge / discharge current detection circuit

The Charge/Discharge current detection circuit is shown in figure 6. This circuit is composed of offset voltage adjustment circuit, buffer amplifier and resistor network.

The pre-amplifier amplifies the voltage of sense resistance to the voltage based on GND. The voltage gain can be selected by microcomputer commands.

Buffer amplifier does an impedance translation between input and output.

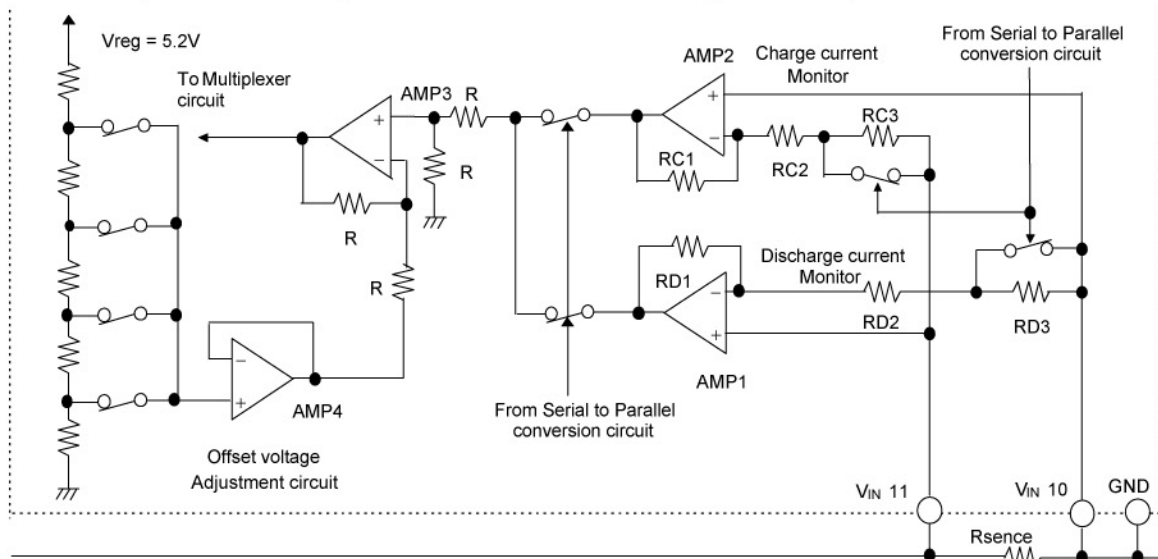


Figure 6. Charge / discharge current detection circuit

The offset voltage can be compensated by adjustment circuit.

The function in detecting discharge current is shown in figure 7. The differential voltage of sense resistor is input to +(plus) terminal of AMP 1 when discharge current is flowing in sense resistor. Selecting high voltage gain by microcomputer's command is capable of monitoring very little discharge current accurately.

The differential voltage of sense resistor is input to -(minus) terminal of AMP 2 when charge current is flowing in sense resistor. The methods of detecting in charging are the same as in discharging except that AMP2 reverses input voltage before outputting.

NOTE: Regard 500μs as the standard of settling time by voltage change in this block.

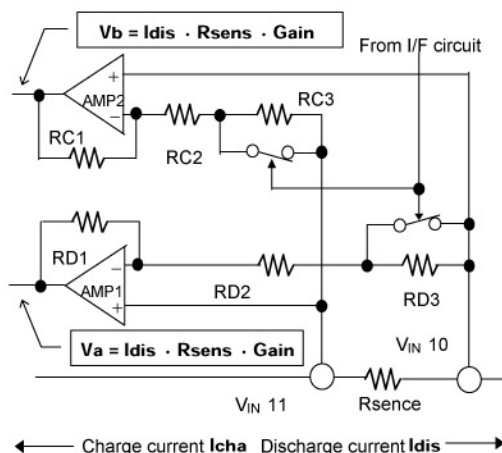


Figure 7. Charge/Discharge current detection

(3) Over current detection circuit

The over current detection circuit is shown in Figure 8. This circuit is composed of comparator, reference voltage and delay circuit.

It can be got high accuracy over current detection by adjusting detection voltage with sense resistor. Microcomputer can detect the over current status through monitoring "CIN_1" pin.

Besides this block contains load-short detection circuit. This circuit detects load-short with VIN_12 pin and protects faster than over current detection.

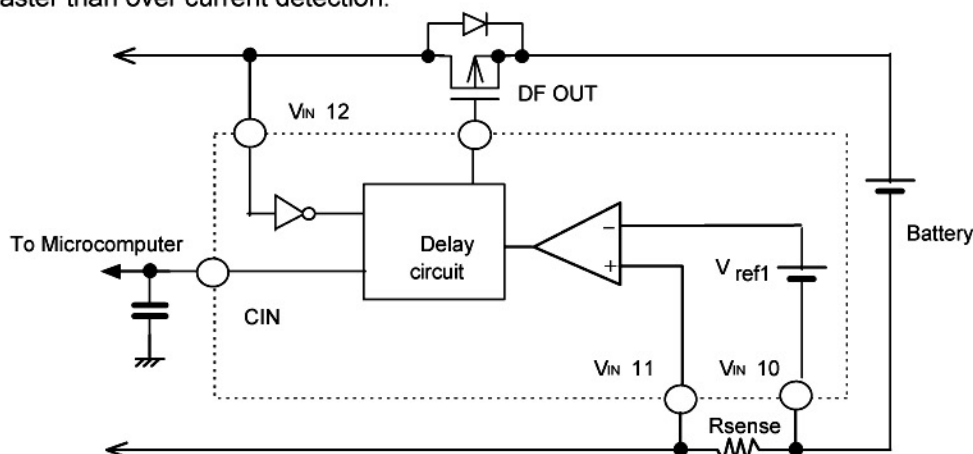


Figure 8.Over current detection circuit

(4) Voltage regulator and reference voltage

Voltage regulator and reference circuit are shown in Figure 9. Pch MOS transistor is used for output driver.

The output voltage can be adjusted by M61040 itself. So the external resistor is not required.

NOTE:

There is a diode put between Vcc and Vreg terminal to prevent the invert current from damaging this IC when Vcc voltage is higher than Vreg voltage. So please always keep Vreg voltage lower than Vcc+0.3V.

Set a condenser on output to suppress input changes or load changes.

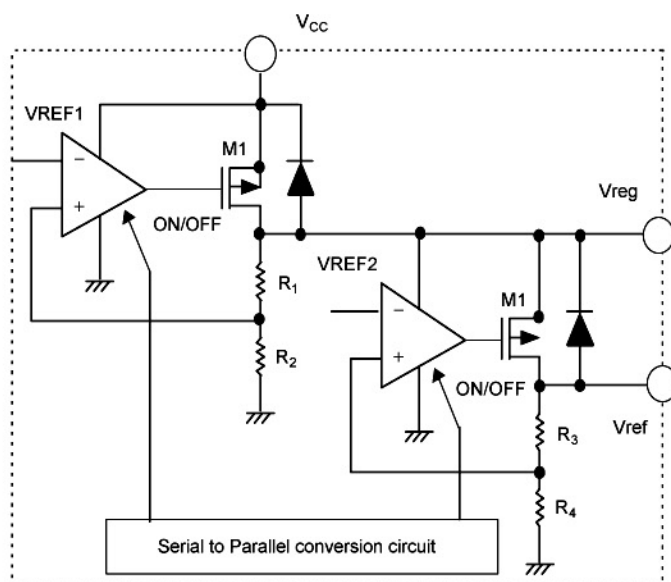


Figure 9 Voltage regulator circuit

(5) Reset circuit

The M61040 reset circuit is shown in Figure 10. This circuit is composed of comparator, reference voltage section and breeder resistor.

The reset output is Nch open drain structure so the reset delay time depends on external CR value.

The reset circuit monitors Vreg output to prevent microcomputer abnormal operation when Vcc voltage goes down abnormally.

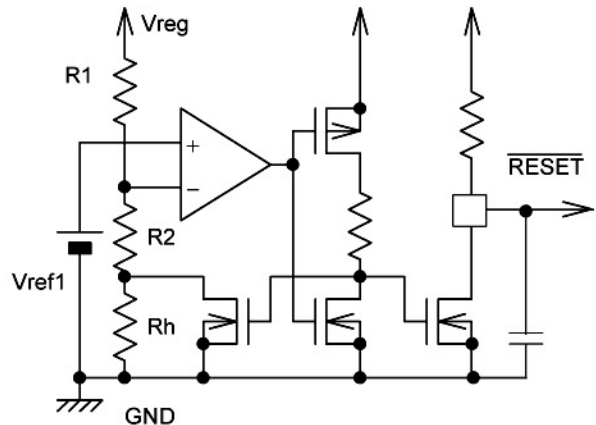


Figure 10. Reset circuit

(6) Conditioning Circuit

The M61040 conditioning circuit is shown in Figure 11. This circuit is composed of switch, resistor and logic circuit.

According to the serial data from microcomputer, the logic circuit can individually control the switches (S60, S61 ... etc.) to do individual cell discharge to a select voltage.

This circuit is capable of making all cells discharge at the same time.

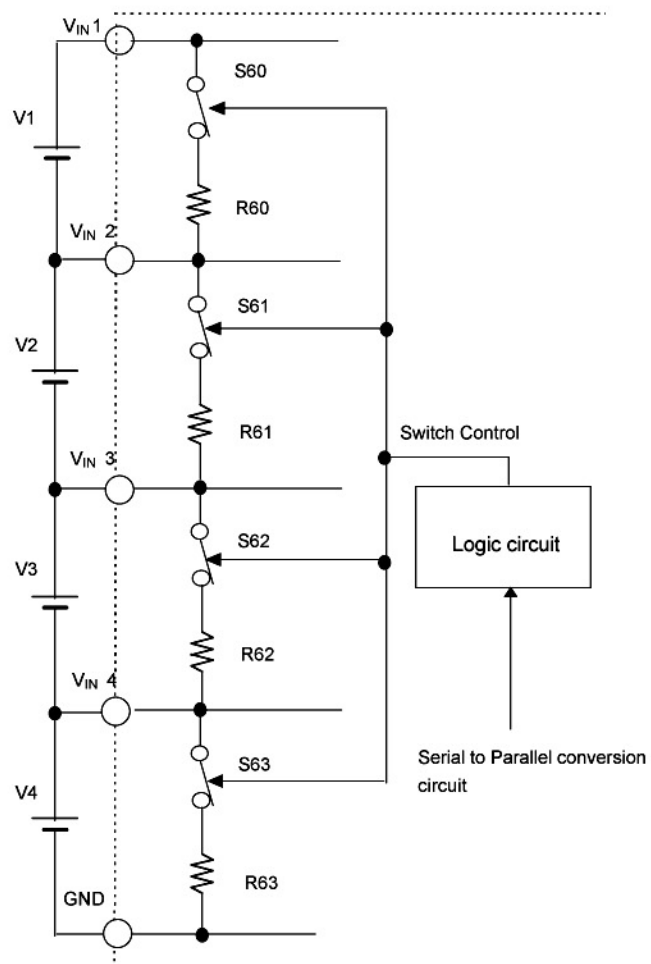
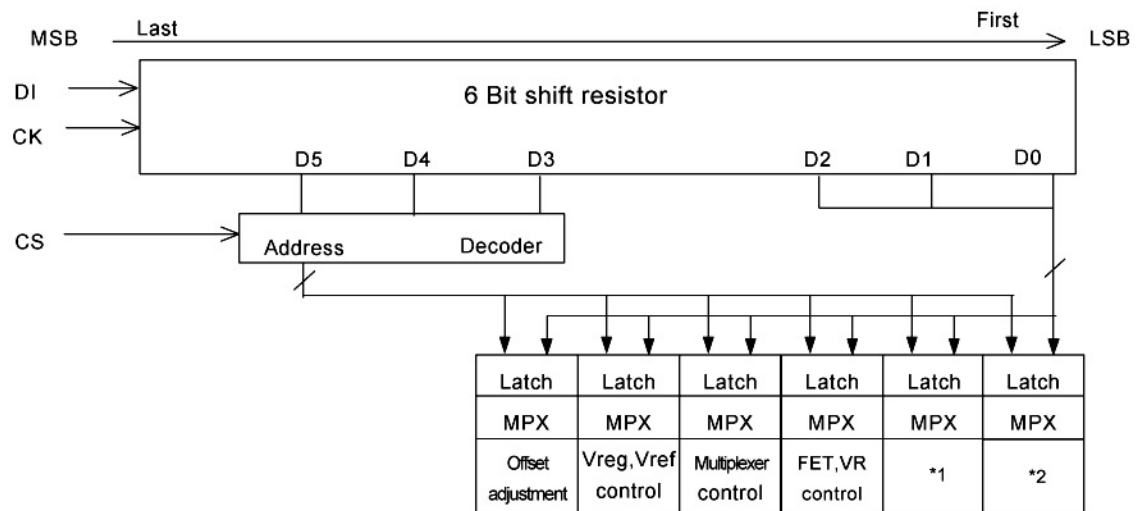


Figure 11. Conditioning Circuit

7. Digital data format



*1 : Charge, discharge current detection

*2 : Battery voltage output

Figure 12 Serial to Parallel Conversion circuit

8. Data timing Example

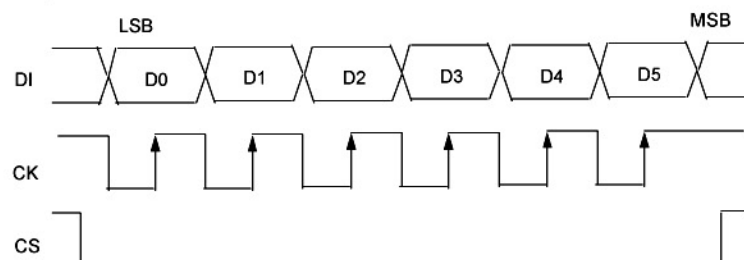


Figure 13. Serial to parallel timing chart

9. Data Timing

Table 5.

ESTABLISHMENT DATA	ADDRESS			DATA			CONTENTS
	D5	D4	D3	D2	D1	D0	
Reset	0	0	0	—	—	—	
Battery voltage output	0	0	1	—	—	—	Refer to table 6.
Offset adjustment	0	1	0	—	—	—	Refer to table 7.
Charge/discharge current detection	0	1	1	—	—	—	Refer to table 8.
FET control	1	0	0	—	—	—	Refer to table 9.
Multiplexer select	1	0	1	—	—	—	Refer to table 10.
Conditioning circuit	1	1	0	—	—	—	Refer to table 11.
Regulator Over current control	1	1	1	—	—	—	Refer to table 12.

Table 6 Battery voltage output

D2	D1	D0	OUTPUT VOLTAGE	DETAIL
0	0	0	V1	
0	0	1	V2	
0	1	0	V3	
0	1	1	V4	
1	0	0	Connect to VIN_2	Offset voltage output
1	0	1	Connect to VIN_3	Offset voltage output
1	1	0	Connect to VIN_4	Offset voltage output
1	1	1	Connect to VIN_10	Offset voltage output

- V1 battery voltage output when system reset

Table 7 Offset voltage control section of discharge current monitor amplifier

			OUTPUT
D2	D1	D0	Offset voltage value
0	0	0	No offset (0V)
0	0	1	1V
0	1	0	2.1V
0	1	1	3.1V
1	0	0	3.7V
1	0	1	1V
1	1	0	1V
1	1	1	1V

- No offset voltage when system reset

Table 8 Charge and discharge current detection

D2	D1	D0	MODE	OUTPUT
0	0	0	AMP stop, resistor open	AMP Operation stop, Current save
0	0	1	gain x40 output	
0	1	0	gain x100 output	
0	1	1	gain x200 output	
1	0	0	AMP stop, resistor open	AMP Operation stop, Current save
1	0	1	Offset output (x40)	
1	1	0	Offset output (x100)	
1	1	1	Offset output (x200)	

♦ Amplifier operation is stopped when system reset

Table 9 FET regulator control

D2	D1	D0	FET CONNECTION TERMINAL		
			CFOUT terminal	DFOUT terminal	PFOUT terminal
0	0	0	High	High	High
0	0	1	High	High	Low
0	1	0	High	Low	High
0	1	1	High	Low	Low
1	0	0	Low	High	High
1	0	1	Low	High	Low
1	1	0	Low	Low	High
1	1	1	Low	Low	Low

♦ CFOUT, DFOUT and PFOUT are high when system reset
(Over current detection is disable when DFOUT is high)

Table. 10 Multiplexer control

D2	D1	D0	OUTPUT
0	0	0	open output (floating) select
0	0	1	open output (floating) select
0	1	0	open output (floating) select
0	1	1	open output (floating) select
1	0	0	Charge current output select
1	0	1	Discharge current output select
1	1	0	Battery voltage output select
1	1	1	GND output select

♦ Multiplexer output is floating when system reset

Table.11 Conditioning Circuit

D2	D1	D0	OUTPUT
0	0	0	OPEN
0	0	1	V1 Conditioning (Short VIN_1 and VIN_2)
0	1	0	V2 Conditioning (Short VIN_2 and VIN_3)
0	1	1	V3 Conditioning (Short VIN_3 and VIN_4)
1	0	0	V4 Conditioning (Short VIN_4 and GND)
1	0	1	V1 ~ V4 Conditioning (Discharge All cells)
1	1	0	OPEN
1	1	1	OPEN

♦Conditioning circuit is floating when system reset

Table.12 Regulator, Over Current detection control

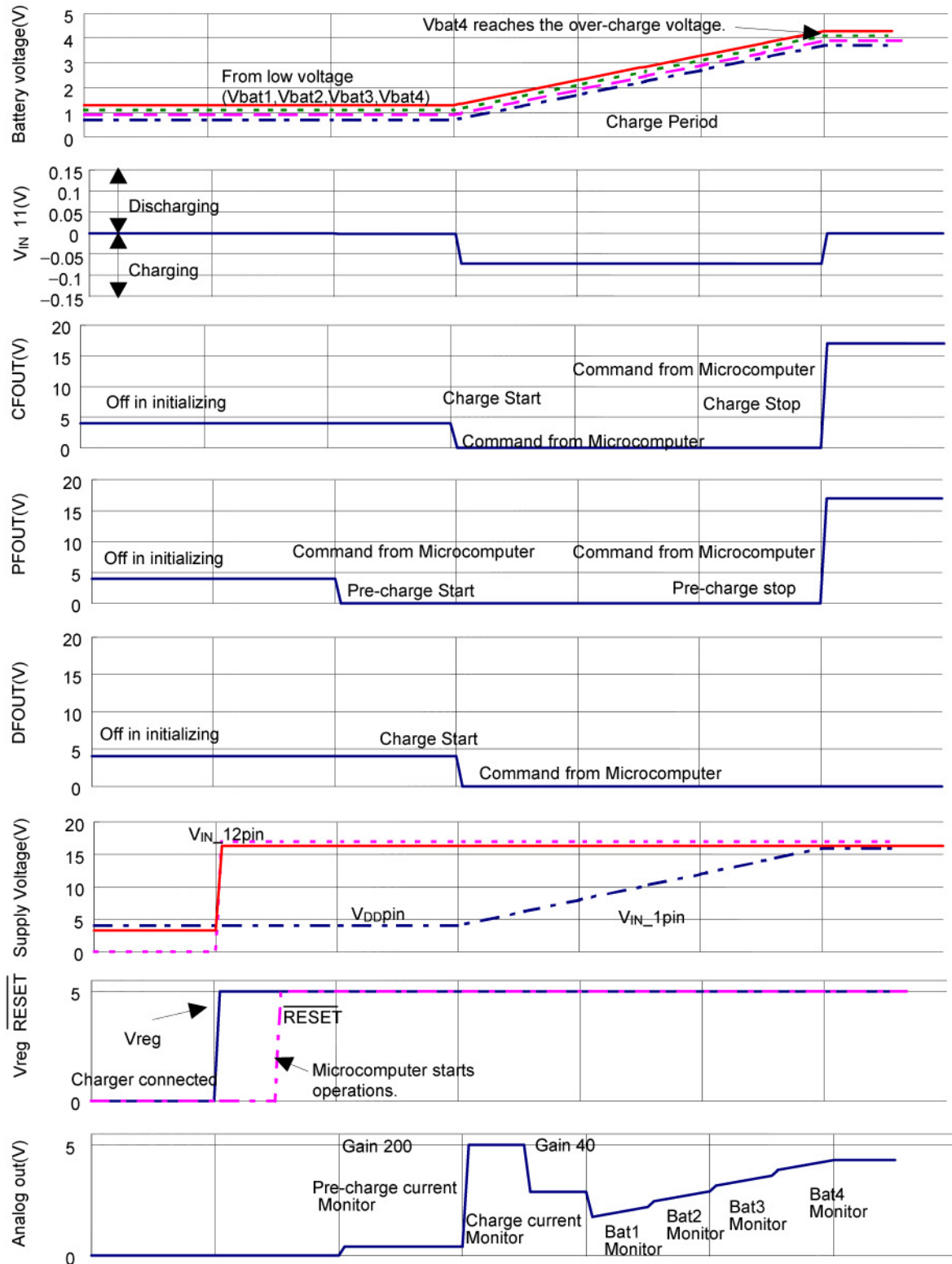
D2	D1	D0	OUTPUT	
			Regulator	Over Current detection circuit
0	0	0	ON	ON
0	0	1	OFF(GND Output) *1	*1
0	1	0	ON	Capacity Delay terminal L fix
0	1	1	ON	Capacity Delay terminal H fix
1	0	0	Don't Care	Don't Care
1	0	1	Don't Care	Don't Care
1	1	0	Don't Care	Don't Care
1	1	1	Don't Care	Don't Care

♦ The regulator output is enable when system reset

*1 All functions of M61040 are stooped. But if the charger is connected then M61040 will not enter power down mode.

10. Timing chart

10-1. Discharge sequence



*Testing in constant voltage

Fig.14

10-2. Discharge sequence

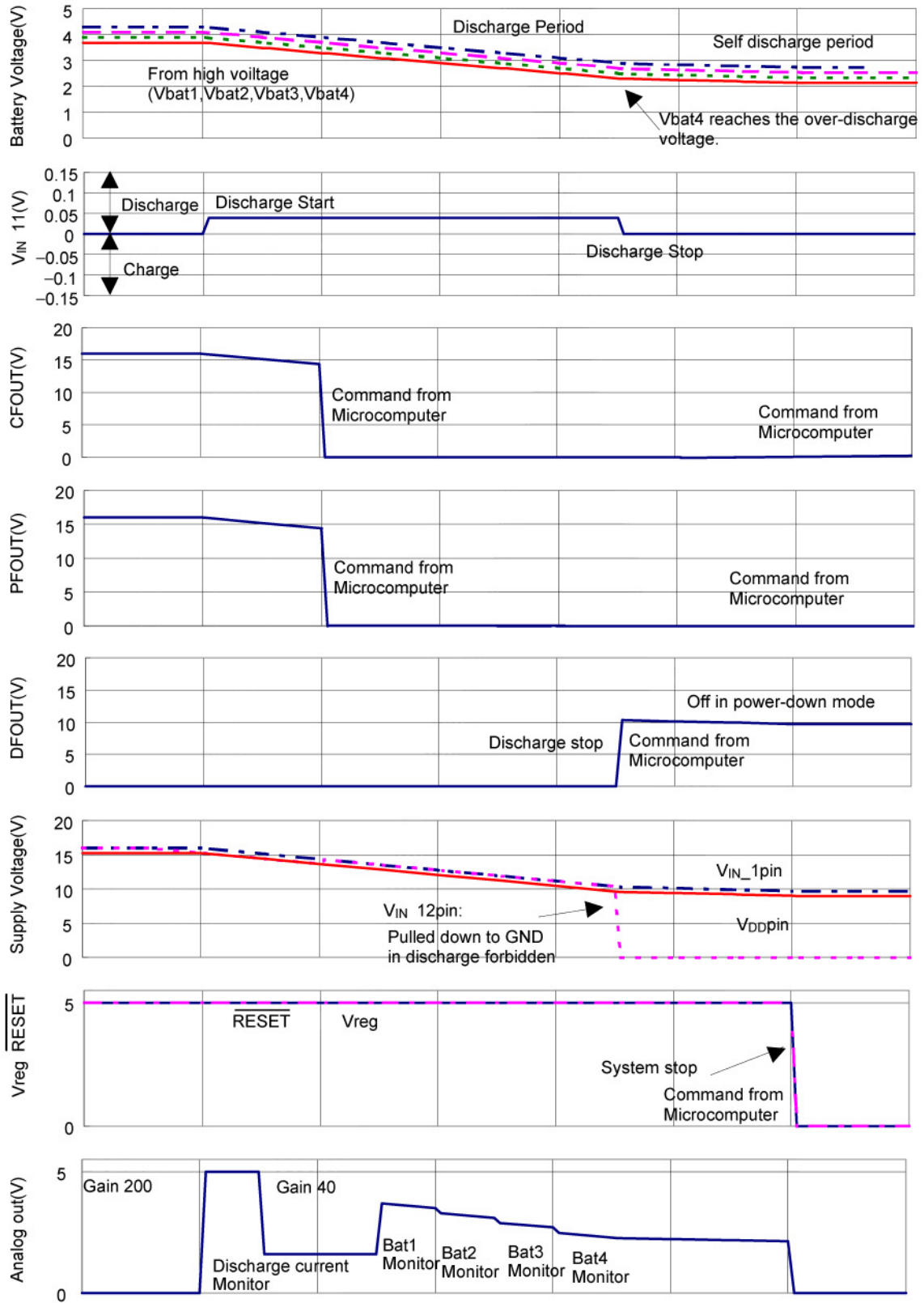


Fig.15

10-3. Over current detection sequence

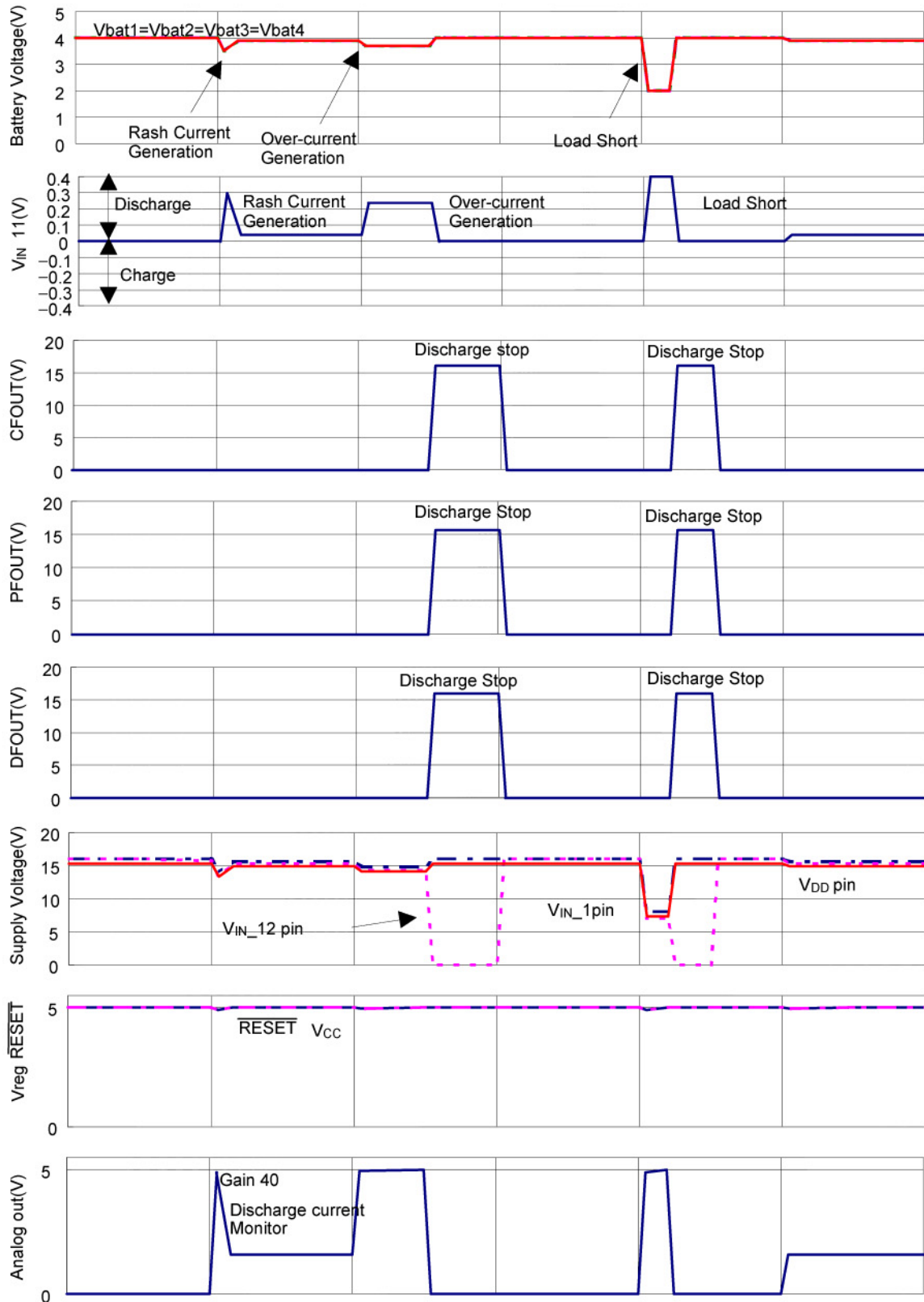


Fig.16

11. Application circuit

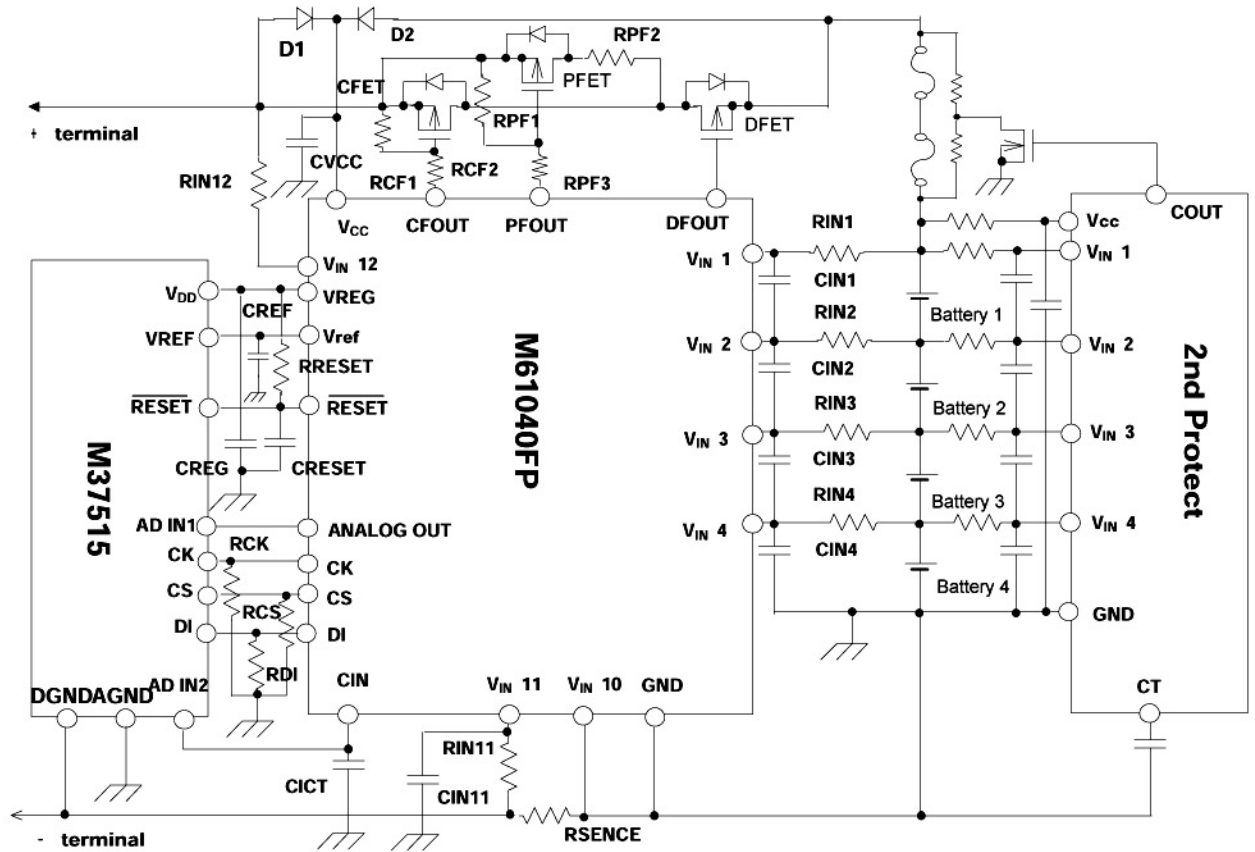


Fig.17

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Table.13 Fixed Number

Symbol	Components	Purpose	Recommend	min.	max.	N.B.
D1	Diode	Supply voltage	—	—	—	Please take care the maximum power dissipation.
D2	Diode	Supply voltage	—	—	—	Please take care the maximum power dissipation.
DFET	Pch MOSFET	Discharge control	—	—	—	—
CFET	Pch MOSFET	Charge control	—	—	—	—
PFET	Nch MOSFET	Precharge control	—	—	—	—
RCF1	Resistor	Pull down resistor	1MΩ	100kΩ	3MΩ	—
RCF2	Resistor	Current limit	100kΩ	—	1MΩ	—
RPF1	Resistor	Pull down resistor	1MΩ	100kΩ	3MΩ	—
RPF2	Resistor	Precharge current control	1kΩ	—	—	—
RPF3	Resistor	Current limit	100kΩ	—	1MΩ	—
RIN1	Resistor	Measure for ESD	10Ω	—	1kΩ	—
CIN1	Capacitor	Measure for ripples of power supply	0.22μF	—	1.0μF	
RIN2	Resistor	Measure for ESD	1kΩ	—	10kΩ	—
CIN2	Capacitor	Measure for ripples of power supply	0.22μF	—	1.0μF	
RIN3	Resistor	Measure for ESD	1kΩ	—	10kΩ	*2)Please set up same value as RIN2,CIN2
CIN3	Capacitor	Measure for ripples of power supply	0.22μF	—	1.0μF	
RIN4	Resistor	Measure for ESD	1kΩ	—	10kΩ	*2)Please set up same value as RIN2,CIN2
CIN4	Capacitor	Measure for ripples of power supply	0.22μF	—	1.0μF	
CICT	Capacitor	Set up delay time	0.01μF	—	0.47μF	—
RIN12	Resistor	Measure for ESD	10kΩ	300Ω	200kΩ	—
CVCC	Capacitor	Measure for ripples of power supply	0.22μF	—	—	—
RSENCE	Sensing resistor	Charge/discharge current monitor	20mΩ	—	—	—
RIN11	Resistor	Measure for ripples of power supply	100Ω	—	1kΩ	—
CIN11	Capacitor	Measure for ripples of power supply	0.1μF	—	1.0μF	
CREG	Capacitor	Eliminate the voltage noise	4.7μF	0.47μF	—	—
CREF	Capacitor	Eliminate the voltage noise	4.7μF	—	—	—
RRESET	Resistor	Set up delay time	47KΩ	10kΩ	3MΩ	*3)It is necessary that you adjust a delay time for MCU.
CRSET	Capacitor	Set up delay time	0.1μF	—	—	
RCK	Resistor	Pull down resistor	—	100kΩ	—	—
RCS	Resistor	Pull down resistor	—	100kΩ	—	—
RDI	Resistor	Pull down resistor	—	100kΩ	—	—

12. Package dimensions

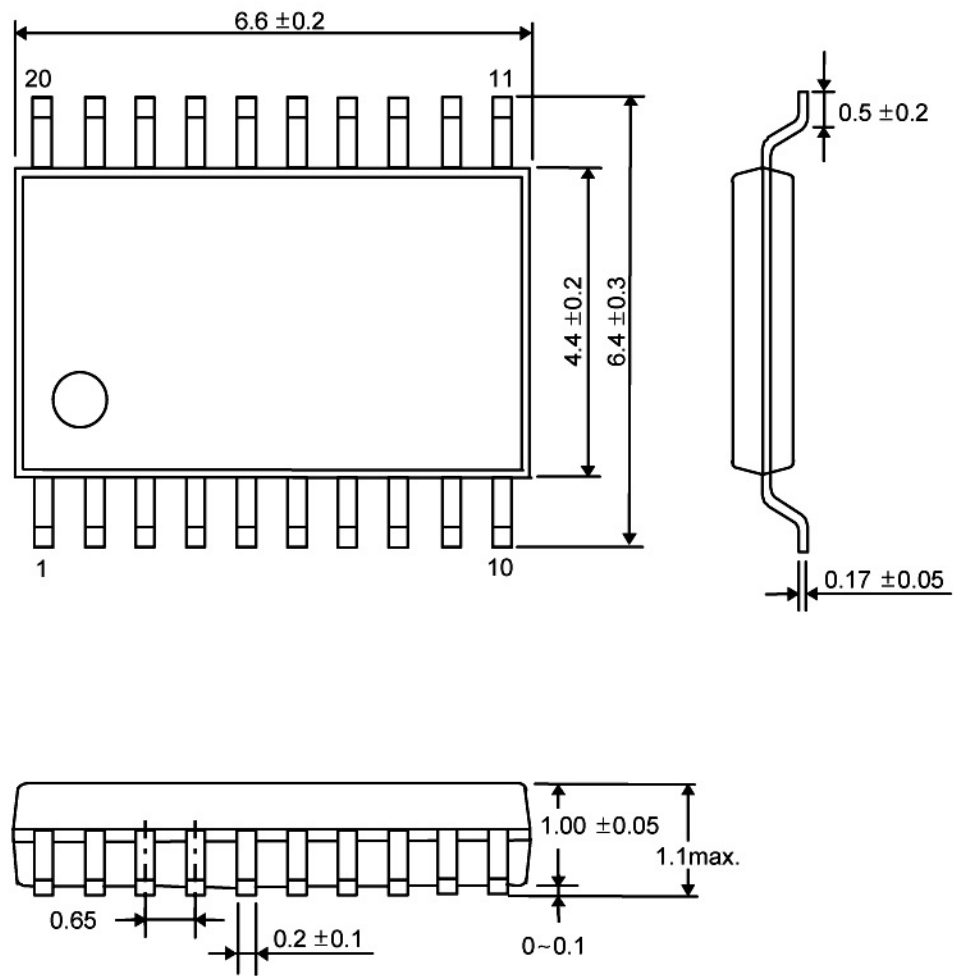


Figure.18