TI TMS320VC5505 ECG 解决方案

TI 公司的 ECG 解决方案是采用 TMS320VC5505 定点 DSP,它是基于 TMS320C55x DSP CPU 核的定点 DSP,它的 C55x™ DSP 架构可得到高性能和低功耗特性,CPU 支持内部总线架构,包括一条可编程总线,一条 321 位数据总总线和两条 16 位数据读总线,两条数据写总线和专门用于外设和 DMA 的其它总线. TMS320VC5505 还包括 4 个 DMA 控制器,每个四路.时钟为 60MHz 或 100MHz,指令周期为 16.67ns 或 10ns.主要用于无线音频设备,回声消除耳机,手提媒体设备,视频,工业控制,指纹生物学和 SDR. 本文介绍了 TMS320VC5505 的主要特性和方框图以及采用 TMS320VC5505 的 ECG 解决方案方框图, ECG 前端板详细电路图和所用材料清单(BOM).

Basic functions of an ECG machine include ECG waveform display, either through LCD screen or printed paper media, and heart rhythm indication as well as simple user interface through buttons. More features, such as patient record storage through convenient media, wireless/wired transfer and 2D/3D display on large LCD screen with touch screen capabilities, are required in more and more ECG products. Multiple levels of diagnostic capabilities are also assisting doctors and people without specific ECG trainings to understand ECG patterns and their indication of a certain heart condition. After the ECG signal is captured and digitized, it will be sent for display and analysis, which involves further signal processing.

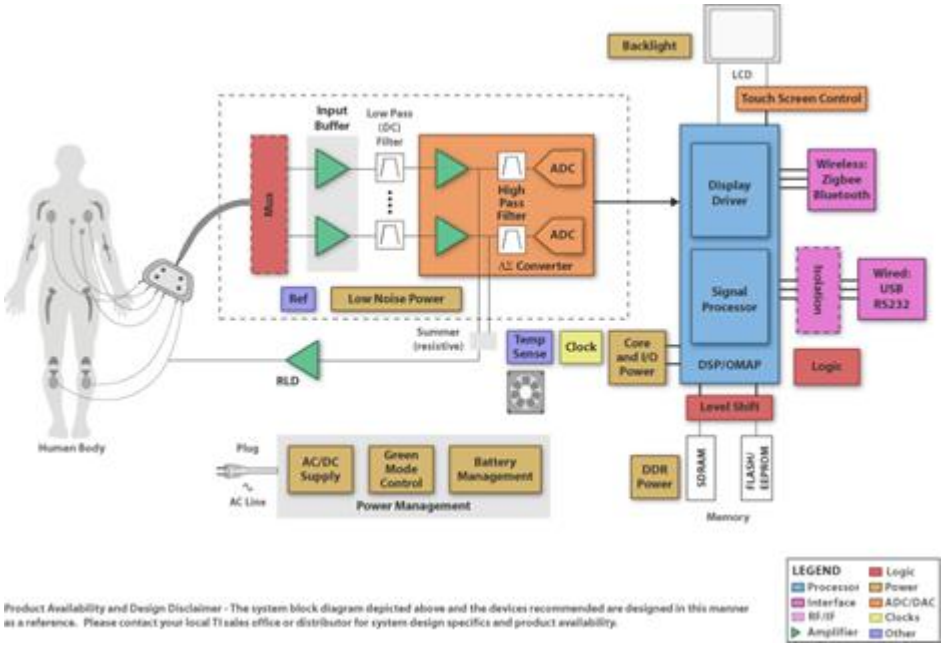

图 1.TI ECG 方框图

ECG Implementation on the TMS320VC5505 DSP Medical Development Kit (Rev. A)

The TMS320VC5505 is a member of TIs TMS320C5000™ fixed-point Digital Signal Processor (DSP) product family and is designed for low-power applications.

The TMS320VC5505 fixed-point DSP is based on the TMS320C55x™ DSP generation CPU processor core. The C55x™ DSP architecture achieves high performance and low power through increased parallelism and total focus on power savings. The CPU supports an internal bus structure that is composed of one program bus, one 32-bit data read bus and two 16-bit data read buses, two 16-bit data write buses, and additional buses dedicated to peripheral and DMA activity. These buses provide the ability to

perform up to four 16-bit data reads and two 16-bit data writes in a single cycle. The TMS320VC5505 also includes four DMA controllers, each with 4 channels, providing data movements for 16-independent channel contexts without CPU intervention. Each DMA controller can perform one 32-bit data transfer per cycle, in parallel and independent of the CPU activity.

The C55x CPU provides two multiply-accumulate (MAC) units, each capable of 17-bit x 17-bit multiplication and a 32-bit add in a single cycle. A central 40-bit arithmetic/logic unit (ALU) is supported by an additional 16-bit ALU. Use of the ALUs is under instruction set control, providing the ability to optimize parallel activity and power consumption. These resources are managed in the Address Unit (AU) and Data Unit (DU) of the C55x CPU.

The C55x CPU supports a variable byte width instruction set for improved code density. The Instruction Unit (IU) performs 32-bit program fetches from internal or external memory and queues instructions for the Program Unit (PU). The Program Unit decodes the instructions, directs tasks to the Address Unit (AU) and Data Unit (DU) resources, and manages the fully protected pipeline. Predictive branching capability avoids pipeline flushes on execution of conditional instructions.

The general-purpose input and output functions along with the 10-bit SAR ADC provide sufficient pins for status, interrupts, and bit I/O for LCD displays, keyboards, and media interfaces. Serial media is supported through two MultiMedia Card/Secure Digital (MMC/SD) peripherals, four Inter-IC Sound (I2S Bus™) modules, one Serial-Port Interface (SPI) with up to 4 chip selects, one I2C multi-master and slave interface, and a Universal Asynchronous Receiver/Transmitter (UART) interface.

The VC5505 peripheral set includes an external memory interface (EMIF) that provides glueless access to asynchronous memories like EPROM, NOR, NAND, and SRAM. Additional peripherals include: a high-speed Universal Serial Bus (USB2.0) device mode only, and a real-time clock (RTC). The DMA controller provides data movement for sixteen independent channel contexts without CPU intervention, providing DMA throughput of up to two 16-bit words per cycle. This device also includesthree general-purpose timers with one configurable as a watchdog timer, and a analog phase-locked loop (APLL) clock generator.

In addition, the VC5505 includes a tightly-coupled FFT Hardware Accelerator. The tightly-coupled FFT Hardware Accelerator supports 8 to 1024-point (in power of 2) real and complex-valued FFTs.

TMS320VC5505 主要特性:

High-Performance, Low-Power, TMS320C55x™ Fixed-Point Digital Signal Processor
16.67-, 10-ns Instruction Cycle Time 60-, 100-MHz Clock Rate

One/Two Instruction(s) Executed per Cycle

Dual Multipliers [Up to 200 Million Multiply-Accumulates per Second (MMACS)]

Two Arithmetic/Logic Units (ALUs)

Three Internal Data/Operand Read Buses and Two Internal Data/Operand Write Buses

Fully Software-Compatible With C55x Devices

Industrial Temperature Devices Available

320K Bytes Zero-Wait State On-Chip RAM, Composed of:

64K Bytes of Dual-Access RAM (DARAM), 8 Blocks of 4K x 16-Bit

256K Bytes of Single-Access RAM (SARAM), 32 Blocks of 4K x 16-Bit

128K Bytes of Zero Wait-State On-Chip ROM (4 Blocks of 16K x 16-Bit)

16-/8-Bit External Memory Interface (EMIF) with Glueless Interface to:

8-/16-Bit NAND Flash, 1- and 4-Bit ECC

8-/16-Bit NOR Flash

Asynchronous Static RAM (SRAM)

Direct Memory Access (DMA) Controller Four DMA With 4 Channels Each (16-Channels Total)

Three 32-Bit General-Purpose Timers

One Selectable as a Watchdog and/or GP

Two MultiMedia Card/Secure Digital (MMC/SD) Interfaces

Universal Asynchronous Receiver/Transmitter (UART)

Serial-Port Interface (SPI) With Four Chip-Selects

Master/Slave Inter-Integrated Circuit (I2C Bus™)

Four Inter-IC Sound (I2S Bus™) for Data Transport

Device USB Port With Integrated 2.0 High-Speed PHY that Supports: USB 2.0 Full- and High-Speed Device

LCD Bridge With Asynchronous Interface

Tightly-Coupled FFT Hardware Accelerator

10-Bit 4-Input Successive Approximation (SAR) ADC

Real-Time Clock (RTC) With Crystal Input, With Separate Clock Domain, Separate Power Supply

Four Core Isolated Power Supply Domains: Analog, RTC, CPU and Peripherals, and USB

Four I/O Isolated Power Supply Domains: RTC I/O, EMIF I/O, USB PHY, and DV_{DDIO}

Low-Power S/W Programmable Phase-Locked Loop (PLL) Clock Generator

On-Chip ROM Bootloader (RBL) to Boot From NAND Flash, NOR Flash, SPI EEPROM, or I2C EEPROM

IEEE-1149.1 (JTAG™) Boundary-Scan-Compatible

Up to 26 General-Purpose I/O (GPIO) Pins (Multiplexed With Other Device Functions)

196-Terminal Pb-Free Plastic BGA (Ball Grid Array) (ZCH Suffix)

1.05-V Core (60 MHz), 1.8-V, 2.5-V, 2.8-V, or 3.3-V I/Os

1.3-V Core (100 MHz), 1.8-V, 2.5-V, 2.8-V, or 3.3-V I/Os

TMS320VC5505 应用:

Wireless Audio Devices (e.g., Headsets, Microphones, Speakerphones, etc.)

Echo Cancellation Headphones

Portable Medical Devices

Voice Applications

Industrial Controls

Fingerprint Biometrics

Software Defined Radio

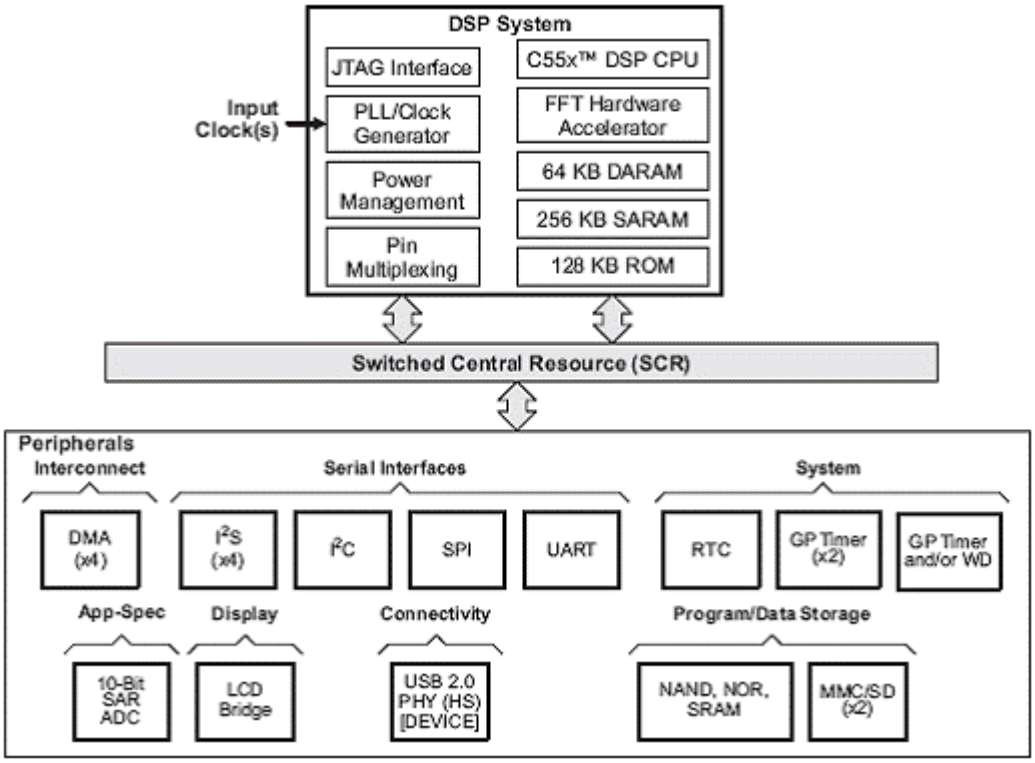

图 2.TMS320VC5505 功能方框图

A number of emerging medical applications such as electrocardiography (ECG), digital stethoscope, and pulse oximeters require DSP processing performance at very low power. The TMS320VC5505 digital signal processor (DSP) is ideally suited for such applications. The VC5505 is a member of TIs C5000™ fixed-point DSP platform. To enable the development of a broad range of medical applications on the VC5505, Texas Instruments has developed an MDK based on the VC5505 DSP. A typical medical application includes:

An analog front end, including sensors to pick up signals of interest from the body

Signal processing algorithms for signal conditioning, performing measurements and running analytics on measurements to determine the health condition

User control and interaction, including graphical display of the signal processing results and connectivity to enable remote patient monitoring

The MDK is designed to support complete medical applications development. It includes the following elements:

Analog front-end boards (FE boards) specific to the key target medical applications of the VC5505 (ECG, digital stethoscope, pulse oximeter), highlighting the use of the TI analog components for medical applications

VC5505 DSP evaluation module (EVM) main board

Medical applications software including example demonstrations Several elements of the MDK pulse oximeter system are:

VC5505 EVM

Pulse oximeter front-end board

Finger probe sensor

The schematics for the ECG front-end board

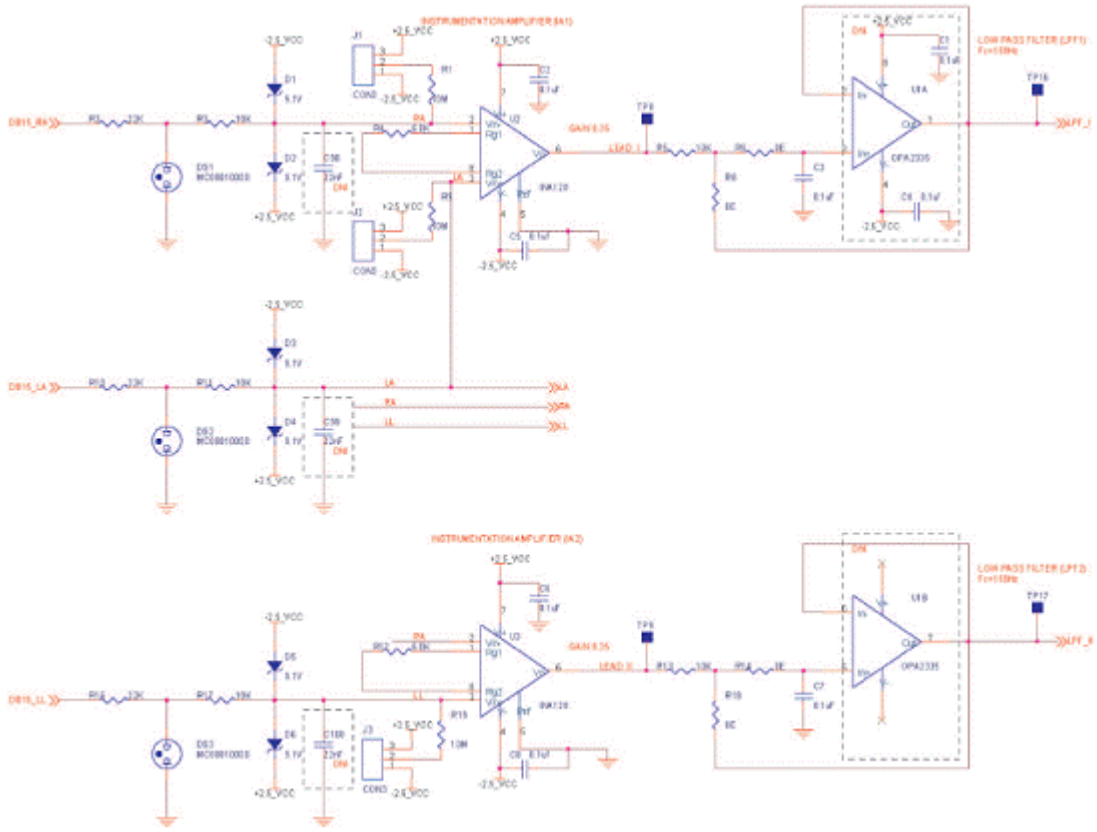

图 3. ECG 前端板电路图(1)

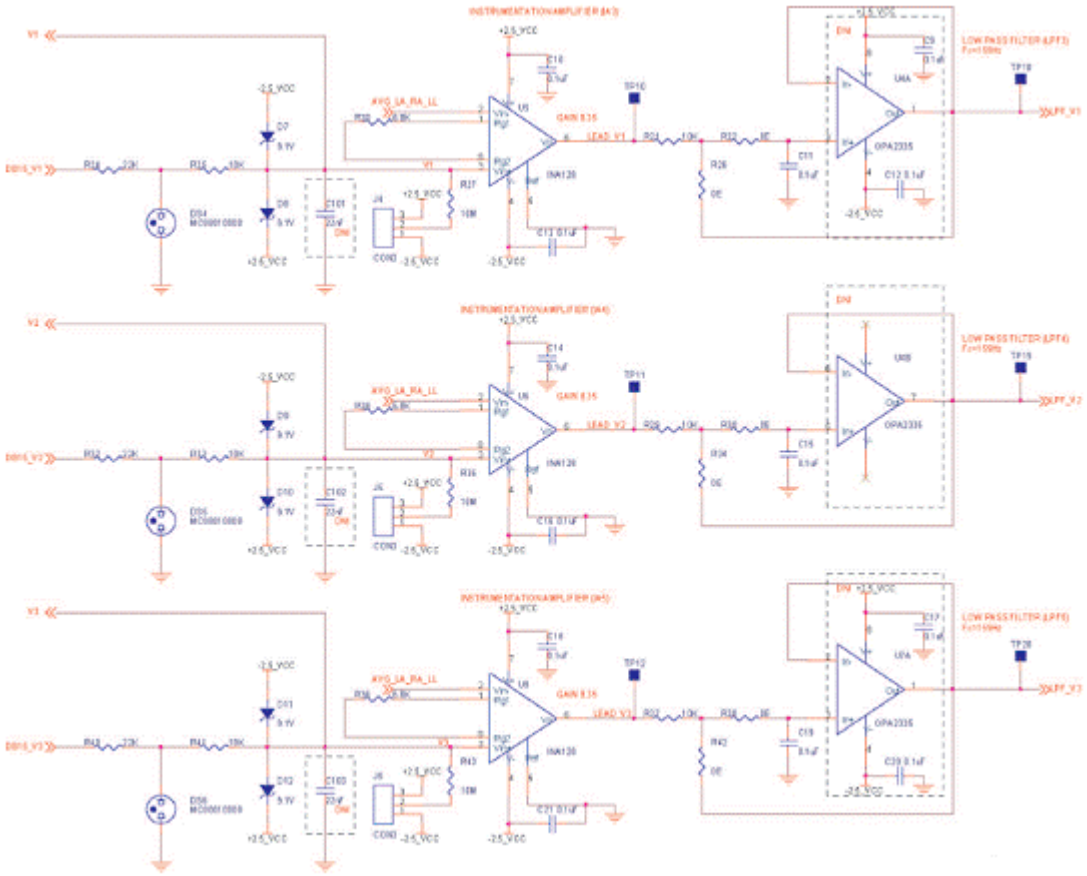

图 4. ECG 前端板电路图(2): ECG 电极:V1 V2 V3

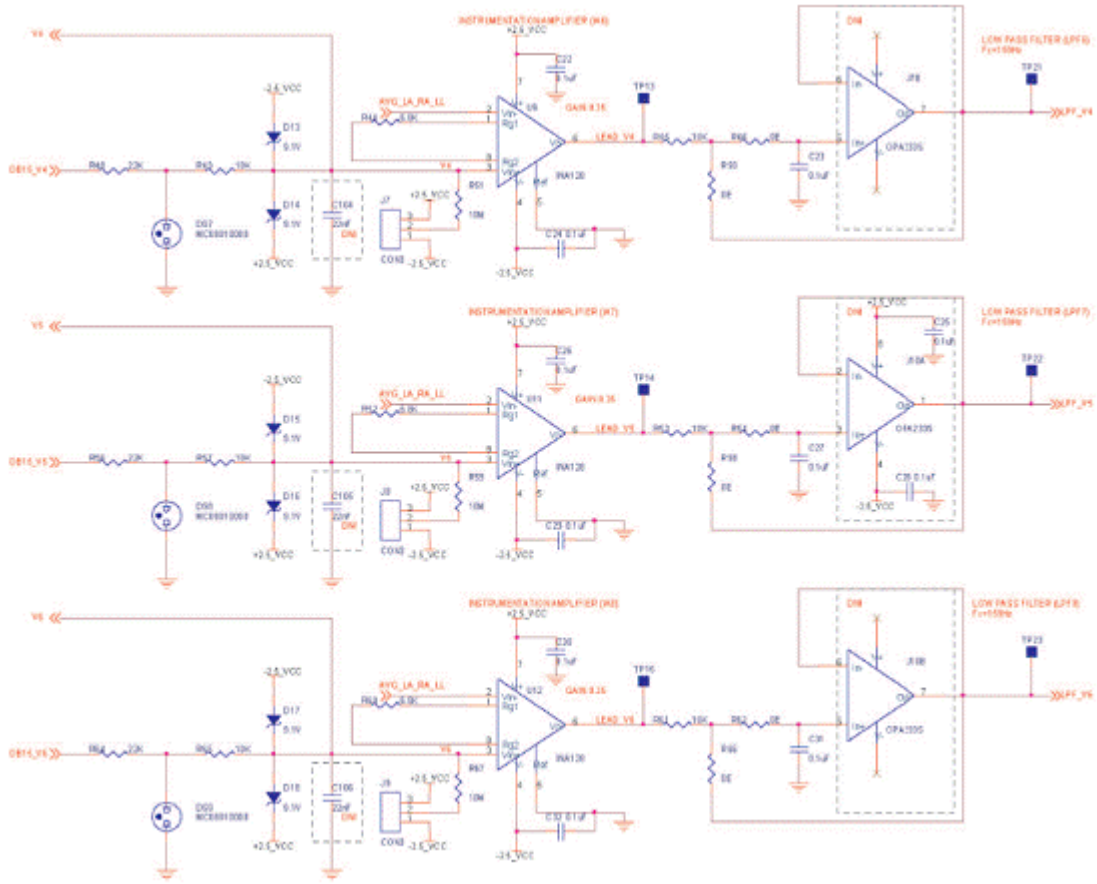

图 5. ECG 前端板电路图(3):ECG 电极:V4 V5 V6

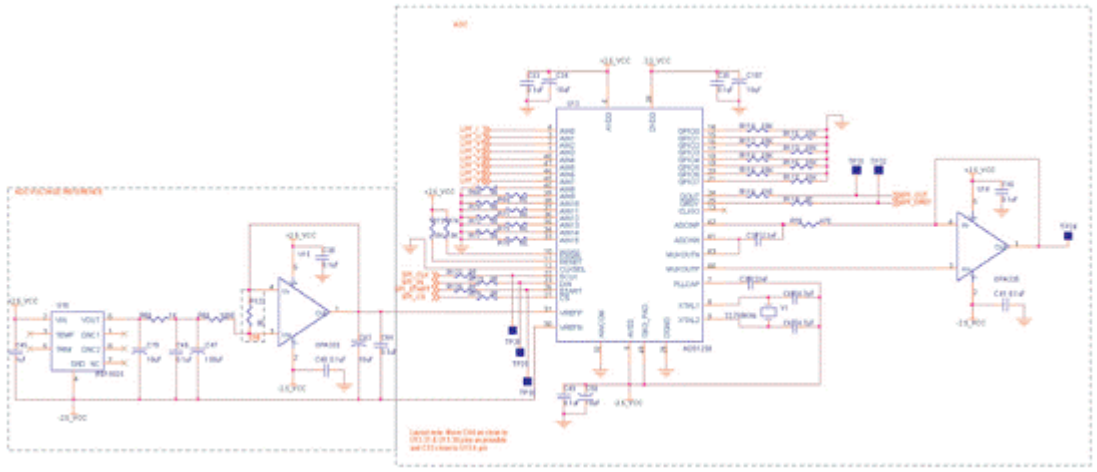

图 6. ECG 前端板电路图(4):ADC 部分

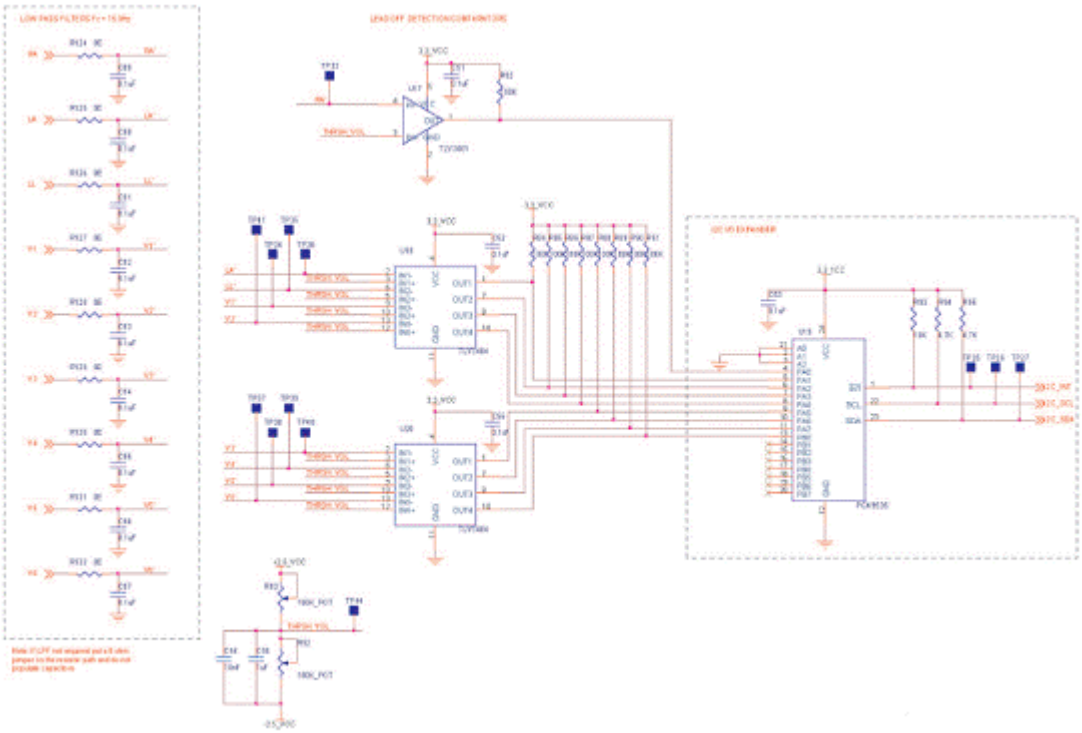

图 7. ECG 前端板电路图(5):ECG 电极检测

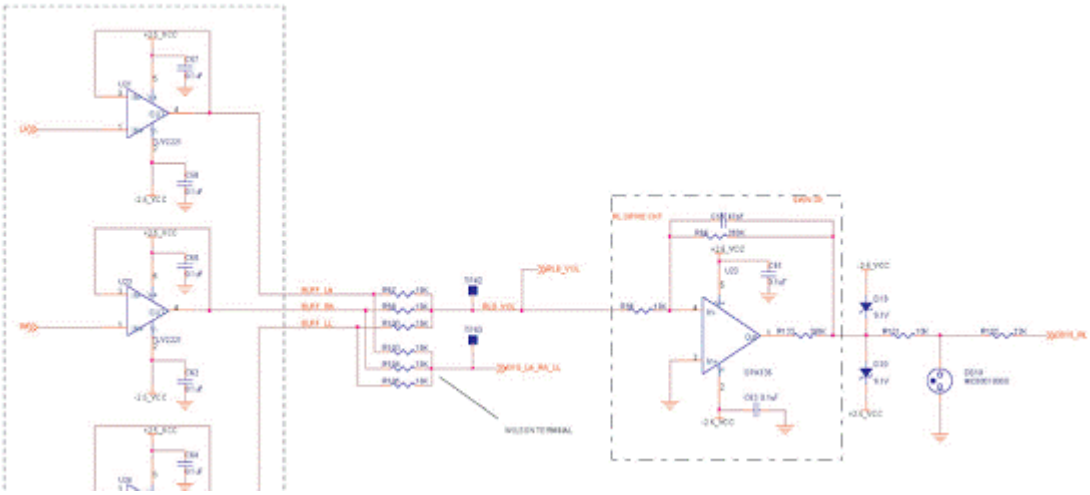

图 8. ECG 前端板电路图(6):右腿驱动部分

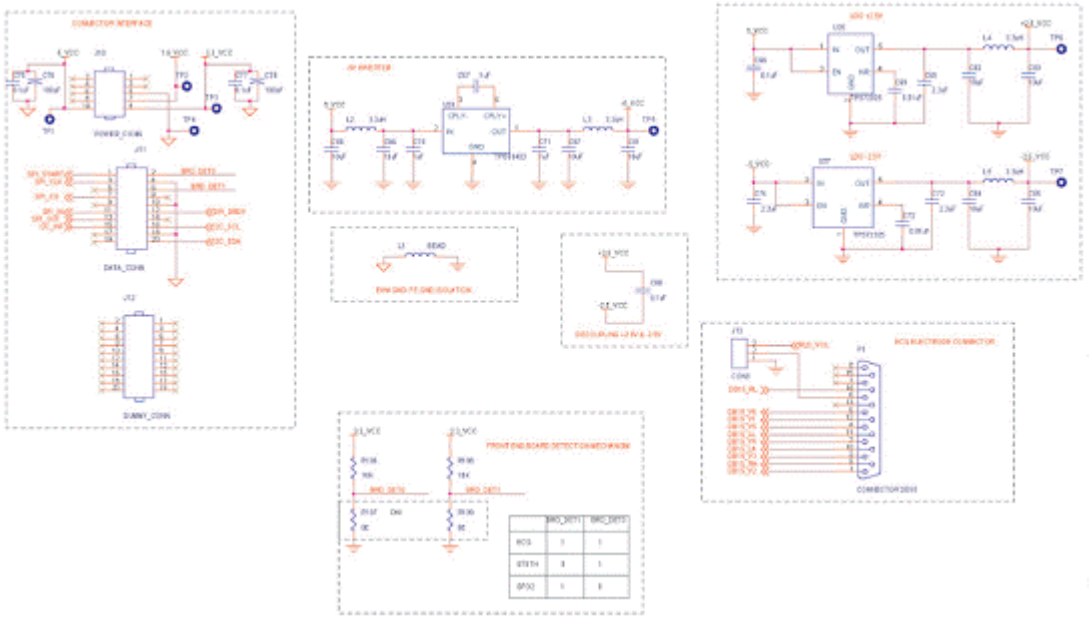

图 9. ECG 前端板电路图(7):电源和接口部分

ECG 前端板材料清单:

Item	Quantity	Value	Reference	Description	Part Number	Manufacturer	DNI
1	17	0.1 µF	C1,C4,C9,C12,C17, C20,C25,C28,C89, C90,C91,C92,C93, C94,C95,C96,C97	CAP CERM 0.10 µF 50 V 5% 0805 SMD	08055C104JAT2A	AVX Corporation	DNI
2	49	0.1 µF	C2,C3,C5,C6,C7, C8,C10,C11,C13, C14,C15,C16,C18, C19,C21,C22,C23, C24,C26,C35,C36, C38,C41,C44,C46, C27,C29,C30,C31, C32,C33, 48,C49, C51,C52,C53,C56, C64,C65,C66,C75, C77,C88 C57,C58, C60,C61,C62,C63	CAP CERM 0.10 µF 50 V 5% 0805 SMD	08055C104JAT2A	AVX Corporation	
3	5	10 µF	C34,C43,C50,C79, C107	CAP TANT LOESR 10 µF 16 V 10% SMD	TPSB106K016R0800	AVX Corporation	
4	1	2.2 nF	C37	CAP CERM 2200 pF 5% 50 V NPO 0805	08055A222JAT2A	AVX Corporation	
5	1	22 nF	C39	CAP CER 22000 pF 50 V X7R 0805	08055C223J4T2A	AVX Corporation	
6	2	4.7 nF	C40,C42	CAP CER 4.7 pF 50 V NPO 0805	08055A4R7BAT2A	AVX Corporation	
7	5	1 µF	C45,C55,C67,C70, C71	CAP CERM 1.0 µF 10% 25 V X7R 0805	08053C105KAZ2A	AVX Corporation	
8	3	100 µF	C47,C76,C78	CAP ELECT 100 µUF 16 V TK SMD	EEE-TK1C101P	Panasonic-ECG	
9	1	10 nF	C54	CAP CER 10000 pF 16 V NPO 0805	0805YA103JAT4A	AVX Corporation	
10	13	47 pF	C59	CAP CERM 47 pF 5% 50 V NPO 0805	08055A470JAT2A	AVX Corporation	
11	3	2.2 µF	C66,C72,C74	CAP CER 2.2 µUF 25 V X7R 0805	08053C225MAT2A	AVX Corporation	
12	2	0.01 µF	C69,C73	CAP CERM 0.01 10% 50 V X7R 0805	08055C103KAT2A	AVX Corporation	
13	8	10 µF	C80,C81,C82,C83,C84, C85, C86,C87	CAP CER 10 µF 16 V X5R 0805	EMK212BJ106KG-T	Taiyo Yuden	
14	9	22 nF	C98,C99,C100,C101,C102, C103,C104,C105,C106	CAP CER 22000 pF 50 V X7R 0805	08055C223J4T2A	AVX Corporation	
15	10	MC08010000	DS1,DS2,DS3,DS4,DS5, DS6, DS7,DS8,DS9,DS10	Neon lamp	MC08010000	Multicomp	
16	20	9.1 V	D1,D2,D3,D4,D5,D6,D7, D8, D9,D10,D11,D12,D13,D14, D15,D16,D17,D18,D19, D20	DIODE ZENER 1W 9.1 V SOD-106	PTZTE259.1B	ROHM	
17	10	CON3	J1,J2,J3,J4,J5,J6,J7, J8, J9,J13	CONN HEADER 3POS .100 VERT TIN	22-28-4030	Molex	
18	1	POWER_CONN	J10	Elevated Female Header 5x2	BB02-KD102-T03-100000	Gradconn	
19	1	DATA_CONN	J11	Elevated Female Header 10x2	BB02-KD202-T03-100000	Gradconn	

Item	Quantity	Value	Reference	Description	Part Number	Manufacturer	DNI
20	1	DUMMY_CONN	J12	Elevated Female Header 10x2	BB02-KD202-T03-100000	Gradconn	
21	1	BEAD	L1	FERRITE BEAD 470 Ω 0805	BK2125HM471-T	Taiyo Yuden	
22	4	3.3 µH	L2,L3,L4,L5	INDUCTOR POWER 3.3 µH 1.3A SMD	VLF4012AT-3R3M1R3	DK Corporation	
23	1	CONNECTOR DB15	P1	CONN D-SUB RCPT R/A 15POS PCB AU	745782-4	Tyco Electronics	
24	9	10M	R1,R9,R19,R27,R35,R43, R51,R59,R67	RES 10.0MΩ 1/8W 1% 0805 SMD	CRCW080510M0FKEA	Vishay	
25	10	22K	R2,R10,R16,R24,R32,R40,R48,R56,R64,R102	RES 22KΩ 1W 5% 2512 SMD	CRCW251222K0JNEG	Vishay	
26	10	10K	R3,R11,R17,R25, R33,R41, R49,R57,R65,R101	RES 10KΩ 1/2W 5% 2010 SMD	CRCW201010K0JNEF	Vishay	
27	8	6.8K	R4,R12,R20,R28,R36, R44, R52,R60	High Precision Chip Resistor 6.8KΩ	Y162406K8000T9R	Vishay	
28	15	10K	R5,R13,R21,R29,R37, R45,R53,R61,R97, R98, R99,R100, R103,R104,R105	High Precision Chip Resistor 10KΩ	Y162410K0000T9R	Vishay	
29	38	0E	R6,R8,R14,R16,R22, R26,R30,R34,R38, R42,R46,R50,R54, R58,R62,R66,R68, R69,R70,R71,R72, R75,R77,R78, R79, R119,R120,R121, R122,R124,R125, R126,R127,R128, R129,R130,R131, R132	RES 0.0 Ω 1/8W 5% 0805 SMD	CRCW08050000Z0EA	Vishay	
30	11	10K	R73,R74,R93,R110, R111,R112,R113, R114,R115,R116, R117	RES 10.0KΩ 1/8W 1% 0805 SMD	CRCW080510K0FKEA	Vishay	
31	1	47E	R76	High Precision Chip Resistor 47 Ω	Y162447R0000T9R	Vishay	
32	1	1K	R80	RES 1.00KΩ 1/8 W 1% 0805 SMD	CRCW08051K00FKEA	Vishay	
33	1	100E	R81	High Precision Chip Resistor 100 µ	Y1624100R000T9R	Vishay	
34	9	100K	R82,R84,R85,R86, R87,R88,R89,R90, R91	RES 100KΩ 1/8W 1% 0805 SMD	CRCW0805100KFKEA	Vishay	
35	2	100K_POT	R83,R92	POT 100KΩ 4MM SQ CERMET SMD	3314G-1-104E	Bourns Inc	
36	2	4.7K	R95,R94	RES 4.70KΩ 1/8W 1% 0805 SMD	CRCW08054K70FKEA	Vishay	
37	2	390K	R96,R133	High Precision Chip Resistor 390KΩ	TNPW0805390KBYTA	Vishay	
38	2	10K	R108,R106	RES 10.0KΩ 1/8W 1% 0805 SMD	CRCW080510K0FKEA	Vishay	DNI
39	3	0E	R107,R109,R123	RES 0.0 Ω 1/8W 5% 0805 SMD	CRCW08050000Z0EA	Vishay	DNI
40	1	51E	R118	RES 51 Ω 1/8W 5% 0805 SMD	CRCW080551R0JNEA	Vishay	
41	4	OPA2335	U1,U4,U7,U10	IC OP AMP CMOS SGL SPLY 8-MSOP	OPA2335AIDGKT	TI	DNI
42	8	INA128	U2,U3,U5,U6,U8,U9,U11, U12	IC LOW PWR INSTR AMP 8-SOIC	INA128UA	TI	
43	1	ADS1258	U13	IC ADC 24 BIT 125 ksps 48-QFN	ADS1258IRTCT	TI	
44	3	OPA335	U14,U15,U23	IC OP AMP CMOS SGL SPLY SOT-23-5	OPA335AIDBVT	TI	
45	1	REF5025	U16	IC PREC V-REF 2.5 V LN 8-SOIC	REF5025AID	TI	

Item	Quantity	Value	Reference	Description	Part Number	Manufacturer	DNI
46	1	TLV3401	U17	IC OUT COMPARATOR NANOPWR SOT23-5	TLV3401IDBVR	TI	
47	2	TLV3404	U18,U20	COMPARATOR LW POWER R-R 14-SOIC	TLV3404IDR	TI	
48	1	PCA9535	U19	IC REMOTE 16-BIT I/O EXP 24-TSSOP	PCA9535PWR	TI	
49	3	TLV2221	U21,U22,U24	IC RAIL-TO-RAIL OP AMP SOT-23-5	TLV2221CDBVR	TI	
50	1	TPS73025	U25	IC LDO REG HI-PSRR 2.5 V SOT23-5	TPS73025DBV	TI	
51	1	TPS60403	U26	IC UNREG CHRG PUMP V INV SOT23-5	TPS60403DBVT	TI	
52	1	TPS72325	U27	IC LDO REG 200MA 2.5 V SOT23-5	TPS72325DBVT	TI	
53	1	32.768KHz	Y1	CRYSTAL 32.7680 KHz 12.5 pF CYL	C-001R 32.7680K-A:PBFREE	Epson Toyocom Corporation	