ET22377A
Datasheet

Revision History

Date	Version	Description
2021.8	V 1.0	First Release
2021.11	V 1.1	Proofread
2022.1	V 1.2	Spelling correction; Modify some DI parameters

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1. General Information

1.1 Introduction

Transmission Control Unit is designed for EV/HEV transmission control. As one of the main control units of the CAN bus-based vehicle control network, TCU controls vehicle transmission shifting based on the user-defined transmission control strategy, vehicle driving modes, driver behaviors, etc. TCU determines the optimal gear shift timing based on various signal inputs such as the ve hicle speed, engine/E-machine RPM, torque command, etc., and coordinates the powertrain torque output to ensure smooth gear shifting and improve the vehicle economy and drivability.

1.1.1 Terminology

The following table lists the abbreviations and definitions of terms in the document

Terminology Abbreviation	Definition
TCU	Transmission Control Unit
Keyon	Key Switch Signal
CAN	CAN Bus

1.1.2 Functionality

ET22377A has the following functions:

Table 1.1.2 ET22377A Features

Feature
1 Key Switch (KEYON)
2 Power Supply (BATT)
2 H-Bridge Power Supply (BATT_MOTOR)
2 H-Bridge Outputs
4 5V Outputs
3 CAN Bus Ports: Support CANA Wake Up at Any Frame
8 Analog Signal Inputs
8 Digital Signal Inputs
4 Frequency Signal Inputs
6 High-Side Driver Outputs, 2 Configurable as PWM Output
Hardware Watchdog

1.1.3 Material

The shell of TCU is formed by aluminum die-casting and assembled with silicone rubber. There is no special treatment or plating on the outside of the shell, no sharp burrs and sharp edges.

The nominal dimensions of the TCU shell are as follows (excluding the female end of the TCU connector, in mm):

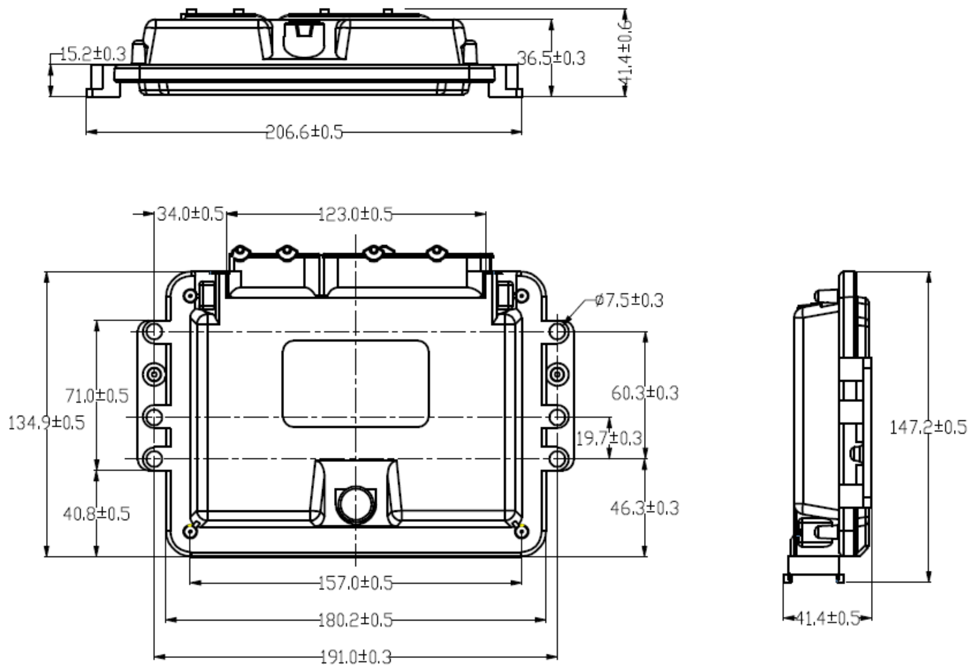


Figure 1 TCU Shell Size

The appearance of the shell is as follows:

Figure 2 TCU Shell Appearance

The socket model used for disassembling the shell: Torx T15. The product identification label is affixed to the TCU shell, which contains the product identification code, customer information, date, batch number, serial number, etc.

1.1.4 Harness Connector

TCU uses the world-renowned "TE connectivity" brand connector, which is a qualified product that meets the automotive safety level and has 121 pins. The specific models of the connectors are as follows.

Table 1.1.4 Harness Connector Info

#	Name	Part number	Supplier	URL
1	PCB Pin Seat	1746979-1	TE	https://www.te.com/usa-en/product-1746979-1.html
2	81P Housing	1473244-1	TE	https://www.te.com/usa-en/product-1473244-1.html
3	40P Housing	1473252-1	TE	https://www.te.com/usa-en/product-1473252-1.html
4	Big Terminal	964286-2	TE	https://www.te.com/usa-en/product-964286-2.html
5	Small Terminal	968220-1	TE	https://www.te.com/usa-en/product-968220-1.html
6	81P Cover Assembly	1473247-1	TE	https://www.te.com/usa-en/product-1473247-1.html
7	40P Cover Assembly	1473255-1	TE	https://www.te.com/usa-en/product-1473255-1.html
8	81P TPA	368382-1	TE	https://www.te.com/usa-en/product-368382-1.html
9	40P TPA	368388-1	TE	https://www.te.com/usa-en/product-368388-1.html

Harness connectors are shown below：

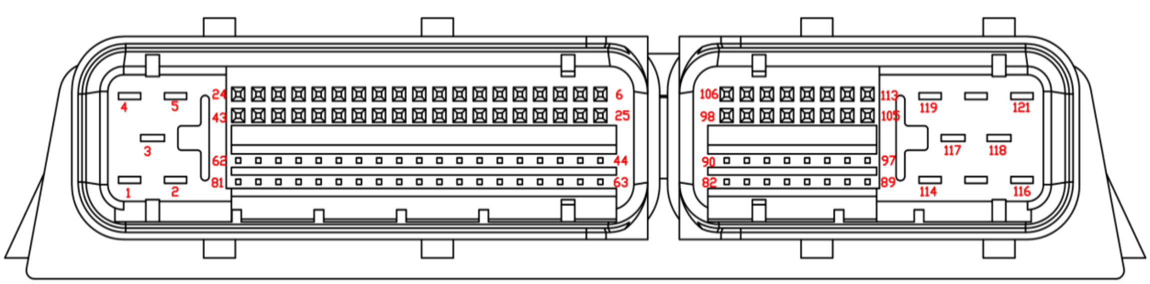


Figure 3 Harness Connector and Pin Distribution Diagram

1.1.5 Chip Information

Table 1.1.5 Chip Info

Feature	Detail
Micro Control Core	32-bit SAK-TC377TP-96F300S AA
Maximum Frequency	300MHz
Flash	6M
SRAM	1.1M
Floating Point Capability	Yes
SPI	50Mbit/s
IIC	20Mbit/s
CAN	1Mbit/s

1.1.6 Power Supply

ET22377A requires 2 continuous power supplies (pin1 and pin3), and the TCU is powered on through the key switch (pin93). TC377 communicates with SBC through SPI communication in the rate of 10Mbps. A 5A fuse in series with pin1 and pin3 is recommended for ET22377A power supply.

ET22377 power-on sequence diagram:

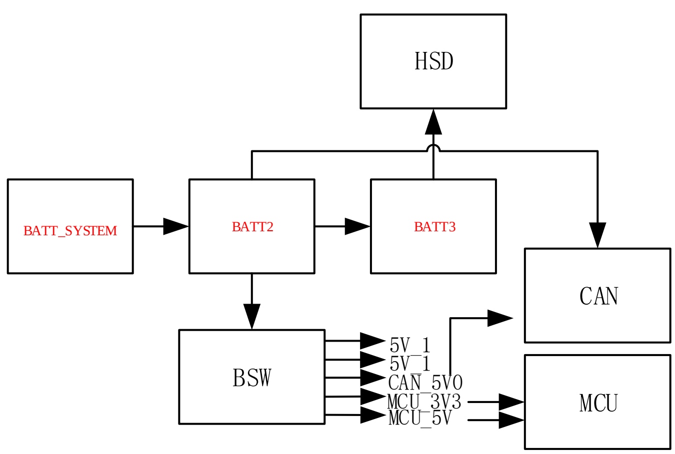
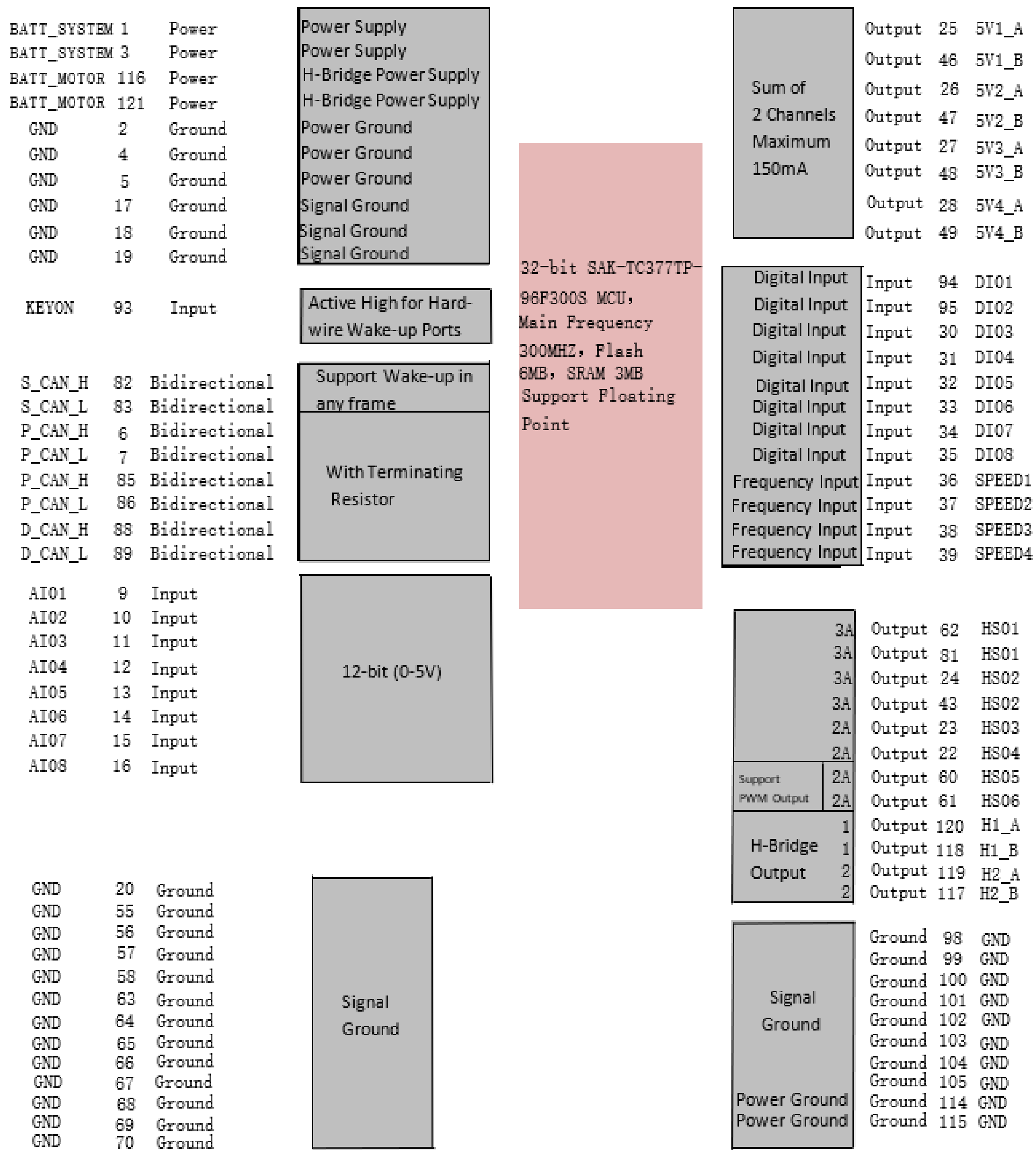


Figure 4 Power-on Sequence

1.2 System Block Diagram



2. Technical Performance

2.1 Electrical Characteristics

Item	Design Specifications
Operating Voltage	Dc 12 V / 24v (9~32v)
Operating Temperature	-40 °C ~85 °C
Working Humidity	0~95%, No Condensation
Storage Temperature	-40 °C ~85 °C
Quiescent Current	<1ma
Rated Power Consumption	3 W (Not Including Load)
Protection Level	IP67
Weight	⩽ 1500g
Controller Size	207×148×41mm
Material	Die-Cast Aluminum
Shell	Equipped With Waterproof Breathable Valve, Good Heat Dissipation

2.2 Electrical Performance Standard

Item	Test Standard
Overvoltage (High Temperature)	ISO 16750-2
Jump Voltage	ISO 16750-2
AC Voltage Superposition Test	ISO 16750-2
Slow Drop and Rise of Supply Voltage	ISO 16750-2
The Supply Voltage Drops Instantaneously	ISO 16750-2
Reset Performance to Voltage Dip	ISO 16750-2
Starting Characteristics	ISO 16750-2
Reverse Voltage	ISO 16750-2
Reference Ground and Power Supply Offset	ISO 16750-2
Open Circuit Experiment -Single Wire Open Circuit	ISO 16750-2
Open Circuit Experiment -Multi-Line Open Circuit	ISO 16750-2
Short Circuit Protection	ISO 16750-2
Withstand Voltage	ISO 16750-2
Insulation Resistance	ISO 16750-2

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2.3 Environmental Standards

Test Item	Test Standard
Waterproof (IP67)	IEC/EN 60529
Dustproof (IP67)	ISO 20653
Salt Spray Leakage Function and Corrosion Test	ISO 16750-4
Mechanical Shock Test	ISO 16750-3
Vibration Test	ISO 16750-3
Drop Test	ISO 16750-3
Temperature Shock	ISO 16750-4
Electrical Operation at Circulating Ambient Temperature	ISO 16750-4
High and Low Temperature Operation Experiment	ISO 16750-4
High and Low Temperature Experiment	ISO 16750-4
Temperature and Humidity Cycle	ISO 16750-4
Constant Temperature and Humidity	ISO 16750-4

2.4 EMC Test Standard

Test Item	Test Standard
Narrow Band Measurement Test	ECE-R10
Wide Band Measurement Test	ECE-R10
Conducted Emission Test	ECE-R10
Electromagnetic Radiation Immunity Test	ECE-R10
Transient Immunity Test	ECE-R10
Electrostatic Discharge Test	ECE-R10

2.5 AI diagnosis

5V Diagnosis	Voltage Acquisition
Overvoltage Range	>2.7V
Undervoltage Range	<2.2V
Short to Power Supply	>4.5V
Short to Ground	<0.5V

3.3V Diagnosis	Voltage Acquisition
Overvoltage Range	>1.9V
Undervoltage Range	<1.4V
Short to Power Supply	>2.3V
Short to Ground	<0.5V

3. Interface Description

3.1 Pin Definition

Table 2.1 Pin Definition

Signal	PIN	Function	Description	Note
		Power		
BATT_SYSTEM	1 3	Power Supply	12V/24V	9-32V
BATT_MOTOR	116 121	Power Supply	H-Bridge Power Supply	9-32V
5V1	25 46	5V Sensor Supply 1	5V Sensor Power Supply	Single Output5v±1%, Three Channels Sum Max 150ma
5V2	26 47	5V Sensor Supply 2	5V Sensor Power Supply	Single Output5v±1%, Three Channels Sum Max 150ma
5V3	27 48	5V Sensor Supply 3	5V Sensor Power Supply	Single Output5v±1%, Three Channels Sum Max 150ma
5V4	28 49	5V Sensor Supply 4	5V Sensor Power Supply	Single Output5v±1%, Three Channels Sum Max 150ma
GND	2 4 5	Power Ground	Power Supply Ground	
GND	114 115	Power Ground	H-Bridge Power Ground	
GND	17 18 19 20 55 56 57 58 63 64 65 66 67 68 69 70 98 99 100 101 102 103	Signal Ground	5v Sensor Ground Signal Ground	

	104 105			
Analog Input				
AI01	9	Analog Input 01	Analog Signal Input 0~5V	Resistance Type, 12bit
AI02	10	Analog Input 02	Analog Signal Input 0~5V	Resistance Type, 12bit
AI03	11	Analog Input 03	Analog Signal Input 0~5V	Resistance Type, 12bit
AI04	12	Analog Input 04	Analog Signal Input 0~5V	Resistance Type, 12bit
AI05	13	Analog Input 05	Analog Signal Input 0~5V	Resistance Type, 12bit
AI06	14	Analog Input 06	Analog Signal Input 0~5V	Resistance Type, 12bit
AI07	15	Analog Input 07	Analog Signal Input 0~5V	Resistance Type, 12bit
AI08	16	Analog Input 08	Analog Signal Input 0~5V	Resistance Type, 12bit
Power-on signal				
KEYON	93	Key Input Signal	Analog Signal Input 0~BATT	12bit, Wake Up Voltage > 9V
Digital Input				
DI01	94	Analog Input 01	Digital Signal Input 0~BATT	Active High
DI02	95	Analog Input 02	Digital Signal Input 0~BATT	Active High
DI03	30	Analog Input 03	Digital Signal Input 0~BATT	Active High
DI04	31	Analog Input 04	Digital Signal Input 0~BATT	Active High
DI05	32	Analog Input 05	Digital Signal Input 0~BATT	Active High
DI06	33	Analog Input 06	Digital Signal Input 0~BATT	Active High
DI07	34	Analog Input 07	Digital Signal Input 0~BATT	Active High
DI08	35	Analog Input 08	Digital Signal Input 0~BATT	Active High
Frequency Input				
SPEED1	36	Frequency Input 1	Frequency Signal Input	Frequency Input Range 1Hz-30kHz
SPEED2	37	Frequency Input 2	Frequency Signal Input	Frequency Input Range 1Hz-30kHz
SPEED3	38	Frequency Input 3	Frequency Signal Input	Frequency Input Range 1Hz-30kHz
SPEED4	39	Frequency Input 4	Frequency Signal Input	Frequency Input Range 1Hz-30kHz
Output Signal				
HS01	62 81	High-side Output 01	Rated 3A, Max 10A	
HS02	24 43	High-side Output 02	Rated 3A, Max 10A	
HS03	23	High-side Output 03	Rated 1A, Max 2A	
HS04	22	High-side Output 04	Rated 1A, Max 2A	
HS05	60	High-side Output 05	Rated 1A, Max 2A	Support PWM Output, Frequency Range 1hz-2khz

HS06	61	High-side Output 06	Rated 1A, Max 2A	Support PWM Output, Frequency Range 1hz-2khz
H1	120 118	H1_A H1_B	Rated 10A, Max 20A	
H2	119 117	H2_A H2_B	Rated 10A, Max 20A	
Serial Communication				
S_CAN_H	82	CANA_H	120Ohm Terminating Resistor Included	Support Wakeup by Any Frame
S_CAN_L	83	CANA_L		
P_CAN_H	6 85	CANB_H	120Ohm Terminating Resistor Included	
P_CAN_L	7 86	CANB_L		
D_CAN_H	88	CANC_H	120Ohm Terminating Resistor Included	
D_CAN_L	89	CANC_L		
Internal Signal				
BATT_MOTOR(AI09)	--	Gather H-Bridge BATT_MOTOR Voltage	--	12bit
BATT_SYSTEM(AI10)	--	Gather Power Supply BATT_SYSTEM Voltage	--	12bit

Note: The high-side/low-side output current data is tested with standard loads and is only for reference. In real life, situations such as inrush current in load may cause misjudgment for fault diagnosis.

3.2 Pin Description

3.2.1 Analog Signal Input

Description

The analog input channel circuit has the same structure, including EMC capacitors, pull-up/pull-down resistors and a first-order low-pass filter circuit.
ADC Value/4095*5*Gain=Vin, Gain = 1 for AI01-AI08.

Main differences：

- Resistance of pull-up/pull-down resistor
- Pull-up voltage

Schematic

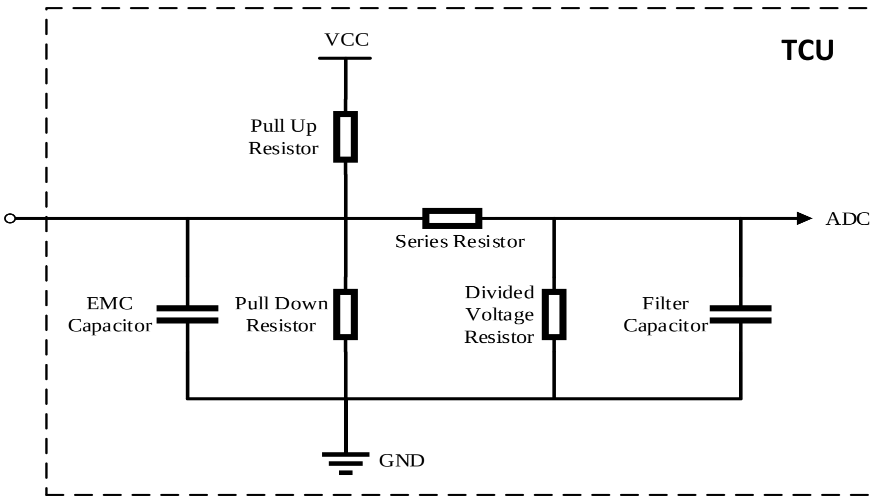


Figure 5 Schematic of Analog Input Channel

Table 2.2.1 Analog Input Channel Parameters

Note: 1) "--" =Unavailable. 2) U_B=BATT Voltage. 3) KEYON=Key Switch Signal.

Pin #	AI	EMC Capacitor	Pull Up Resistor		Pull Down Resistor	Series Resistor	Divided Voltage Resistor	Filter Capacitor	Operation Range		Input Range		Rate	Conditions / Remarks
		(F)	to U_B (Ohm)	to 5V (Ohm)	to GND (Ohm)	(Ohm)	(Ohm)	(F)	V_{Low}	V_{High}	Min	Max		
9	AI01	100n	--	2K	--	68K	--	1n	0V	5V	0V	5V	1	
10	AI02	100n	--	2K	--	68K	--	1n	0V	5V	0V	5V	1	
11	AI03	100n	--	2K	--	68K	--	1n	0V	5V	0V	5V	1	
12	AI04	100n	--	2K	--	68K	--	1n	0V	5V	0V	5V	1	
13	AI05	100n	--	10K	--	68K	--	1n	0V	5V	0V	5V	1	
14	AI06	100n	--	10K	--	68K	--	1n	0V	5V	0V	5V	1	
15	AI07	100n	--	10K	--	68K		1n						
16	AI08	100n	--	10K	--	68K	--	1n	0V	5V	0V	5V	1	
116 121	BATT_MOTOR	100n	--	--	--	99.8K	16K	1n	0V	32V	0V	32V	7.24375	
1 3	BATT_SYSTEM	100n	--	--	--	99.8K	16K	1n	0V	32V	0V	32V	7.24375	
93	KEYON/AI27	100n	--	--	--	99.8K	16K	1n	0V	32V	0V	32V	7.24375	
25 46	5V_1	100n	--	--	--	22K	22K	1n	0V	5V	0V	5V	2	
26 47	5V_2	100n	--	--	--	22K	22K	1n	0V	5V	0V	5V	2	

27 48	5V_3	100n	--	--	--	22K	22K	1n	0V	5V	0V	5V	2	
28 49	5V_4	100n	--	--	--	22K	22K	1n	0V	5V	0V	5V	2	
	VCC	100n	--	--	--	22K	22K	1n	0V	5V	0V	5V	2	
	CAN_5V0	100n	--	--	--	22K	22K	1n	0V	5V	0V	5V	2	
	MCU_3V3	100n	--	--	--	22K	22K	1n	0V	5V	0V	5V	2	
	MCU_5V	100n	--	--	--	22K	22K	1n	0V	5V	0V	5V	2	
	BATT3	--	--	--	--	99.8K	16K	1n	0V	32V	0V	32V	7.24375	
	ID1	--	--	10K	--	--	2.2K	1n	0V	5V	0V	5V	1	
	ID2	--	--	10K	--	--	2.2K	1n	0V	5V	0V	5V	1	

3.2.2 Digital Signal Input

Description

The digital input channel circuit has the same structure, including EMC capacitors, pull-up/pull-down resistors, voltage divider resistors, and a first-order low-pass filter.

Main differences：

- Resistance of pull-up/pull-down resistor
- Pull-up/pull-down selection

Schematic

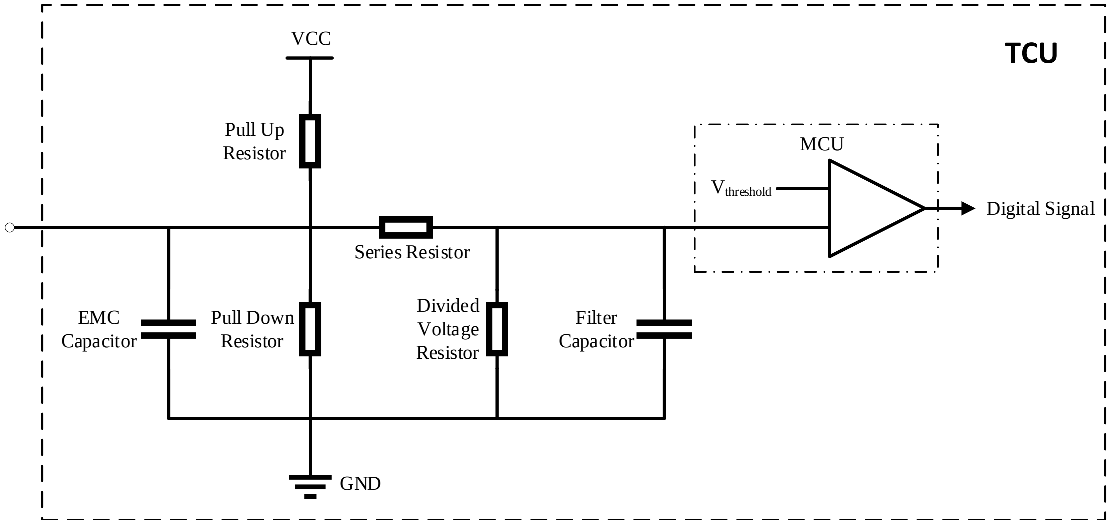


Figure 6 Schematic of Digital Input Channel

Table 2.2.2 Digital Input Channel Parameter

Note: 1) "--" =Unavailable. 2)UB=BATT Voltage. 3)KEYON, WAKE2, WAKE3 only for wake-up signal.

DI#	EMC Cap.	Filter Cap.	Pull Up Resistor to UB	Pull Up Resistor to 5V	Pull Down Resistor	Serial Resistor	Divided Voltage Resistor	Operation Threshold for Input Signal		Input Range		Conditions/ Remarks
	(F)	(F)	(Ohm)	(Ohm)	(Ohm)	(Ohm)	(Ohm)	VLow	VHigh	Min	Max	
DI01	1n	10p	--	1k	--	45.3 k	--	0.945V	3.11V	0V	5V	
DI02	1n	10p	--	1k	--	45.3 k	--	0.945V	3.11V	0V	5V	
DI03	10n	100p	--	--	10k	45.3 k	--	0.931V	3.09 V	0V	5V	
DI04	10n	100p	--	--	10k	45.3 k	--	0.931V	3.09 V	0V	5V	
DI05	10n	100p	--	1k	--	45.3 k	--	0.931V	3.09 V	0V	5V	
DI06	10n	100p	--	1k	--	45.3 k	--	0.931V	3.09 V	0V	5V	
DI07	10n	100p	--	1k	--	45.3 k	--	0.931V	3.09 V	0V	5V	
DI08	10n	100p	--	1k	--	45.3 k	--	0.931V	3.09 V	0V	5V	

Note: DI port configuration can be adjusted according to customer needs, above is only for reference.

3.2.3 Frequency Signal Input

Description

The frequency input channel circuit has the same structure, including EMC capacitors, pull-up/pull-down resistors, voltage divider resistors and a first-order low-pass filter.

Main difference：

- Resistance of pull-up/pull-down resistor
- Selection of pull up/down resistor

Schematic

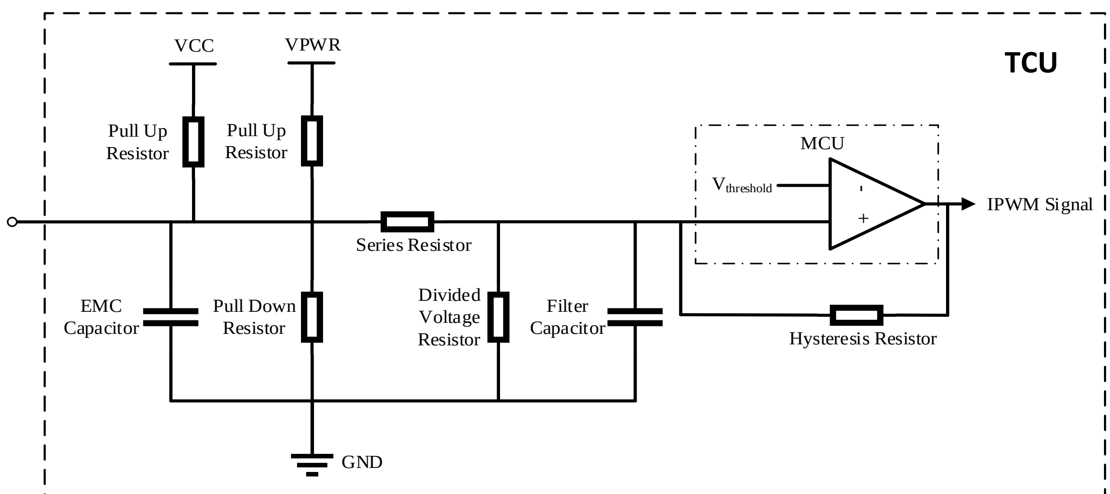


Figure 7 Schematic Diagram of Digital Frequency Input Channel

Table 2.2.3 Frequency Signal Input Channel Parameters

Note: 1) “--” =Unavailable

Pin #	Description	EMC Cap..	Filter Cap..	Pull Up Resistor to UB	Pull Up Resistor to 5V	Pull Down Resistor	Serial Resistor	Divided Voltage Resistor	Hysteresis Resistor	Operation Threshold for Input Signal		Input Range	
		(F)	(F)	(Ohm)	(Ohm)	(Ohm)	(Ohm)	(Ohm)	(Ohm)	Vlow	Vhigh	min	max
36	SPEED1	100p	--	--	1K	--	55.3K		91K	0.931V	3.09V	0 V	5V
37	SPEED1	100p	--	--	1K	--	55.3K		91K	0.931V	3.09V	0 V	5V
38	SPEED1	100p	--	--	1K	--	55.3K		91K	0.931V	3.09V	0 V	5V
39	SPEED4	100p	--	--	1K	--	55.3K		91K	0.931V	3.09V	0 V	5V

Table 8 Frequencies of Frequency Signal Input Channel and Duty Cycle Reference Values

	Input Duty Cycle (%) / Input Frequency	Detection Frequency	Detection Duty Cycle (%)
IPMW1-DI29_36	40%/1Hz	1Hz	39.939%
IPMW2-DI30_37	40%/1Hz	1Hz	39.939%
IPMW3-DI31_38	40%/1Hz	1Hz	39.939%
IPMW4-DI32_39	40%/1Hz	1Hz	39.939%

	Input Duty Cycle (%) / Input Frequency	Detection Frequency	Detection Duty Cycle (%)
IPMW1-DI29_36	50%/100Hz	100Hz	49.989%
IPMW2-DI30_37	50%/100Hz	100Hz	49.989%
IPMW3-DI31_38	50%/100Hz	100Hz	49.989%
IPMW4-DI32_39	50%/100Hz	100Hz	49.989%

	Input Duty Cycle (%) / Input Frequency	Detection Frequency	Detection Duty Cycle (%)
IPMW1-DI29_36	50%/30KHz	29940Hz	48.6%
IPMW2-DI30_37	50%/30KHz	29940Hz	48.6%
IPMW3-DI31_38	50%/30KHz	29940Hz	48.6%
IPMW4-DI32_39	50%/30KHz	29940Hz	48.6%

3.2.4 High-side Driver

Description

The high-side driver can be used as a switch for driving peripheral devices. It controls the output channel through the GPIO pins and controls the DEN and DSEL pins for the diagnostic functions.

Main differences：

- Driving current
- With or without PWM function
- Current leakage
- With or without freewheeling diode

Schematic

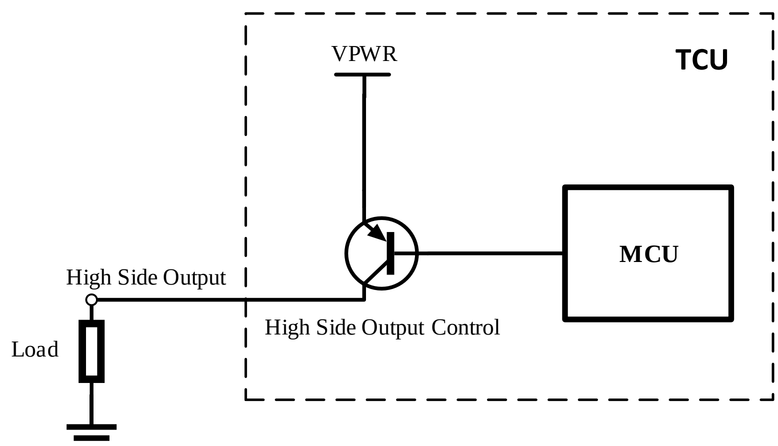


Figure 8 Schematic Diagram of High-Side Drive Channel

Table 2.2.4 High-Side Drive Channel Parameters

Pin #	Description	EMC Capacitor	Output current	Leakage Current	Free Wheeling Diode	Conditions / Remarks
			Max(A)	Max(uA)		
62 81	HS01	10nF/50V	10	0.5	Yes	
24 43	HS02	10nF/50V	10	0.5	Yes	
23	HS03	10nF/50V	2	0.5	Yes	
22	HS04	10nF/50V	2	0.5	Yes	
60	HS05	10nF/50V	2	0.5	Yes	
61	HS06	10nF/50V	2	0.5	Yes	

Note：

1) "--" = Not Installed
2) The total load of all high-side drive channels does not exceed 5A.

Fault Diagnosis of High-Side Driver

High-Side Driver Channel	Diagnosis Fault	
	Disable	Enable
HSO01、HSO02、HSO03、HSO04 HSO05、HSO06	•Short to Power	•Short to Ground

Note: All of the high-side driver channels have short-circuited protection. When the channel is enabled, if a channel is short-circuited to ground, the channel will automatically activate the short-circuit protection function. This function may cause the channel to have a fault code jump phenomenon in this case, which is normal.

3.2.5 CAN Bus

Description

CAN interface circuit is used for communication between TCU and other vehicle electronic controllers. The maximum communication speed is 1Mbit/s.

Schematic

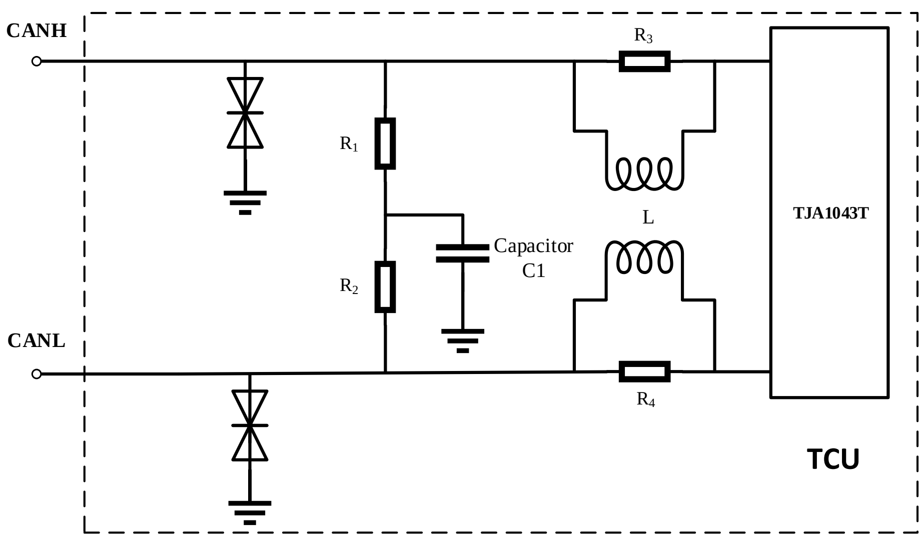


Figure 9 CAN Bus Schematic

Table 10 CAN Bus Parameters

Pin #	Description	Capacitor C1	R1, R2 (Ohm)	Choke L	Conditions / Remarks
82	S_CAN_H	100nF/100V	60	Yes	Support CAN2.0A/B, Support CAN wakeup by any frame
83	S_CAN_L		60		
6 85	P_CAN_H	100nF/100V	60	Yes	Support CAN2.0A/B
7 86	P_CAN_L		60		
88	D_CAN_H	100nF/100V	0	Yes	Support CAN2.0A/B
89	D_CAN_L		60		

3.2.6 5V Output

Description

The 5V voltage output channel can provide 5V power supply voltage for external sensors and has the following functions:

- Accurate 5V output for internal IC power supply
- 4 channel sensors 5V power supply output
- Inverse polarity protection, short circuit protection, over temperature protection

Table 2.2.6 5V Sensor Power Output Parameters

Pin #	Description	Imax(mA)	Output Voltage
25 46	5V Supply Voltage 1	Sum of 2 Channels Maximum 150mA	Single Output 5V ± 1%
26 47	5V Supply Voltage 2	Sum of 2 Channels Maximum 150mA	Single Output 5V ± 1%
27 48	5V Supply Voltage 3	Sum of 2 Channels Maximum 150mA	Single Output 5V ± 1%
28 49	5V Supply Voltage 4	Sum of 2 Channels Maximum 150mA	Single Output 5V ± 1%

3.2.7 H-bridge

Description

The H-bridge is a DC motor control drive that can reverse the voltage/current at both ends of the connected load or output terminal. All of it channels have fault diagnosis function.

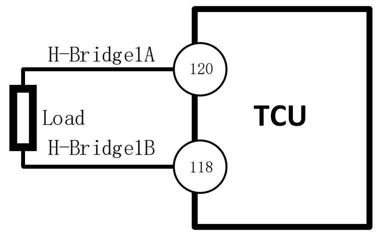


Figure 10 H-bridge working schematic

Note：
1) “--” = Not Installed
2) All the H -bridge drive channel does not exceed the total load of 40 A.
3) The maximum temperature of ET22377A when outputting 4A current reaches 42 °C in room temperature.
4) Please use the signal generator to define the frequency accuracy, high frequency, or low frequency.

Table 2.2.7-1 H-Bridge Output Parameters

	Continuous Current	MAX Current	Output Frequency
H1	10A	20A@10S	Low frequency: 2 Hz- 1 KHz
H2			High frequency: 1 KHz -20KHz

Fault Diagnosis of H-bridge DC Motor Control Circuit
The H-bridge drive diagnosis can directly feedback the voltage value. Users can make further specific analyses through the collected voltage value to obtain the fault information of the H bridge.
The H-bridge power supply voltage acquisition corresponds to the analog channel BATT_MOTOR (AI09).
The conversion formula of H-bridge voltage acquisition into current:
When there is no current on the H-bridge, the measured bias voltage V0 at ISO ≈1.246V. The magnification of the amplifier is 30.9, so the voltage at ISO, V_{ISO} = (0.002Ω*I*30.9)+V0。
That is, I≈(VISO-V0)*16.18. Since the maximum chip overcurrent alarm threshold is

V_{ISO}=4.99V, at this time, I overcurrent=($V_{ISO} - V_0$)*16.18≈60A, so the maximum current that triggers the overcurrent alarm is 60A. The minimum threshold of the chip overcurrent alarm is V_{ISO}=4.5V, at this time, I overcurrent=($V_{ISO} - V_0$)*16.18≈52A, so the minimum current that triggers the overcurrent alarm is 52A.

Diagnosis of H-bridge output pin status

1. ENA=0. The H-bridge MOSFETs are all off. The voltages of AN28 and AN29 are the voltages divided by VCC. The maximum value is taken to ignore the voltage drop of the diodes connected in series. All voltages are divided among the resistors. The voltage between VCC and AD reference voltage is + 0.2% error, voltage divider resistance +1% error, series resistance -1% error, the calculated maximum value of AN28 is
5*1.002*(16*1.01/(16*0.99+16*0.99+16*0.99+16*1.01)=1.268V

The minimum value of AN28 takes the voltage drop of the series diode as 0.46V, the difference between the VCC voltage and the AD reference voltage is -0.2%, the voltage divider resistance is -1%, and the series resistance is +1%. The calculated minimum value of AN28 is (5*0.998-0.46)*(16*0.99/(16*0.99+16*1.01+16*1.01+16*1.01)=1.15V

When H bridge connects to a load, since the load resistance Rx of the motor is much less than 16K, ignoring the influence of the load, AN29≈AN28=(5-0.46)*((16*3)//(16*3)/((16* 3)//(16*3) +16))/3=0.9V. Take the threshold 0.6V<AN28≈AN29<1V

When the H bridge load pin is short-circuited to ground, AN29≈AN28=0V, and the threshold value AN29≈AN28<0.3V

When the H bridge load pin is short-circuited to the power supply, AN29≈AN28=BATT*16/(16+16+16), when BATT=12V, AN29≈AN28=4V. Considering that the lowest BATT is 8V, take the threshold AN29≈AN28>2.6V

When the H bridge load pin is shorted to 5V, AN29≈AN28=5*16/(16+16+16)=1.67V. Take the threshold 1.4<AN29≈AN28<1.8V

When the H bridge is not connected to the load, AN28 is about 1.1V, and AN19 is about 0V. The threshold of AN28 is 0.9-1.3V; AN29<0.3V

A short-circuit fault occurs when the H bridge is not connected to the load. When 0.9<AN28<1.3V, H1_A is floating. When 1.4<AN28<1.8V, the H bridge is short-circuited to 5V. When AN28>2.6V, the H bridge is short-circuited to BATT. When AN28<0.3 V, H bridge is short-circuited to the ground (AN29≈AN28 in this state, but it is impossible to judge whether the load is connected or not. At this time, it can only report a short-circuit fault to the ground). When 1.4<AN29<1.8V, H1_B is short-circuited to 5V. When AN29>2.6V, H bridge is short-circuited to BATT. When AN29<0.3V, it cannot be judged whether the H1_B is floating or shorted to ground.

Table 2.2.7-2 H-Bridge Test Frequencies and Duty Cycle Accuracy Reference Values

Direction	Input Frequency	Test Frequency	Input Duty Cycle	Test Duty Cycle	Input Duty Cycle	Test Duty Cycle	Input Duty Cycle	Test Duty Cycle
A->B Forward Current	100hz	100hz	10.0%	10.4%	50.0%	50.4%	90.0%	90.4%
	1000Hz	1000Hz	10.0%	10.0%	50.0%	50.0%	90.0%	90.0%
	2000Hz	2000Hz	10.0%	9.7%	50.0%	50.0%	90.0%	90.3%
B->A Reverse Current	100hz	100hz	10.0%	9.91%	50.0%	49.95%	90.0%	89.90%
	1000Hz	1000Hz	10.0%	10.0%	50.0%	49.60%	90.0%	89.52%
	2000Hz	2000Hz	10.0%	9.7%	50.0%	50.0%	90.0%	90.3%

3.2.8 Gyroscope

The gyroscope sensor reads the sensor status and performs calibration by SPI communication at a rate of 10Mbps

3.2.9 EEPROM

The EEPROM uses 25LC512T chip. It communicates with MCU through SPI and supports maximum rate of 20Mhz.

4. Installation Requirements

It is recommended to install the TCU in the cockpit. If the OEM wants to assemble the TCU in another location, the corresponding installation location should be evaluated by Ecotron's engineers and the OEM's engineers.

The precautions for TCU installation are as follows：

1. The installation of TCU and wiring harness should be firm and reliable, and there should be no looseness. Avoid supporting the wiring harness by TCU. At the same time, the arrangement of TCU wiring harness should prevent and protect all wires in the wiring harness from damage due to wear and overheating.
2. Try to avoid installing in places where dust is easy to gather, a large amount of dust accumulation will affect the reliability of TCU work.
3. TCU should keep away from the location where the temperature of the shell itself may exceed 85°C. At the same time, it is necessary to prevent the surrounding parts from releasing heat to the TCU.
4. Avoid installing the TCU in locations where oil, moisture, and water droplets are likely to splash on it.
5. Avoid the possibility of additional mechanical shock and external impact due to the installation position and fixing method of the TCU and avoid installing the TCU at the resonance point of the car body.
6. Avoid installing the TCU where it may come into contact with the battery or other parts that are prone to seepage of acid and alkaline solutions, and near the TCU power terminal.
7. TCU should be installed in the horizontal and vertical position according to the connector downwards and maintain a certain angle to prevent water from entering the connector. In the horizontal direction, the recommended installation angle is -170° to -10°, as shown in Figure 10 below. In the vertical direction, the recommended installation angle is -170°~ -10°, as shown in Figure 11 below.

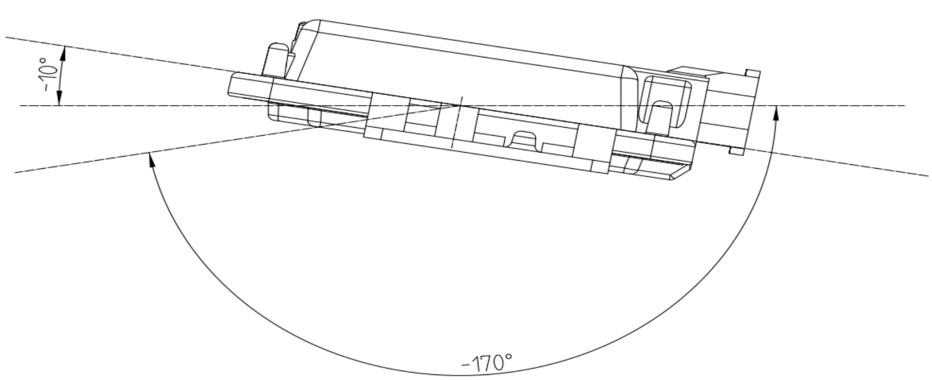
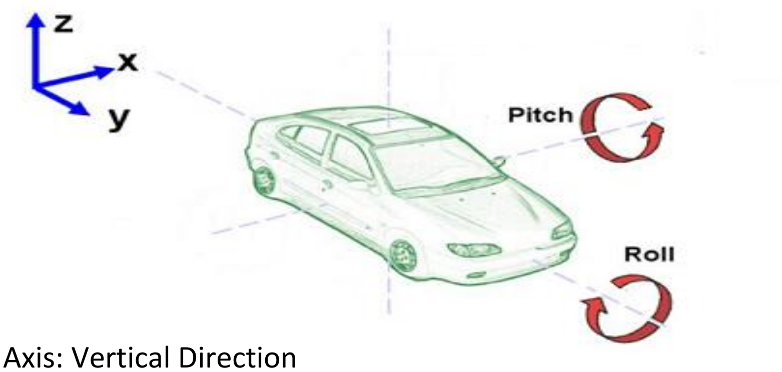


Figure 11 Horizontal Installation Angle



Z Axis: Vertical Direction
X Y Axes: Horizontal Direction

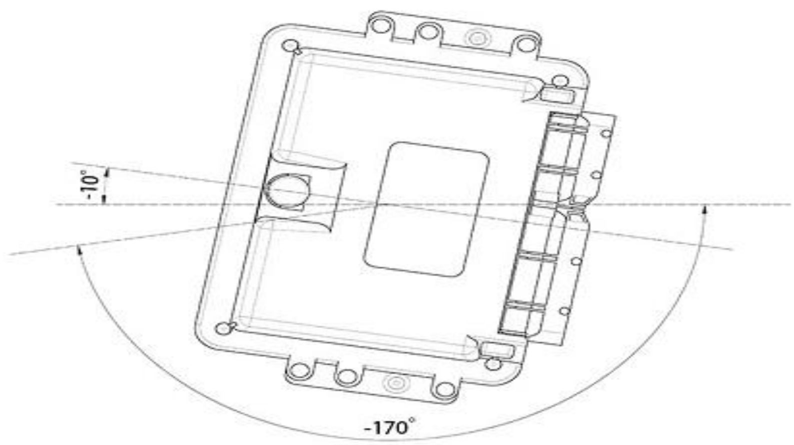


Figure 12 Vertical Installation Angle

Ecotron recommends using the six installation points on the TCU for installation and fixation. It is recommended to use metal materials such as aluminum alloy for the mounting bracket, and the housing should have a reliable electrical connection with the vehicle body through the bracket. If other materials are used, the customer must ensure that it can meet the requirements of TCU for vibration, heat dissipation, temperature, EMC, etc. If there is any deviation, it needs to be confirmed with Ecotron.

The TCU system adopts Ground through the vehicle's body. The specific requirement is to directly connect the ground wire in the wiring harness to the vehicle's body and ensure reliable electrical connection.