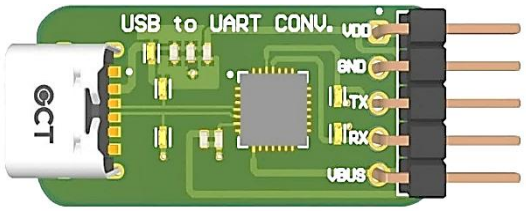
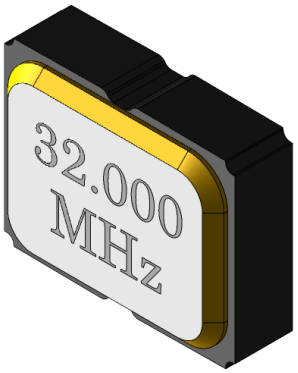
Hardware Engineer's Guide

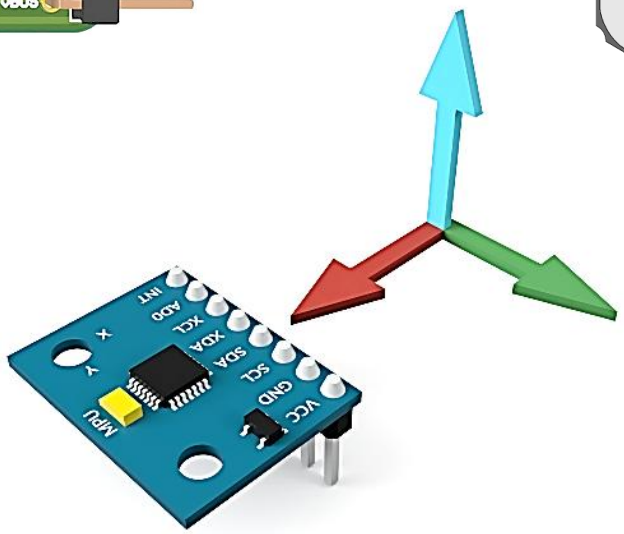
20

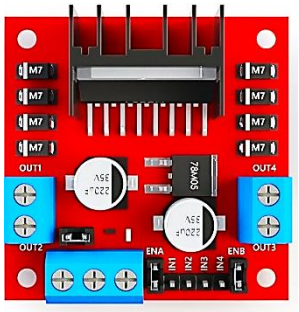
ACTIVE ICs

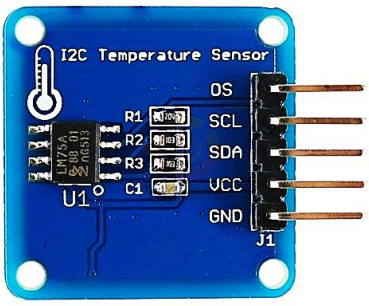
You should know











By Shimi Cohen

Popular Active Components

1. **Level Shifter**
2. **USB-to-UART Bridge**
3. **Reset Circuit**
4. **LED Driver**
5. **Motor Driver**
6. **Half-Bridge Driver**
7. **Load Switch**
8. **IMU (Inertial Measurement Unit)**
9. **Temperature Sensor**
10. **Current Sense Amplifier**
11. **Analog-to-Digital Converter (ADC)**
12. **Crystal Oscillator**
13. **Comparator**
14. **Analog Switch/Multiplexer**
15. **RS-485 Transceiver**
16. **EEPROM**
17. **I2C Expander**
18. **Pulse-Width Modulation (PWM) Controller**
19. **Digital Potentiometer**
20. **MIPI Retimer**

1.Level Shifter

Level shifters enable communication between circuits operating at different voltage levels. They translate digital signals from one voltage domain to another while maintaining signal integrity and timing characteristics.

KEY FUNCTIONS

Level shifters perform voltage translation for digital signals. They ensure proper logic levels when interfacing between different voltage domains. These components maintain signal timing and reduce power consumption in mixed-voltage systems.

TECHNICAL SPECIFICATIONS

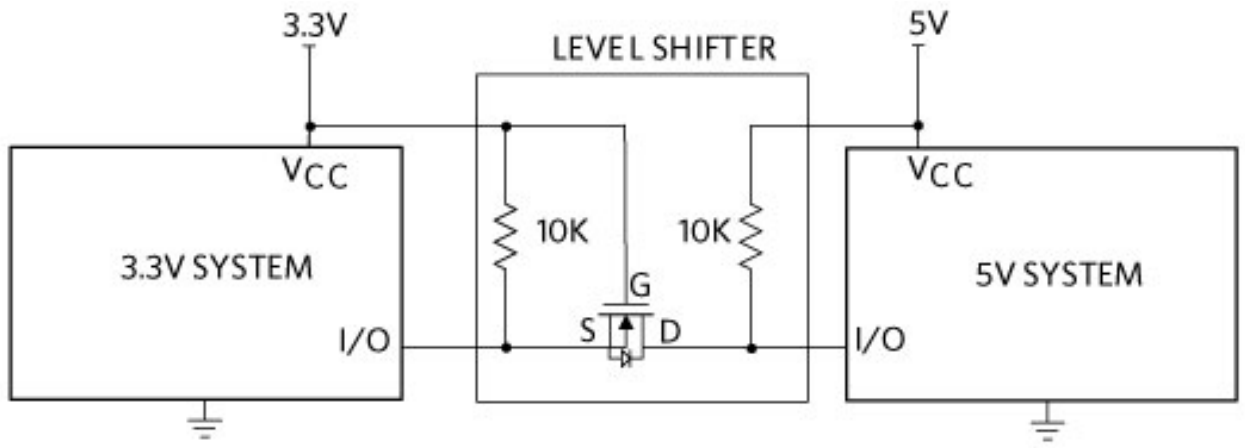
Operating voltage ranges typically span 1.2V to 5.5V. Propagation delay varies from 1ns to 50ns depending on implementation. Output drive strength ranges from 2mA to 50mA per channel.

MARKET SOLUTIONS

Part Number	Manufacturer	Channels	Voltage Range	Propagation Delay	Package
TXS0108E	TI	8	1.2V-3.6V	1.5ns	TSSOP-20
74LVC8T245	Nexperia	8	1.2V-5.5V	3.2ns	TSSOP-24
LSF0204	TI	4	1.2V-3.6V	2.5ns	QFN-12
SN74AVC4T774	TI	4	1.2V-3.6V	2.1ns	TSSOP-14
74ALVC164245	Nexperia	16	1.2V-3.6V	2.8ns	TSSOP-48

APPLICATIONS

- MCU (3.3V) communicating with 1.8V sensor via I2C
- Bridging 5V legacy logic to 3.3V FPGA inputs
- External Interrput via Opoticoupler (5V) to MCU input (3.3V)



2.USB-to-UART Bridge

USB-to-UART bridges convert USB protocols to serial UART communication. They eliminate the need for USB stacks in microcontroller firmware and provide simple serial interfaces for development and production systems.

KEY FUNCTIONS

These components handle USB enumeration automatically. They provide virtual COM port functionality on host systems. UART configuration occurs through USB control transfers or external pins.

TECHNICAL SPECIFICATIONS

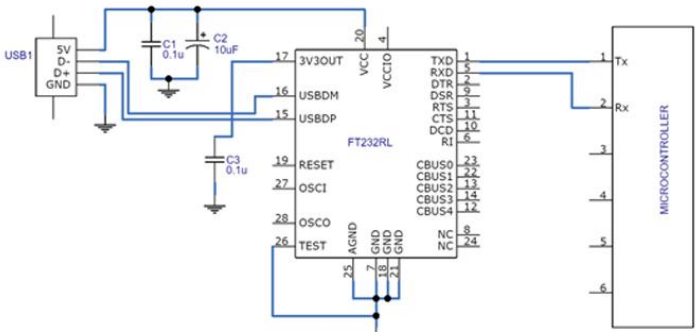
USB compliance includes USB 2.0 Full Speed (12Mbps) operation. UART baud rates support up to 3Mbaud typically. Power consumption ranges from 8mA to 50mA during operation.

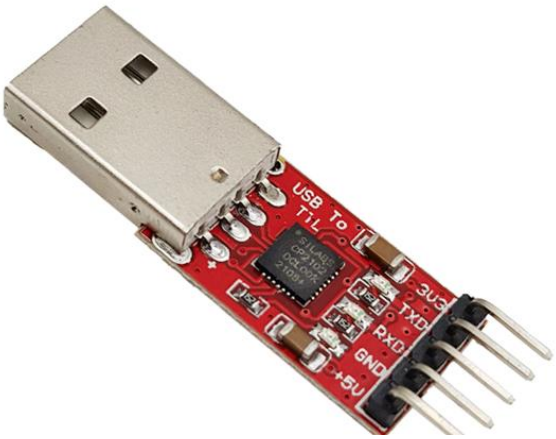
MARKET SOLUTIONS

Part Number	Manufacturer	Max Baud Rate	USB Standard	GPIO Pins	Package
FT232RL	FTDI	3Mbaud	USB 2.0	4	SSOP-28
CP2102N	Silicon Labs	3Mbaud	USB 2.0	8	QFN-28
CH340G	WCH	2Mbaud	USB 2.0	0	SOP-16
FT230XS	FTDI	3Mbaud	USB 2.0	4	SSOP-16
CP2104	Silicon Labs	2Mbaud	USB 2.0	12	QFN-24

APPLICATIONS

- USB-UART "Dongle"
- Multiple UART Comm merged in to one USB on-board hub to PC
- Firmware updates/debug via serial terminal





3.Reset Circuit

Reset circuits ensure reliable system startup and recovery from fault conditions. They monitor supply voltages and generate reset signals when voltages fall below specified thresholds or during power transitions.

KEY FUNCTIONS

Voltage monitoring provides brownout protection. Power-on reset ensures proper startup sequences. Watchdog functionality enables automatic recovery from software failures. Manual reset inputs allow external control.

TECHNICAL SPECIFICATIONS

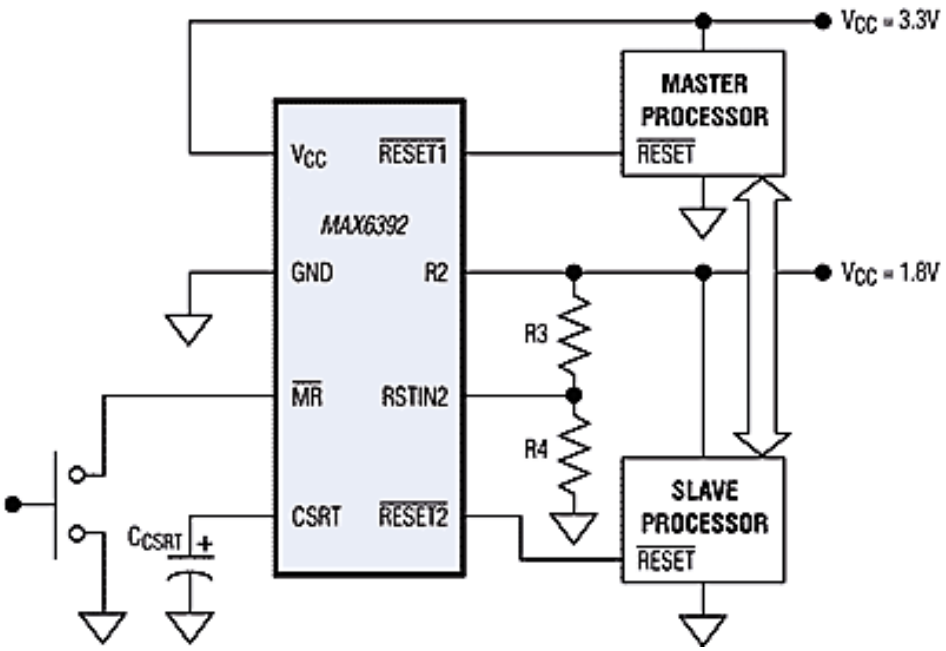
Reset threshold voltages range from 1.0V to 5.0V with ±2% accuracy. Reset timeout periods vary from 1ms to 10s. Quiescent current consumption stays below 10µA typically.

MARKET SOLUTIONS

Part Number	Manufacturer	Threshold Voltage	Reset Timeout	Watchdog	Package
MAX809	Maxim	2.93V	200ms	No	SOT-23-3
TPS3809	TI	2.93V	400ms	No	SOT-23-3
ADM809	Analog	2.93V	200ms	No	SOT-23-3
MAX6369	Maxim	1.8V-5.0V	140ms-1.6s	Yes	SOT-23-6
TPS3430	TI	1.8V-5.5V	Programmable	Yes	SOT-23-6

APPLICATIONS

- System power-on reset for MCUs
- Brown-out reset detection in embedded systems
- Manual reset button debounce and timing



4.LED Driver

LED drivers provide constant current regulation for LED loads. They ensure consistent brightness, extend LED lifetime, and protect against overcurrent conditions while maintaining high efficiency.

KEY FUNCTIONS

Constant current regulation maintains LED brightness consistency. Dimming control enables brightness adjustment through PWM or analog signals. Thermal protection prevents overheating damage. Multiple channel support drives LED arrays.

TECHNICAL SPECIFICATIONS

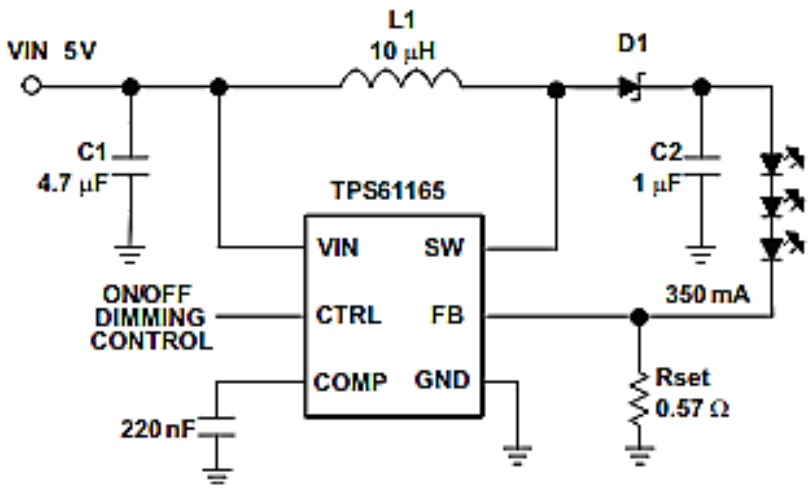
Output current ranges from 10mA to 3A per channel. Input voltage spans 3V to 60V depending on topology. Efficiency typically exceeds 90% in switching implementations. Dimming resolution reaches 12-16 bits in advanced controllers.

MARKET SOLUTIONS

Part Number	Manufacturer	Channels	Output Current	Input Voltage	Efficiency
LM3414	TI	1	1A	6V-42V	94%
AL8805	Diodes Inc	1	1.5A	6V-60V	95%
TLC5940	TI	16	120mA	3V-17V	85%
MAX16832	Maxim	1	2A	4.5V-28V	93%
LT3756	Linear Tech	1	3A	6V-42V	94%

APPLICATIONS

- Driving high-current RGB LEDs
- Backlighting in LCD displays
- Automotive indicator lights



5.Motor Driver

Motor drivers control DC motors, stepper motors, and brushless DC motors. They provide bidirectional current control, speed regulation, and protection features while interfacing between low-power control signals and high-power motor loads.

KEY FUNCTIONS

H-bridge configuration enables bidirectional motor control. Current limiting protects motors and drivers from overcurrent. Speed control utilizes PWM techniques for efficiency. Fault detection includes overcurrent, overtemperature, and undervoltage protection.

TECHNICAL SPECIFICATIONS

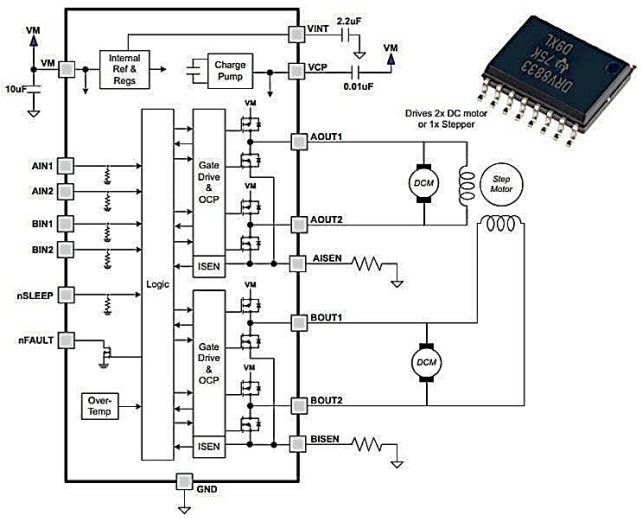
Output current capabilities range from 100mA to 50A. Operating voltages span 1.8V to 100V. PWM frequencies reach up to 1MHz. Thermal resistance values determine power dissipation limits.

MARKET SOLUTIONS

Part Number	Manufacturer	Channels	Max Current	Max Voltage	PWM Frequency
DRV8833	TI	2	1.2A	10.8V	250kHz
L293D	STMicroelectronics	2	600mA	36V	5kHz
A4988	Allegro	1 (Stepper)	2A	35V	Variable
TB6612FNG	Toshiba	2	1.2A	15V	100kHz
DRV8825	TI	1 (Stepper)	2.2A	45V	Variable

APPLICATIONS

- Driving DC brushed motors in robotics
- Controlling stepper motors in 3D printers
- Actuating BLDC motors in drones



6.Half-Bridge Driver

Half-bridge drivers control high-side and low-side power switches in applications like motor drives, DC-DC converters, and inverters. They provide isolated gate drive signals with precise timing control and protection features.

KEY FUNCTIONS

Gate drive capability charges and discharges MOSFET gates rapidly. Dead-time control prevents shoot-through currents. Level shifting enables high-side switch control. Fault protection includes desaturation detection and thermal shutdown.

TECHNICAL SPECIFICATIONS

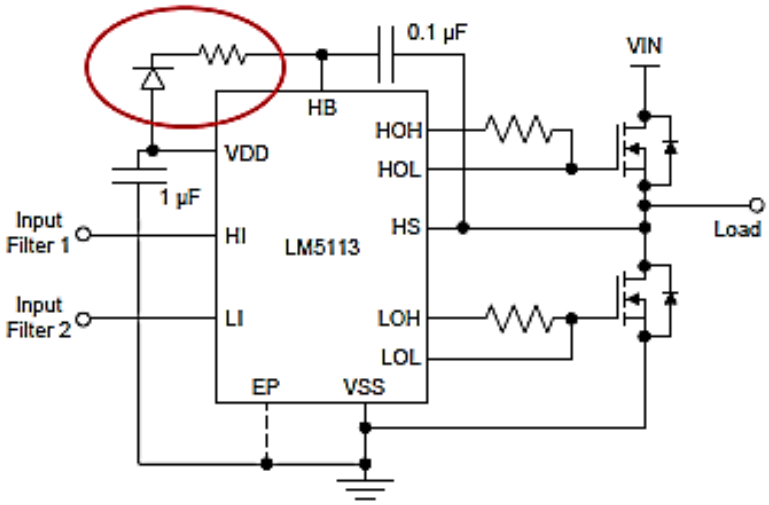
Gate drive current ranges from 100mA to 4A peak. Operating frequency extends up to 1MHz. Dead-time adjustment spans 10ns to 1µs. Isolation voltage ratings reach 5kV in isolated versions.

MARKET SOLUTIONS

Part Number	Manufacturer	Peak Current	Max Frequency	Dead Time	Isolation
IR2110	Infineon	2A	500kHz	External	No
UCC27211A	TI	4A	1MHz	15ns	No
ACPL-332J	Broadcom	2.5A	1MHz	Variable	5kV
LM5113	TI	1.2A	5MHz	4ns	No
Si8271	Skyworks	4A	1MHz	10ns	5kV

APPLICATIONS

- Power stage driver for DC-DC converters
- Driving MOSFETs in motor control inverters
- Class D audio amplifier output stage



7.Load Switch

Load switches provide controlled power distribution with protection features. They act as intelligent power switches with current limiting, thermal shutdown, and soft-start capabilities to protect downstream circuits.

KEY FUNCTIONS

Power switching enables controlled connection of loads. Current limiting prevents damage from overcurrent conditions. Soft-start reduces inrush current during turn-on. Fault reporting provides system status information.

TECHNICAL SPECIFICATIONS

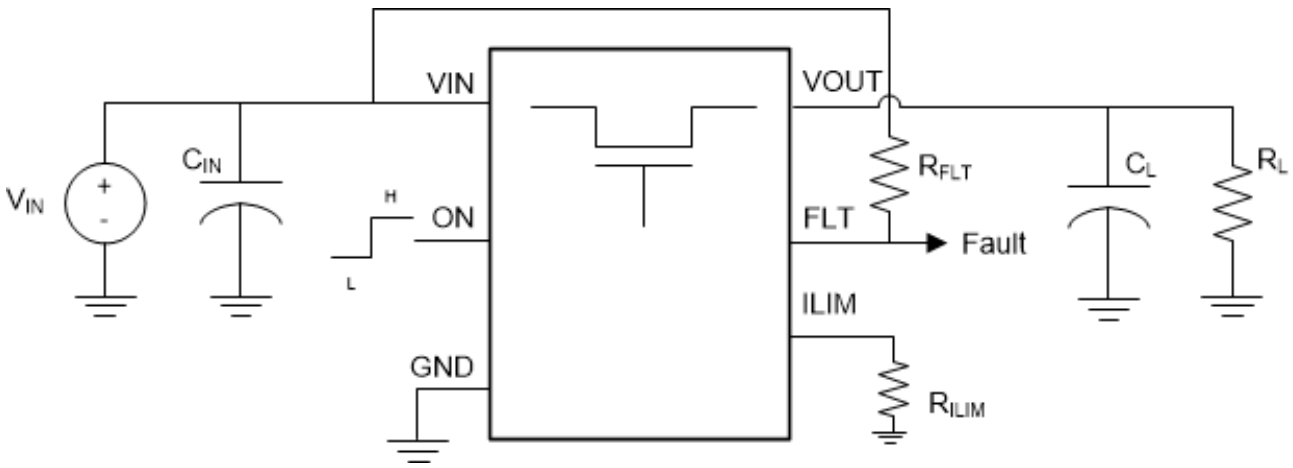
Current handling ranges from 100mA to 10A. On-resistance values span 10mΩ to 1Ω. Rise time control varies from 100µs to 10ms. Operating temperature extends from -40°C to +125°C.

MARKET SOLUTIONS

Part Number	Manufacturer	Max Current	On-Resistance	Rise Time	Package
TPS22918	TI	5.5A	22mΩ	150µs	SON-8
FPF2895C	ON Semi	5A	28mΩ	1ms	WLCSP-9
MAX4821	Maxim	1.2A	85mΩ	300µs	SOT-23-6
SIP32431	Vishay	6A	18mΩ	2ms	PowerPAK-8
NCP45521	ON Semi	3A	45mΩ	500µs	WLCSP-6

APPLICATIONS

- Power gating of peripheral sections on a PCB
- Battery power switching in portable devices
- Enabling/disabling charging or load sections



8.IMU (Inertial Measurement Unit)

IMUs combine accelerometers, gyroscopes, and magnetometers in single packages. They provide motion sensing capabilities for applications including navigation, stabilization, and orientation detection.

KEY FUNCTIONS

Acceleration measurement detects linear motion and gravity. Angular velocity sensing measures rotation rates. Magnetic field detection provides compass functionality. Digital filtering reduces noise and improves accuracy.

TECHNICAL SPECIFICATIONS

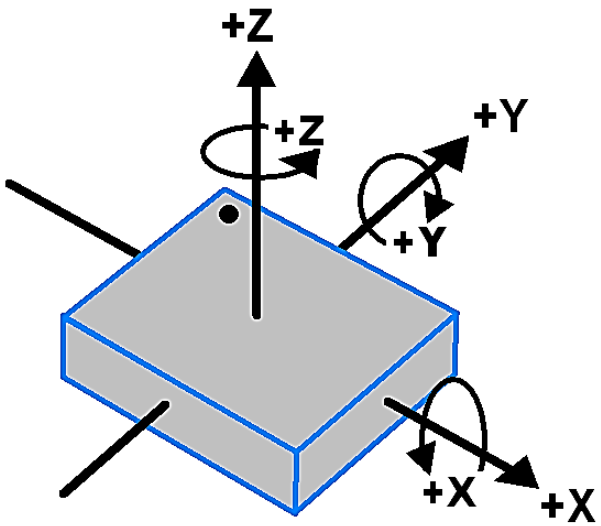
Accelerometer ranges span ±2g to ±16g with 16-bit resolution. Gyroscope ranges extend from ±250°/s to ±2000°/s. Magnetometer sensitivity reaches 0.6µT/LSB. Output data rates vary from 1Hz to 8kHz.

MARKET SOLUTIONS

Part Number	Manufacturer	Accel Range	Gyro Range	Magnetometer	Interface
MPU-9250	TDK	±16g	±2000°/s	Yes	I2C/SPI
LSM9DS1	STMicroelectronics	±16g	±2000°/s	Yes	I2C/SPI
BMI160	Bosch	±16g	±2000°/s	No	I2C/SPI
ICM-20948	TDK	±16g	±2000°/s	Yes	I2C/SPI
LSM6DS3	STMicroelectronics	±16g	±2000°/s	No	I2C/SPI

APPLICATIONS

- Detecting motion/orientation in smartphones
- Stabilization control in drones or cameras (Gimbal)
- Fitness trackers measuring steps and activity



9.Temperature Sensor

Temperature sensors monitor thermal conditions in electronic systems. They provide accurate temperature measurements for thermal management, calibration, and protection functions with various output formats.

KEY FUNCTIONS

Temperature measurement provides thermal monitoring capabilities. Digital output eliminates ADC requirements. Programmable limits enable automatic thermal protection. Multiple sensor support allows zone monitoring.

TECHNICAL SPECIFICATIONS

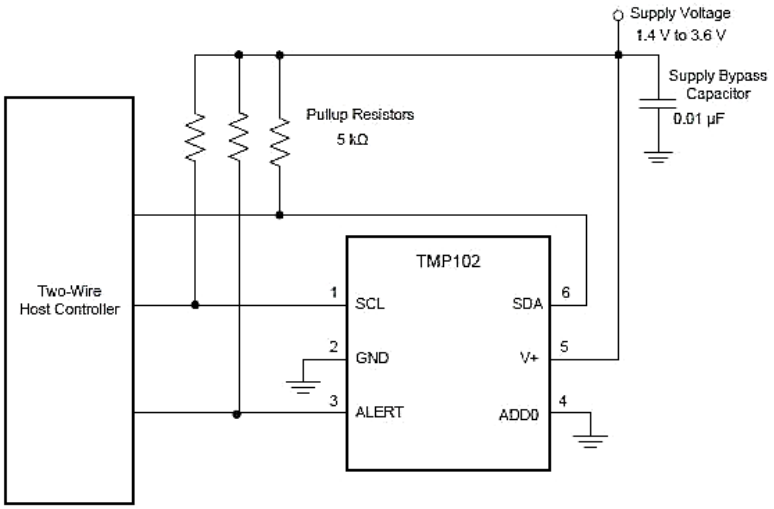
Measurement ranges typically span -55°C to +150°C. Accuracy varies from ±0.5°C to ±3°C depending on implementation. Resolution reaches 0.0625°C in high-precision devices. Response time ranges from 100ms to 10s.

MARKET SOLUTIONS

Part Number	Manufacturer	Range	Accuracy	Resolution	Interface
LM75A	NXP	-55°C to +125°C	±2°C	0.125°C	I2C
DS18B20	Maxim	-55°C to +125°C	±0.5°C	0.0625°C	1-Wire
TMP102	TI	-55°C to +150°C	±3°C	0.0625°C	I2C
ADT7420	Analog	-40°C to +150°C	±0.25°C	0.0078°C	I2C
MCP9808	Microchip	-40°C to +125°C	±0.5°C	0.0625°C	I2C

APPLICATIONS

- Thermal management in computing systems
- HVAC system temperature monitoring
- Battery pack thermal protection



10.Current Sense Amplifier

Current sense amplifiers measure current by amplifying small voltage drops across sense resistors. They provide high-accuracy current monitoring with minimal power loss and excellent common-mode rejection.

KEY FUNCTIONS

Differential amplification measures voltage across sense resistors. Common-mode rejection eliminates ground potential differences. High-side sensing enables load monitoring. Low offset voltage ensures measurement accuracy.

TECHNICAL SPECIFICATIONS

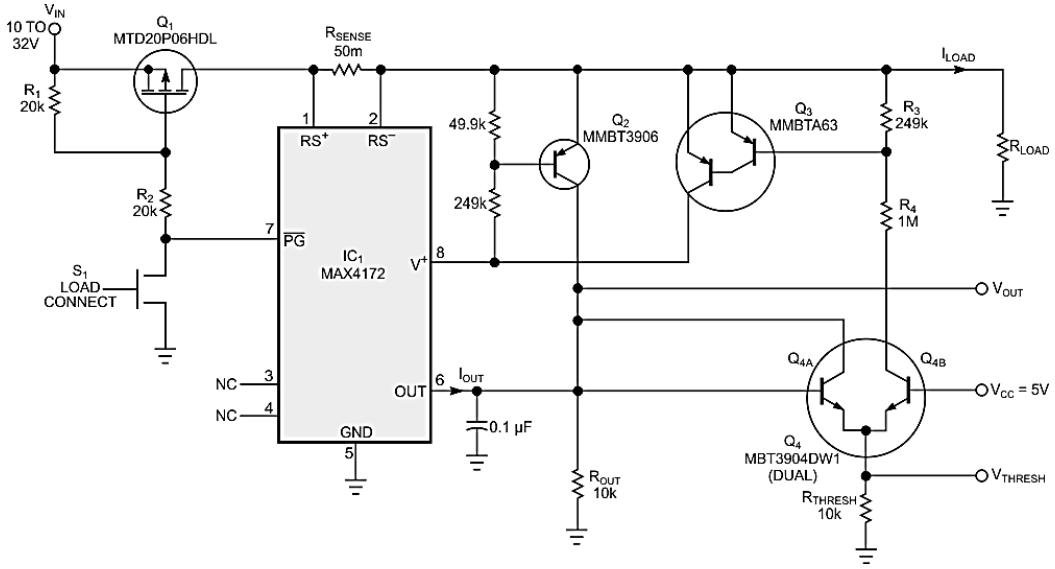
Input offset voltage stays below 100µV typically. Common-mode voltage ranges from -0.3V to +80V. Bandwidth extends from DC to 1MHz. Gain options include fixed ratios from 20V/V to 200V/V.

MARKET SOLUTIONS

Part Number	Manufacturer	Gain	Bandwidth	Offset Voltage	Max Common-Mode
INA219	TI	Programmable	1MHz	40µV	26V
MAX4172	Maxim	20V/V	500kHz	50µV	28V
LTC6102	Linear Tech	External	1MHz	250µV	60V
INA180	TI	20-200V/V	350kHz	25µV	26V
AD8210	Analog	20V/V	500kHz	100µV	65V

APPLICATIONS

- Battery charge/discharge current monitoring
- Over-current protection in power supplies
- Motor phase current sensing



11.Analog-Digital Converter (ADC)

ADCs convert analog signals to digital values for processing by digital systems. They provide the interface between analog sensors and digital controllers with various architectures optimized for different applications.

KEY FUNCTIONS

Analog-to-digital conversion enables signal processing in digital domain. Sample and hold circuits capture instantaneous signal values. Digital filtering improves signal quality. Multiple channel support reduces system complexity.

TECHNICAL SPECIFICATIONS

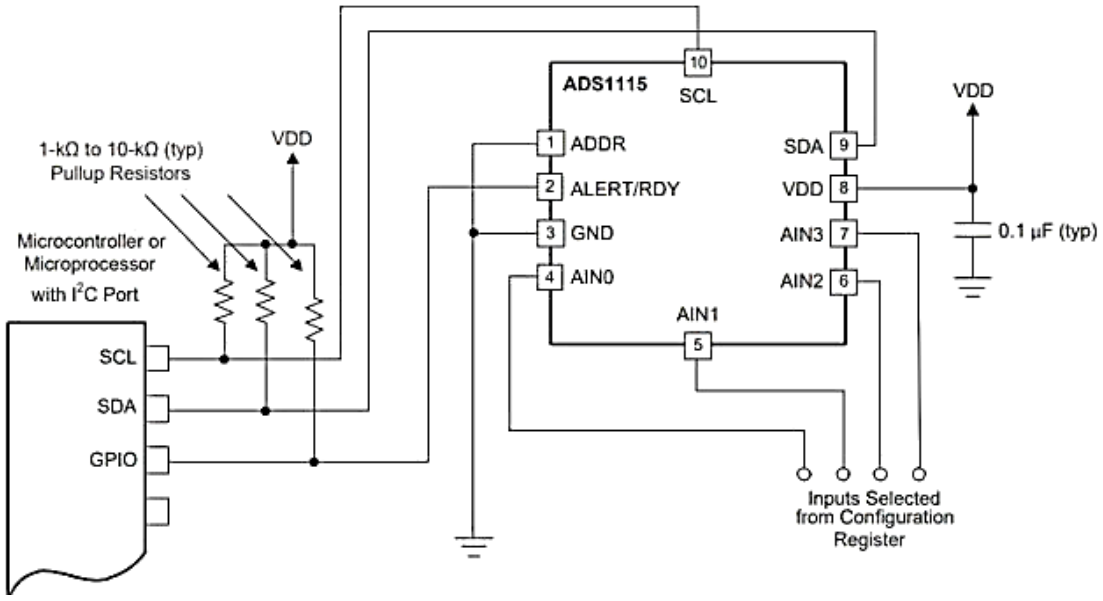
Resolution ranges from 8 bits to 32 bits depending on architecture. Sample rates extend from 1SPS to 1GSPS. Input voltage ranges typically span single-supply or bipolar operation. Power consumption varies from microamps to watts.

MARKET SOLUTIONS

Part Number	Manufacturer	Resolution	Sample Rate	Channels	Interface
ADS1115	TI	16-bit	860SPS	4	I2C
MCP3008	Microchip	10-bit	200kSPS	8	SPI
AD7606	Analog	16-bit	200kSPS	8	Parallel
LTC2348-16	Linear Tech	16-bit	200kSPS	8	SPI
MAX11644	Maxim	12-bit	300kSPS	2	I2C

APPLICATIONS

- Sensor signal digitization in embedded systems
- Audio signal conversion to digital domain
- Current Sensing via Shunt and instrumentation OPAMP



12.Crystal Oscillator

Crystal oscillators generate precise frequency references for digital systems. They provide stable clock signals with low jitter and excellent frequency accuracy over temperature and time variations.

KEY FUNCTIONS

Frequency generation provides system clock references. Low jitter ensures proper digital system timing. Temperature stability maintains frequency accuracy. Multiple output formats support different logic families.

TECHNICAL SPECIFICATIONS

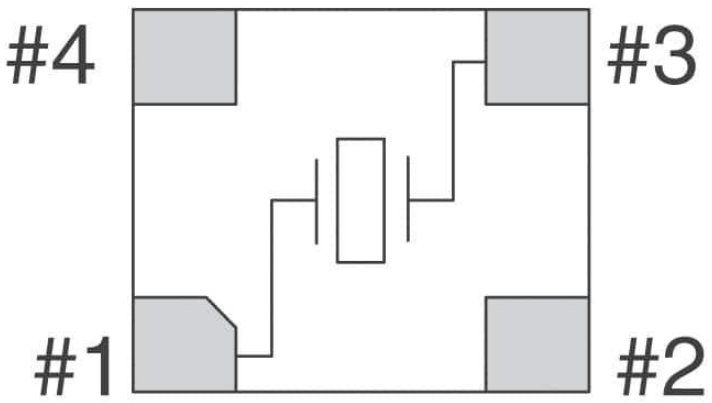
Frequency ranges span 32.768kHz to 200MHz typically. Frequency stability varies from ±10ppm to ±100ppm over temperature. Jitter performance reaches sub-picosecond levels. Output formats include CMOS, LVDS, and differential pairs.

MARKET SOLUTIONS

Part Number	Manufacturer	Frequency	Stability	Output Type	Package
SiT9102	SiTi me	1MHz-110MHz	±20ppm	CMOS	2.0x1.6mm
DSC1001	Microchip	1MHz-200MHz	±50ppm	CMOS	2.5x2.0mm
NX3225GA	NDK	1MHz-50MHz	±10ppm	CMOS	3.2x2.5mm
SiT8008B	SiTime	1MHz-110MHz	±25ppm	CMOS	2.0x1.6mm
KC3225A	Kyocera	8MHz-60MHz	±30ppm	CMOS	3.2x2.5mm

APPLICATIONS

- MCU or digital IC clock generation
- Timing reference in communication systems
- Real-time clock (RTC) frequency reference



13.Comparator

Comparators determine relative magnitudes between two analog input signals. They provide digital outputs indicating which input voltage is higher, enabling threshold detection and analog signal processing functions.

KEY FUNCTIONS

Voltage comparison generates digital output based on input relationships. Hysteresis prevents output oscillation near threshold. High-speed operation enables rapid signal detection. Open-drain outputs allow wired-OR configurations.

TECHNICAL SPECIFICATIONS

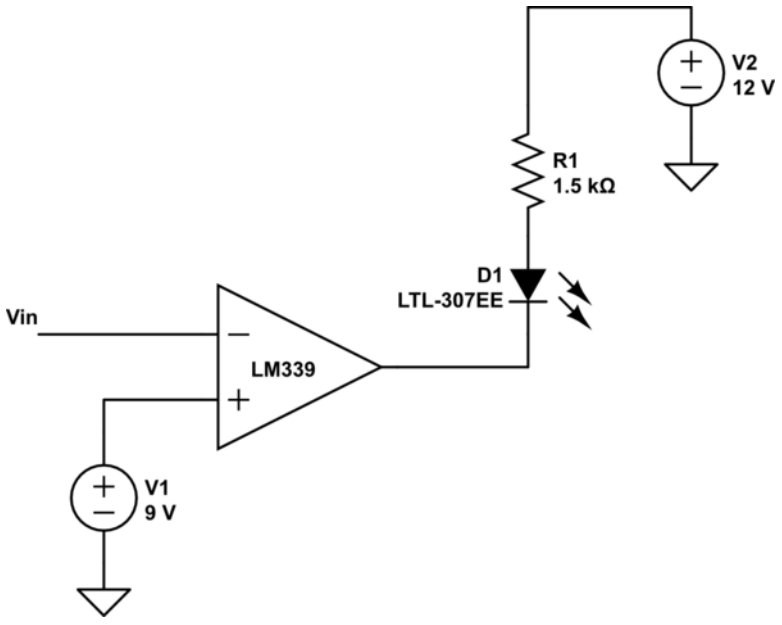
Propagation delay ranges from nanoseconds to microseconds. Input offset voltage typically stays below 5mV. Supply voltage spans single or dual supply operation. Common-mode range determines input voltage limits.

MARKET SOLUTIONS

Part Number	Manufacturer	Channels	Propagation Delay	Offset Voltage	Supply Voltage
LM339	TI	4	300ns	2mV	2V-36V
TLV3501	TI	1	4.5ns	2mV	2.7V-5.5V
MAX9117	Maxim	1	4ns	1mV	2.7V-5.5V
LT1016	Linear Tech	1	10ns	2mV	±5V-±15V
ADCMP562	Analog	1	2.9ns	4mV	2.7V-5.5V

APPLICATIONS

- Zero-cross detection in AC power circuits
- Threshold voltage detection for alarms
- Pulse width modulation generation (sine-in Pulse-out)



14.Analog Switch/Multiplexer

Analog switches and multiplexers route analog signals between multiple paths. They enable signal routing, channel selection, and analog signal processing with minimal signal distortion and low power consumption.

KEY FUNCTIONS

Signal routing connects inputs to outputs based on digital control. Low on-resistance minimizes signal attenuation. Break-before-make switching prevents signal shorting. Charge injection compensation maintains signal integrity.

TECHNICAL SPECIFICATIONS

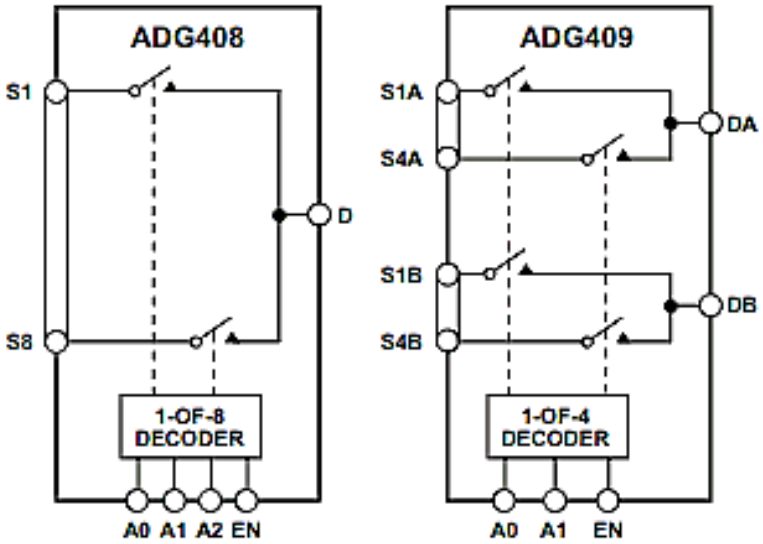
On-resistance values range from 1Ω to 1000Ω depending on technology. Off-leakage current stays below 1nA typically. Bandwidth extends from DC to 1GHz in high-frequency devices. Channel-to-channel isolation exceeds 80dB.

MARKET SOLUTIONS

Part Number	Manufacturer	Channels	On-Resistance	Bandwidth	Supply Voltage
ADG408	Analog	8:1 MUX	25Ω	50MHz	±15V
MAX4617	Maxim	SPDT	5Ω	200MHz	1.8V-5.5V
CD4051B	TI	8:1 MUX	120Ω	10MHz	3V-20V
TS5A3159	TI	SPDT	5Ω	300MHz	1.65V-5.5V
ADG1414	Analog	4xSPST	2Ω	350MHz	1.8V-5.5V

APPLICATIONS

- Routing multiple sensor inputs to a single ADC
- Signal switching in audio/video equipment
- Circuit testing and diagnostics setups



15.RS-485 Transceiver

RS-485 transceivers enable differential serial communication over long distances. They provide noise immunity, multi-drop capability, and bidirectional data transmission for industrial and automotive applications.

KEY FUNCTIONS

Differential signaling provides noise immunity and common-mode rejection. Half-duplex operation enables bidirectional communication on two-wire systems. Bus protection includes ESD and overvoltage protection. Fail-safe operation maintains known states during fault conditions.

TECHNICAL SPECIFICATIONS

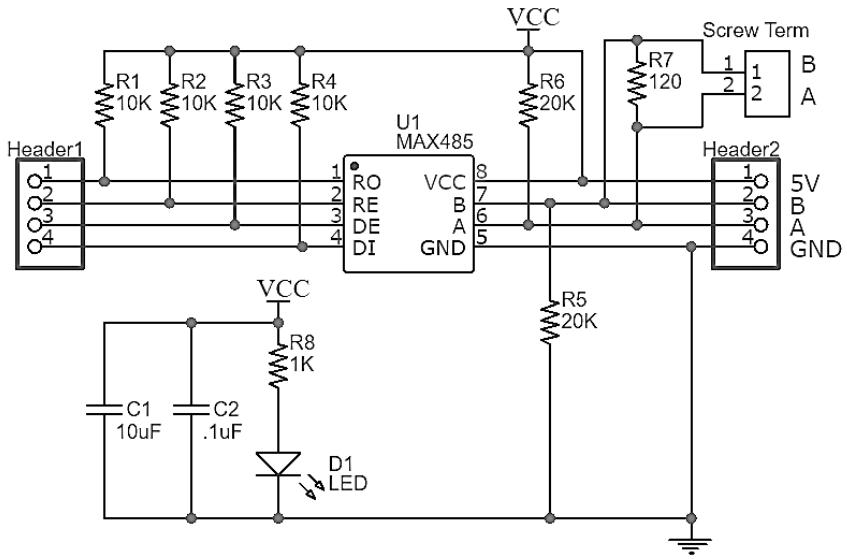
Data rates reach up to 50Mbps depending on distance. Bus loading supports up to 256 nodes typically. Common-mode range spans -7V to +12V. ESD protection exceeds ±15kV Human Body Model.

MARKET SOLUTIONS

Part Number	Manufacturer	Data Rate	Bus Nodes	Protection	Package
MAX485	Maxim	2.5Mbps	32	Basic	DIP-8
SN75176B	TI	10Mbps	32	Enhanced	DIP-8
ADM2587E	Analog	16Mbps	256	±15kV ESD	SOIC-8
MAX13487E	Maxim	16Mbps	256	±15kV ESD	SOIC-8
LTC2855	Linear Tech	20Mbps	256	±60V Fault	MSOP-8

APPLICATIONS

- Industrial fieldbus communication
- Building automation control networks
- Long-distance serial communication over twisted pair



16.EEPROM

EEPROMs provide non-volatile memory storage for configuration data, calibration values, and small data sets. They offer electrically erasable and reprogrammable storage with long data retention periods.

KEY FUNCTIONS

Non-volatile storage retains data without power. Byte-level programming enables selective data updates. Serial interfaces reduce pin count requirements. Write protection prevents accidental data corruption.

TECHNICAL SPECIFICATIONS

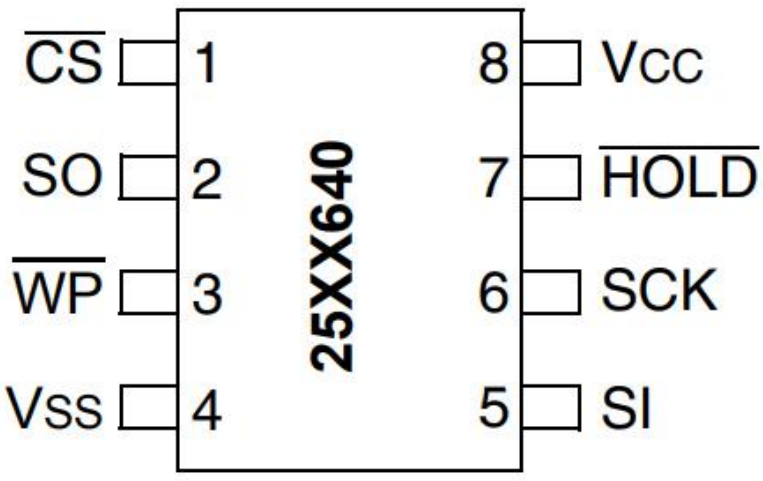
Memory sizes range from 1Kbit to 4Mbit typically. Endurance exceeds 1 million erase/write cycles. Data retention spans 100 years at room temperature. Operating temperature extends from -40°C to +85°C.

MARKET SOLUTIONS

Part Number	Manufacturer	Size	Interface	Endurance	Package
24LC256	Microchip	256Kbit	I2C	1M cycles	DIP-8
AT24C32	Atmel	32Kbit	I2C	1M cycles	SOIC-8
25LC640	Microchip	64Kbit	SPI	1M cycles	SOIC-8
M24C64	STMicroelectronics	64Kbit	I2C	4M cycles	SOIC-8
CAT25128	ON Semi	128Kbit	SPI	1M cycles	TSSOP-8

APPLICATIONS

- Non-volatile storage for configuration data
- User preference storage in embedded devices
- System Log for UAV "Black Box"



17.I2C Expander

I2C expanders increase the number of I2C devices that can be connected to a single bus. They provide bus buffering, voltage level translation, and signal conditioning to extend I2C communication capabilities.

KEY FUNCTIONS

Bus extension increases I2C network size beyond electrical limits. Signal buffering restores signal integrity over long distances. Voltage translation enables mixed-voltage I2C systems. Bus isolation prevents fault propagation between segments.

TECHNICAL SPECIFICATIONS

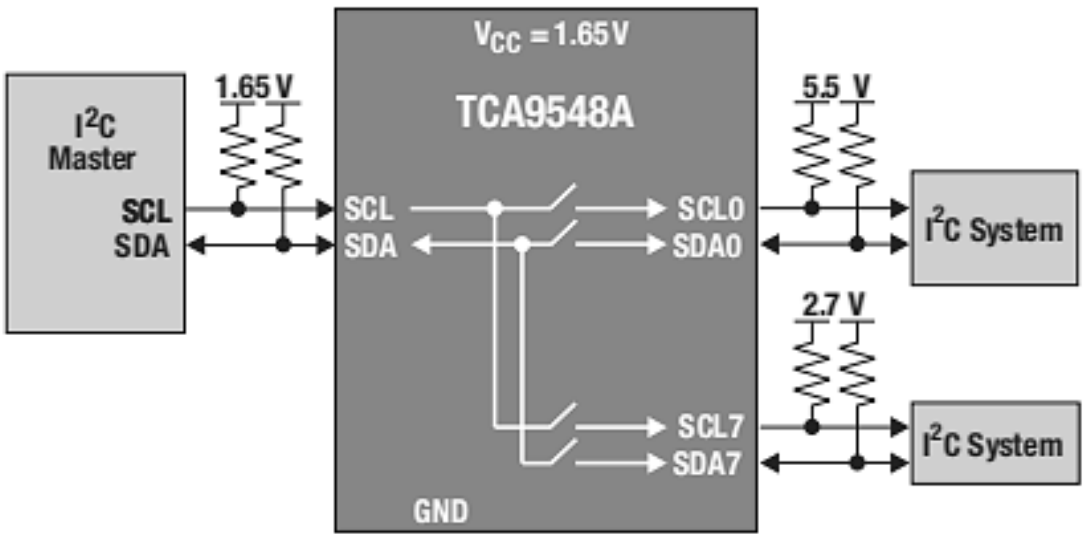
Channel count typically ranges from 2 to 8 separate I2C buses. Operating frequency supports up to 400kHz typically. Voltage translation spans 1.2V to 5.5V. Bus capacitance loading stays within I2C specifications.

MARKET SOLUTIONS

Part Number	Manufacturer	Channels	Max Frequency	Voltage Range	Package
PCA9548A	NXP	8	400kHz	2.3V-5.5V	TSSOP-24
TCA9548A	TI	8	400kHz	1.65V-5.5V	TSSOP-24
PCA9544A	NXP	4	400kHz	2.3V-5.5V	SOIC-20
MAX7367	Maxim	2	400kHz	1.7V-5.5V	TQFN-16
LTC4316	Linear Tech	2	400kHz	2.25V-5.5V	MSOP-12

APPLICATIONS

- Extending the number of digital I/O pins
- Controlling multiple LEDs/buttons from MCU
- Multiple IMUs on one board communicating via I2C and connecitng to one MCU



18.PWM Controller

PWM controllers generate precise pulse-width modulated signals for motor control, power regulation, and analog output generation. They provide programmable duty cycles, frequencies, and multiple output channels.

KEY FUNCTIONS

Duty cycle control enables power regulation and motor speed control. Multiple channels support complex control schemes. Frequency programming optimizes switching performance. Dead-time insertion prevents shoot-through currents.

TECHNICAL SPECIFICATIONS

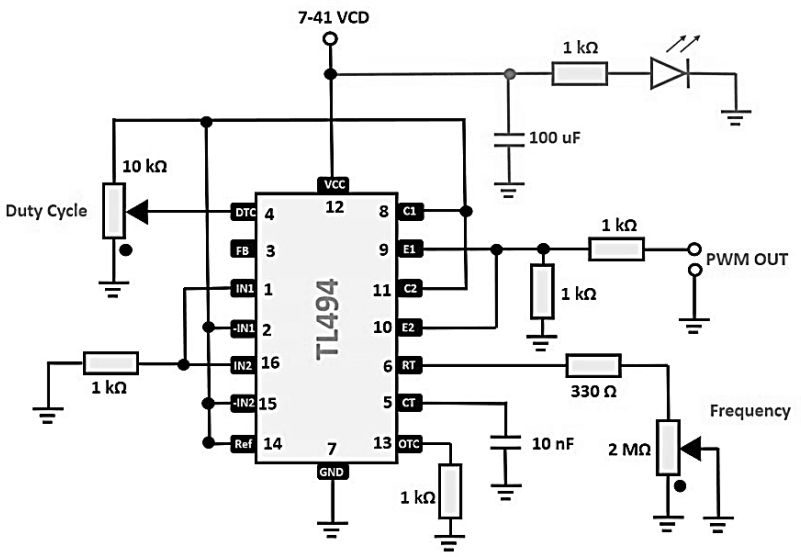
Resolution ranges from 8 bits to 16 bits typically. Operating frequency spans DC to 1MHz. Channel count varies from 1 to 16 outputs. Phase relationships enable advanced control topologies.

MARKET SOLUTIONS

Part Number	Manufacturer	Channels	Resolution	Max Frequency	Interface
TL494	TI	2	8-bit	300kHz	Analog
LM2524	TI	1	8-bit	500kHz	Analog
PCA9685	NXP	16	12-bit	1.5kHz	I2C
TLC5940	TI	16	12-bit	Variable	SPI
SG3525A	ON Semi	2	8-bit	400kHz	Analog

APPLICATIONS

- Motor speed and torque control
- LED brightness dimming
- SMPS Power supply voltage regulation



19.Digital Potentiometer

Digital potentiometers provide electronically adjustable resistance for gain control, threshold adjustment, and analog signal conditioning. They replace mechanical potentiometers with digital control interfaces.

KEY FUNCTIONS

Resistance adjustment enables electronic control of analog parameters. Non-volatile memory stores settings through power cycles. Multiple channels support complex analog circuits. Linear and logarithmic tapers match application requirements.

TECHNICAL SPECIFICATIONS

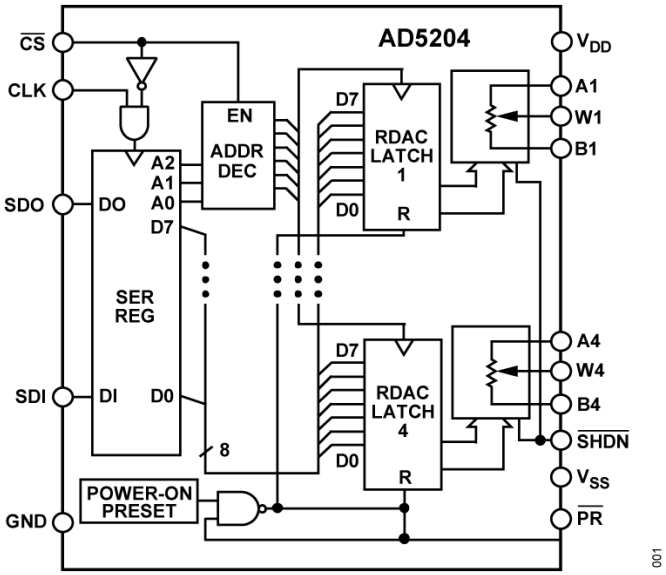
Resolution ranges from 6 bits to 10 bits typically. Resistance values span 1kΩ to 1MΩ. Temperature coefficient stays below 35ppm/°C. Endurance exceeds 50,000 wiper movements.

MARKET SOLUTIONS

Part Number	Manufacturer	Resolution	Resistance	Channels	Interface
MCP4131	Microchip	7-bit	5kΩ-100kΩ	1	SPI
AD5204	Analog	8-bit	10kΩ-100kΩ	4	SPI
X9C102	Renesas	8-bit	1kΩ	1	3-Wire
MAX5477	Maxim	7-bit	10kΩ-50kΩ	1	I2C
MCP4661	Microchip	8-bit	5kΩ-100kΩ	2	I2C

APPLICATIONS

- Electronic volume control in audio devices
- Segment adjustment in sensor calibration
- Real-time Programmable Voltage output of Switching regulator



20.MIPI Retimer

MIPI retimers regenerate high-speed differential signals for camera and display interfaces. They extend transmission distances, improve signal integrity, and enable flexible board routing in mobile and embedded systems.

KEY FUNCTIONS

Signal regeneration restores degraded high-speed signals. Clock recovery extracts timing information from data streams. Equalization compensates for transmission losses. Protocol transparency maintains compatibility with MIPI standards.

TECHNICAL SPECIFICATIONS

Data rates support up to 4.5Gbps per lane typically. Lane counts range from 1 to 4 lanes per direction. Power consumption stays below 100mW per lane. Operating temperature spans -40°C to +85°C.

MARKET SOLUTIONS

Part Number	Manufacturer	Lanes	Max Data Rate	Protocol	Package
DS90UB913A	TI	4	1.5Gbps	CSI-2	BGA-40
MAX96717F	Maxim	4	6Gbps	CSI-2	BGA-60
SN65DSI86	TI	4	3Gbps	DSI	BGA-64
LT8619C	Lontium	4	4.5Gbps	CSI-2/DSI	QFN-88
MAX96755F	Maxim	4	3.12Gbps	GMSL2	BGA-73

APPLICATIONS

- Signal conditioning in high-speed camera interfaces
- Extending MIPI DSI (Display Serial Interface) displays controlled by CPU
- Multi-Sensor IoT extension to Linux based Chipset