SPI - Serial Peripheral Interface

Preface

With this article, the possibilities of serial communication with peripheral devices via SPI (Serial Peripheral Interface) will be discussed. More and more serial bus systems are preferred instead of a parallel bus, because of the simpler wiring. As the efficiency of serial buses increases, the speed advantage of the parallel data transmission gets less important. The clock frequencies of SPI devices can go up to some Megahertz and more. There are a lot of application where a serial transmission is perfectly sufficient. The usage of SPI is not limited to the measuring area, also in the audio field this type of transmission is used.

The SPI (this name was created by Motorola) is also known as Microwire, trade mark of National Semiconductor. Both have the same functionality. There are also the extensions QSPI (Queued Serial Peripheral Interface) and MicrowirePLUS.

The popularity of other serial bus system like I^2C, CAN bus or USB shows, that serial busses get used more and more.

Below is a list of SPI devices. However this list neither claims to be complete nor is the availablability of the listed components guaranteed. In addition there is a list of manufacturers with the type of SPI components they produce.

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The Principle

The Serial Peripheral Interface is used primarily for a synchronous serial communication of host processor and peripherals. However, a connection of two processors via SPI is just as well possible and is described at the end of the chapter.

In the standard configuration for a slave device (see illustration 1), two control and two data lines are used. The data output SDO serves on the one hand the reading back of data, offers however also the possibility to cascade several devices. The data output of the preceding device then forms the data input for the next IC.

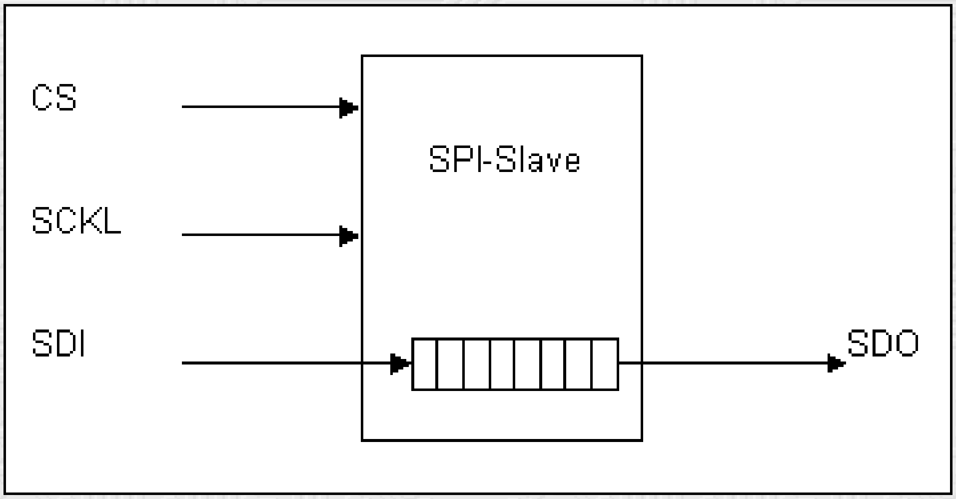

Illustration 1: SPI slave

There is a MASTER and a SLAVE mode. The MASTER device provides the clock signal and determines the state of the chip select lines, i.e. it activates the SLAVE it wants to communicate with. CS and SCKL are therefore outputs.

The SLAVE device receives the clock and chip select from the MASTER, CS and SCKL are therefore inputs.

This means there is one master, while the number of slaves is only limited by the number of chip selects.

A SPI device can be a simple shift register up to an independent subsystem. The basic principle of a shift register is always present. Command codes as well as data values are serially transferred, pumped into a shift register and are then internally available for parallel processing. Here we already see an important point, that must be considered in the philosophy of SPI bus systems: The length of the shift registers is not fixed, but can differ from device to device. Normally the shift registers are 8Bit or integral multiples of it. Of course there also exist shift registers with an odd number of bits. For example two cascaded 9Bit EEPROMs can store 18Bit data.

If a SPI device is not selected, its data output goes into a high-impedance state (hi-Z), so that it does not interfere with the currently activated devices. When cascading several SPI devices, they are treated as one slave and therefore connected to the same chip select.

Thus there are two meaningful types of connection of master and slave devices. illustration 2 shows the type of connection for cascading several devices.

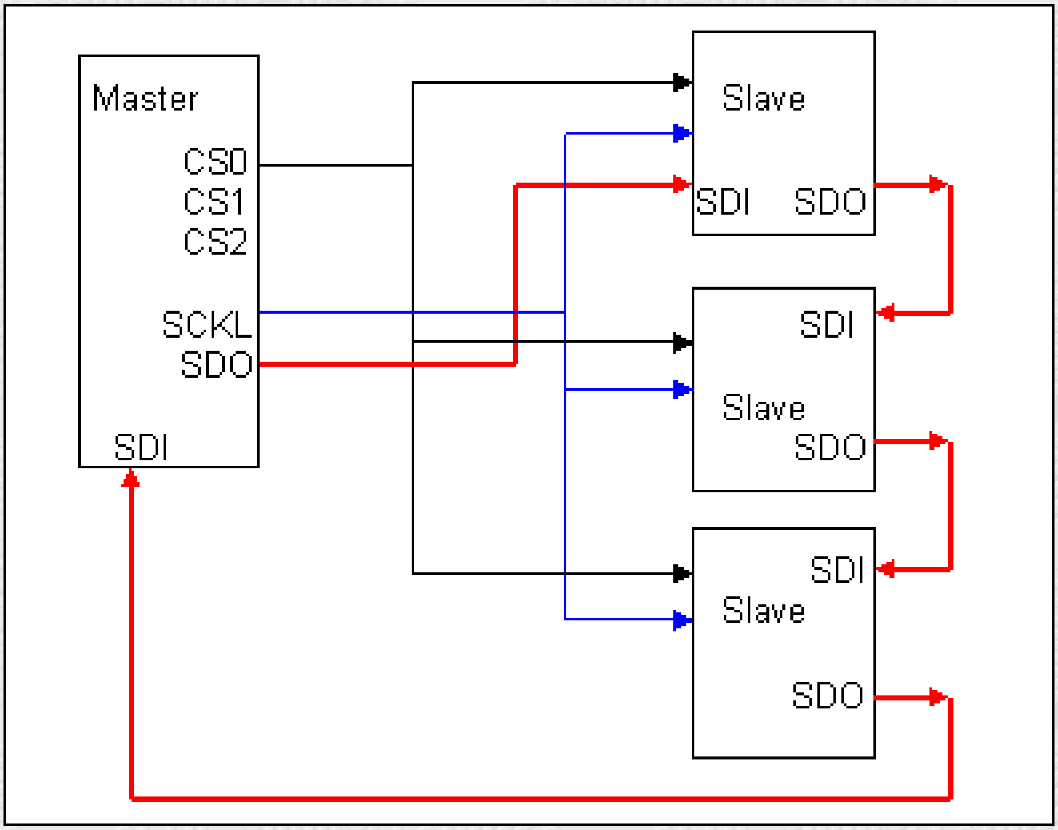

Illustration 2: Cascading several SPI devices

In illustration 2 the cascaded devices are evidently looked at as one larger device and receive therefore the same chip select. The data output of the preceding device is tied to the data input of the next, thus forming a wider shift register.

If independent slaves are to be connected to a master an other bus structure has to be chosen, as shown in illustration 3. Here, the clock and the SDI data lines are brought to each slave. Also the SDO data lines are tied together and led back to the master. Only the chip selects are separately brought to each SPI device.

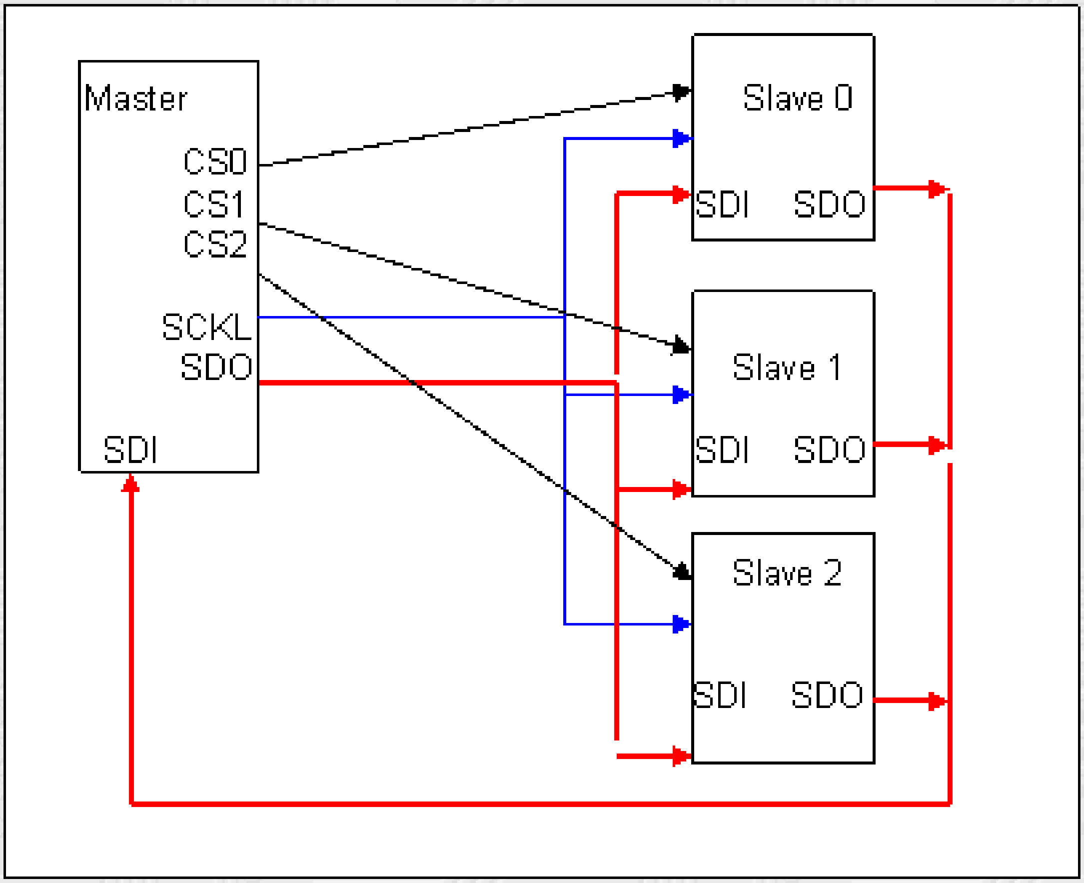

Illustration 3: Master with independent slaves

Last not least both types may be combined.

It is also possible to connect two micro controllers via SPI. For such a network, two protocol variants are possible. In the first, there is only one master and several slaves and in the second, each micro controller can take the role of the master. For the selection of slaves again two versions would be possible but only one variant is supported by hardware. The hardware supported variant is with the chip selects, while in the other the selection of the slaves is done by means of an ID packed into the frames. The assignment of the IDs is done by software. Only the selected slave drives its output, all other slaves are in high-impedancd state. The output remains active as long as the slave is selected by its address.

The first variant, named single-master protocol, resembles the normal master-slave communication. The micro controller configured as a slave behaves like a normal peripheral device.

The second possibility works with several masters and is therefore named multi-master protocol. Each micro processor has the possibility to take the roll of the master and to address another micro processor. One controller must permanently provide a clock signal. The MC68HC11 provides a harware error recognition, useful in multiple-master systems.

There are two SPI system errors. The first occurs if several SPI devices want to become master at the same time. The other is a collision error that occurs for example when SPI devices work with with different polarities. More details can be found in the MC68HC11 manual.

Data and Control Lines of the SPI

The SPI requires two control lines (CS and SCLK) and two data lines (SDI and SDO). Motorola names these lines MOSI (Master-Out-Slave-In) and MISO (Master-In-Slave-Out). The chip select line is named SS (Slave-Select).

With CS (Chip-Select) the corresponding peripheral device is selected. This pin is mostly active-low. In the unselected state the SDO lines are hi-Z and therefore inactive. The master decides with which peripheral device it wants to communicate. The clock line SCLK is brought to the device whether it is selected or not. The clock serves as synchronization of the data communication.

The majority of SPI devices provide these four lines. Sometimes it happens that SDI and SDO are multiplexed, for example in the temperature sensor LM74 from National Semiconductor, or that one of these lines is missing. A peripheral device which must or can not be configured, requires no input line, only a data output. As soon as it gets selected it starts sending data. In some ADCs therefore the SDI line is missing (e.g. MCCP3001 from Microchip).

There are also devices that have no data output. For example LCD controllers (e.g. COP472-3 from National Semiconductor), which can be configured, but cannot send data or status messages.

SPI Configuration

Because there is no official specification, what exactly SPI is and what not, it is necessary to consult the data sheets of the components one wants to use. Important are the permitted clock frequencies and the type of valid transitions.

There are no general rules for transitions where data shouls be latched. Although not specified by Motorola, in practice four modes are used. These four modes are the combinations of CPOL and CPHA. In table 1, the four modes are listed.

SPI-mode	CPOL	CPHA

0	**0**	**0**
1	**0**	**1**
2	**1**	**0**
3	**1**	**1**

Table 1: SPI Modes

If the phase of the clock is zero, i.e. CPHA = 0, data is latched at the rising edge of the clock with CPOL = 0, and at the falling edge of the clock with CPOL = 1. If CPHA = 1, the polarities are reversed. CPOL = 0 means falling edge, CPOL = 1 rising edge.

The micro controllers from Motorola allow the polarity and the phase of the clock to be adjusted. A positive polarity results in latchig data at the rising edge of the clock. However data is put on the data line already at the falling edge in order to stabilize. Most peripherals which can only be slaves, work with this configuration. If it should become necessary to use the other polarity, transitions are reversed.

The different Peripheral Types

The question is of course, which peripheral types exist and which can be connected to the host processor. The available types and their characteristics are now discussed. Peripheral types can be subdivided into the following categories:

- Converters (ADC and DAC)
- Memories (EEPROM and FLASH)
- Real Time Clocks (RTC)
- Sensors (temperature, pressure)
- Others (signalmixer, potentiometer, LCD controller, UART, CAN controller, USB controller, amplifier)

In the three categories converters, memories and RTCs, there is a great variety of component. Devices belonging to the last both groups are more rarely.

There are lots of converters with different resolutions, clock frequencies and number of channels to choose from. 8, 10, 12 up to 24Bit with clock frequencies from 30ksps up to 600ksps.

Memory devices are mostly EEPROM variants. There are also a few SPI flash memories. Capacities range from a couple of bits up to 64KBit. Clock frequencies up to 3MHz. Serial EEPROMS SPI are available for different supply voltages (2.7V to 5V) allowing their use in low-voltage applications. The data retention time duration from 10 years to

100 years. The permitted number of write accesses is 1 million cycles for most components. By cascading memory devices any number of bits/word can be obtained.

RTCs are ideally suited for serial communication because only small amounts of data have to be transferred. There is also a great variety of RTCs with supply voltages from 2.0V. In addition to the standard functions of a "normal" clock, some RTCs offer an alarm function, non-volatile RAM etc. Most RTCs come from DALLAS and EPSON.

The group of the sensors is yet weakly represented. Only a temperature and a pressure sensor could be found.

CAN and USB controllers with SPI make it easier to use these protocols on a micro controller and inerfacing a LCD via SPI saves the troublesome parallel wiring.

Manufacturer List

Manufacturer	Device Types	Internet address
AKM	EEPROM	http://www.akm.com
Analog Devices	DSP, ADC, digital Poti	http://www.analog.com
Atmel	EEPROM, digital Poti	http://www.atmel.com
Crystal	ADC	http://www.cirrus.com
Dallas	RTC	http://www.dalsemi.com
EPSON	RTC	http://www.epson.com
Fairchild	EEPROM	http://www.fairchildsemi.com
Infineon	Pressure Sensor	http://www.infineon.com
Intel	CAN Controller	http://www.intel.com
Linear Technology	ADC, DAC, Temperature Sensor + Voltage Monitor	http://www.linear-tech.com
Maxim	ADC, DAC, UART, Analog Switches	http://www.maxim-ic.com

Microchip	Micro controller, EEPROM, ADC, CAN controller	http://www.microchip.com
Motorola	DSP, MCU	http://www.motorola.com
National Semiconductor	LCD Controller, dig. Temperature Sensor, USB Controller	http://www.national.com
NeXFlash	FLASH	http://www.nexflash.com
SanDisk	FLASH, MultiMediaCard	http://www.sandisk.com
SGS-Thomson	EEPROM, Micro controller	http://us.st.com
Texas Instruments	DSP, ADC, DAC	http://www.ti.com
Xicor	CPU Supervisor, EEPROMs, FLASH	http://www.xicor.com
Zilog	DSP	http://www.zilog.com

Device List (Peripherals)

No.	Device	Type	Features	Manufacturer
1	AK93C85A AK93C95A AK93C10A	EEPROM	Low power consumption 0.8µA standby	AKM
2	SSM2163	8x2 Audio Mixer	63dB attenuation in 1dB steps	Analog Devices
3	AD1893	Sample Rate Converter	Converts 1:2 to 2:1	Analog Devices
4	AD5302 AD5312 AD5322	DAC	8/10/12Bit buffered outputs dual DAC	Analog Devices
5	AD5530 AD5531	DAC	12/14Bit cascadeable	Analog Devices

6	AD7303	DAC	8Bit clock rate up to 30MHz	Analog Devices
7	AD7394 AD7395	DAC	12/10Bit	Analog Devices
8	AD7715	ADC	Sigma-Delta	Analog Devices
9	AD7811 AD7812	ADC	10Bit 4/8 channel 300ksps	Analog Devices
10	AD7816 AD7817 AD7818	ADC+ Temperature Sensor	10Bit	Analog Devices
11	AD7853	ADC	12Bit 200ksps 3V to 5V operation	Analog Devices
12	AD7858	ADC	12Bit, 8 channel 200ksps	Analog Devices
13	AD8303	DAC	12Bit dual DAC	
14	AD8400 AD8402 AD8403	Digital Poti	1/2/4 channel 256 positions 1, 10, 50 100kOhm 10MHz update rate	Analog Devices
15	DAC8143	DAC	12Bit cascadeable	Analog Devices
16	DAC8420	DAC	12Bit quad DAC wide supply range	Analog Devices
17	AT25010 AT25020 AT25040	EEPROM	Low voltage operation 1.8V/2.7V/5.0V block write protection 100 years data retention	ATMEL

18	AT25080 AT25160 AT25320 AT25640	EEPROM	Low voltage operation 1.8V/2.7V/5.0V block write protection	ATMEL
19	AT25P1024	EEPROM	Low voltage operation 1.8V/2.7V/5.0V block write protection	ATMEL
20	AT25HP256	EEPROM	Low voltage operation 1.8V/2.7V/5.0V block write protection	ATMEL
21	AT45D011	FLASH	5V 1MBit 15MHz clock rate	ATMEL
22	AT45D021	FLASH	5V 2MBit 10MHz	ATMEL
23	AT45DB021	FLASH	2.7V 2MBit 5MHz clock rate	ATMEL
24	AT45DB041	FLASH	5V 4MBit 10MHz	ATMEL
25	AT45D081	FLASH	5V 8MBit 10MHz	ATMEL
26	AT45DB161	FLASH	2.7V 16MBit 13MHz	ATMEL
27	ADS1210 ADS1211	ADC	24Bit	BURR-BROWN
28	ADS1212 ADS1213	ADC	22Bit	BURR-BROWN

29	ADS1286	ADC	12Bit micro power 20ksps	BURR-BROWN
30	ADS7812	ADC	12Bit, multiple input ranges low power 40ksps	BURR-BROWN
31	ADS7813	ADC	16Bit low power 40ksps	BURR-BROWN
32	ADS7818	ADC	12Bit low power 500ksps internal reference	BURR-BROWN
33	ADS7834	ADC	12Bit low power 500ksps internal reference	BURR-BROWN
34	ADS7835	ADC	12Bit low power 500ksps	BURR-BROWN
35	ADS7846	Touch-screen controller	2.2V to 5.25V	BURR-BROWN
36	ADS7870		16Bit 2.7V to 5.5V 52ksps	BURR-BROWN
37	ADSS8320	ADC	2.7V to 5V 100ksps	BURR-BROWN
38	ADS8321	ADC	16Bit 5V 100ksps	BURR-BROWN
39	CS5531 CS5533	ADC	16Bit, 2 channel Low noise up to 23Bit selectable word rates	Crystal

40	CS5532 CS5534	ADC	24Bit, 2 channel Low noise up to 23Bit selectable word rates	Crystal
41	DS1267	Digital potentiomenter	Dual 10k, 50k und 100k	DALLAS
42	DS1305	RTC	96-byte User-RAM	DALLAS
43	DS1306	RTC	96-byte User-RAM	DALLAS
44	DS1722	Digital Thermometer	-55 °C bis 120 °C accuracy +/- 2°C wide supply range	DALLAS
45	DS1844	Digital Poti	4 channel, linear 64 positions 10, 50 und 100kOhm	DALLAS
46	RTC4553	RTC	built-in crystal RAM 30x4Bit	EPSON
47	NM25C020 NM25C040 NM25C041 NM25C160 NM25C640	EEPROM	data retention >40 years hard- und software write protection	Fairchild
48	NM93C06 NM93C56 NM93C66	EEPROM	data retention >40 years hard- und software write protection	Fairchild
49	NM93C46 NM93C56	EEPROM	1k/2k	Fairchild
50	NM93C46A NM93C46A	EEPROM	1k/2k selectable organization	Fairchild
51	NM93S46 NM93S56	EEPROM	1K/2K data protect sequential read	Fairchild
52	KP100	Pressure Sensor	range 60... 130kPa	infineon

53	82527	CAN Controller	Flexible CPU-interface CAN 2.0 Programmable Bit rate	intel
54	IS93C46-3	EEPROM		issi
55	LTC1091 LTC1092 LTC1093 LTC1094	ADC	1-/2-/6-/8-Kanal wide supply range : 5V to 10V	Linear Technology
56	LTC1096 LTC1098	A/D-Wabdler	8Bit 33ksps	Linear Technology
57	LTC1197 LTC1199	ADC	10Bit 500ksps low-power version	Linear Technology
58	LTC1285 LTC1288	ADC	12Bit 7.5ksps/6.5ksps 3V	Linear Technology
59	LTC1287	ADC	12Bit 3.3V 30ksps	Linear Technology
60	LTC1289	ADC	12Bit 25ksps 3.3V	Linear Technology
61	LTC1290	ADC	12Bit 50ksps variable word length	Linear Technology
62	LTC1291	ADC	12Bit 5V	
63	LTC 1329-10 LTC 1329-50 LTC1329A-50	DAC	Wide supply range 2.7V to 6.5V 8Bit Current output	Linear Technology
64	LTC1392	Temperatur +Power Monitor	10Bit	Linear Technilogy

65	LTC1404	ADC	12Bit 600ksps	Linear Technology
66	LTC1418	ADC	14Bit 200ksps serial/parallel I/O	Linear Technology
67	LTC1451 LTC1452 LTC1453	DAC	12Bit kaskadierbar	Linear Technology
68	LTC1594 LTC1598	ADC	12Bit 4/8 channel	Linear Technology
69	LTC1655	DAC	16Bit kaskadierbar	Linear Technology
70	LTC2400	ADC	24Bit Sigma/Delta	Linear Technology
71	LTC2408	ADC	24Bit Sigma/Delta no latency	Linear Technology
72	LTC2410	ADC	24Bit	
73	LTC2420	ADC	20Bit, no latency	Linear Technology
74	MAX144 MAX145	ADC	12Bit Low power 2 channel 108ksps	Maxim
75	MAX146 MAX147	ADC	12Bit Low power 8 channel	Maxim
76	MAX157 MAX159	ADC	10Bit 2 channels	Maxim
77	MAX186 MAX188	ADC	12Bit 8 channel 133ksps	Maxim

78	MAX349 MAX350	MUX	8-to-1 dual 4-to-1	Maxim
79	MAX395	Switch	8 channel	Maxim
80	MAX504	DAC	10Bit low power internal reference	Maxim
81	MAX522	DAC	8Bit 5MHz	Maxim
82	MAX525	DAC	12Bit quad DAC	Maxim
83	MAX531	DAC	12Bit low power	Maxim
84	MAX534	DAC	8Bit rail-to-rail output buffers low power 10MHz clock rate	Maxim
85	MAX535 MAX5351	DAC	13Bit schmitt-trigger inputs	Maxim
86	MAX536 MAX537	DAC	12Bit quad DAC calibrated	Maxim
87	MAX 548 MAX549 MAX550	DAC	8Bit low power single/dual DAC 10MHz clock rate	Maxim
88	MAX551 MAX552	DAC	12Bit 12.5MHz clock rate schmitt-trigger inputs	Maxim
89	MAX1084 MAX1085	ADC	10Bit 300ksps/400ksps internal reference	Maxim

90	MAX1106 MAX1107	ADC	8Bit low power 25ksps	Maxim
91	MAX1110 MAX1111	ADC	8Bit low power multi-channel	Maxim
92	MAX1112 MAX1113	ADC	8Bit 50ksps multi-channel	Maxim
93	MAX1202 MAX1203	ADC	12Bit 8 channel 133ksps internal reference	Maxim
94	MAX1204	ADC	10Bit 8 channel 133ksps internal reference	Maxim
95	MAX1240 MAX1241	ADC	12Bit low power 73ksps	Maxim
96	MAX1242 MAX1243	ADC	10Bit 8 channel low power 73ksps	Maxim
97	MAX1270 MAX1271	ADC	12Bit 8 channel multi-range 110ksps internal reference	Maxim
98	MAX1400	ADC	18Bit, Sigma-Delta multi-channel programmable gain +offset 480sps	Maxim

99	MAX1401	ADC	18Bit, Sigma-Delta multi-channel 480sps	Maxim
100	MAX1403	ADC	18Bit, Sigma-Delta multi-channel 480sps	
101	MAX1402	ADC	18Bit multi-channel	Maxim
102	MAX3100	UART	Up to 230kBaud Schmitt-trigger inputs	Maxim
103	MAX3110E MAX3111E	UART	ESD-protected internal capacitors	Maxim
104	MAX3140	UART		Maxim
105	MAX4548	Switch	Triple 3x2-crosspoint switch	Maxim
106	MAX4550 MAX4570	Switch	Dual 4x2 crosspoint switch	Maxim
107	MAX4562 MAX4573	Switch	Clickless Audio/ Video Switch	Maxim
108	MAX4571 MAX4574	Switch	Audio/Video	Maxim
109	MAX4588	MUX	Dual 4 channel 180MHz bandwidth	Maxim
110	MAX4589	MUX	Dual 2 channel 200MHz bandwidth	Maxim
111	MAX5104	DAC	12Bit	Maxim
112	MAX5120 MAX5121	DAC	12Bit internal reference	Maxim
113	MAX5122 MAX5123	DAC	12Bit internal reference buffered output can drive up to 20mA	Maxim

114	MAX5130 MAX5131	DAC	13Bit internal reference	Maxim
115	MAX5132 MAX5133	DAC	13Bit internal reference	Maxim
116	MAX5150 MAX5151	DAC	13Bit, dual 16 us settling time	Maxim
117	MAX5152 MAX5153	DAC	13Bit dual DAC configurable outputs drive up to 20mA	Maxim
118	MAX5156 MAX5157	DAC	12Bit dual DAC configurable outputs drive up to 20mA	Maxim
119	MAX5170 MAX5172	DAC	14Bit low power	Maxim
120	MAX5171 MAX5173	DAC	14Bit Force/Sense voltage output	Maxim
121	MAX5174 MAX5176	DAC	12Bit	Maxim
122	MAX5175 MAX5177	DAC	12Bit Force/Sense voltage output	Maxim
123	MAX5222	DAC	8Bit dual DAC 25MHz clock rate	Maxim
124	MAX5250	DAC	10Bit quad DAC schmitt-trigger inputs	Maxim
125	MAX5251	DAC	10Bit quad DAC schmitt-trigger inputs	Maxim
126	MAX5253	DAC	12Bit	

127	MAX5302	DAC	12Bit 5V	Maxim
128	MAX5352	DAC	12Bit schmitt-trigger inputs low power	Maxim
129	MAX5354	DAC	10Bit schmitt-trigger inputs	Maxim
130	MAX5541	DAC	16Bit schmitt-trigger inputs 10MHz clock rate	Maxim
131	MAX5544	DAC	14Bit schmitt-trigger inputs 10MHz	Maxim
132	MAX7219 Max7221	LED display driver	8-digit 10MHz clock rate digital/analog brightness control	Maxim
133	25AA040 25LC040 25C040	EEPROM	4k max. 3MHz clock data retention >200 years	Microchip
134	25AA080 25LC080 25C080	EEPROM	8k, max 3MHz clock data retention >200 years	Microchip
135	25AA160 25LC160 25C160	EEPROM	16k, max 3MHz clock data retention >200 years	Microchip
136	25LC320 25C320	EEPROM	32k, max 3MHz clock data retention >200 years	Microchip
137	25AA640 25LC640	EEPROM	64k, max 3MHz clock data retention >200 years	Microchip

138	MCP3001	ADC	10Bit, 2.7V to 5V 200ksps @ 5V low power	Microchip
139	MCP3002	ADC	10Bit, 2.7V to 5V, 2 channel 200ksps @ 5V	Microchip
140	MCP3004 MCP3008	ADC	10Bit 4/8 channel 200ksps @ 5V 2.7V to 5V	Microchip
141	MCP3201	ADC	12Bit 100ksps 2.7V to 5V industrial temp range	Microchip
142	MCP3202	ADC	12Bit 2 channel 100ksps @ 5V	Microchip
143	MCP3204/3208	ADC	12Bit 4/8 channel 100ksps @ 5V	Microchip
144	MCP2510	CAN Controller	Programmable Bit rate up tp 1MHz 0... 8 Bytes message frame	Microchip
145	MC68HC86T1	RTC + RAM	32x8Bit static-RAM	Motorola
146	CLC5506	GTA (Gain Trim Amplifier)	600MHz bandwidth control range 16dB	National Semiconductor
147	COP472-3	LCD Controller	Keine SDO-Leitung	National Semiconductor
148	LM74	Temperature Sensor	12Bit + sign 3V to 5V -55 °C bis +150 °C max resolution: 1.25 °C	National Semiconductor

149	MM5483	LCD Controller	31 segment outputs cascadable	National Semiconductor
150	MM58342	High Voltage Display Drive	35V max. cascadeable	National Semiconductor
151	TP3465	Microwire Interface Device	Allows memory- mapped SPI devices Clock 5MHz/20MHz	National Semiconductor
152	USBN9602	USB Controller	DMA-Support Several FIFOs	National Semiconductor
153	NX25F011A NX25F041A	FLASH	Data retention 10 years Clock 16MHz	NexFlash
154	NX25F080A	FLASH	8MBit data retention 10 years DOS-compatible sectors	NexFlash
155	NX25M	FLASH	Serial FLASH module, removeable	NexFlash
156	SDMB-4 SDMB-8 SDMB-16 SDMB-32	MultiMediaCard	Bis zu 32MB FLASH SPI und PCMCIA- Schnittststelle	SanDisk
157	M35080	EEPROM	8KBit 5MHz clock rate data retention >40 years	SGS-Thomson
158	M93C86 M93C76 M93C66 M93C56 M93C46 M93C06	EEPROM	Word or byte organization 16K/8K/4K /2K/1K/256 data retention: 40 years	SGS-Thomson
159	M93S46 M93S56 M93S66	EEPROM	Block protection 1k/2K/4kx16Bit	SGS-Thomson

160	M95010 M95020 M95040	EEPROM	5MHz clock rate	SGS-Thomson
161	M95080 M95160 M95320 M95640	EEPROM	8/16/32/64KBit 5MHz clock rate	SGS-Thomson
162	M95128 M95256	EEPROM	128/256KBit 5MHz	SGS-Thomson
163	ST95010 ST95020 ST95040	EEPROM	1K,2K,4K 2MHz	SGS-Thomson
164	TLV1504 TLV1508	ADC	10Bit 200ksps 4/8 channel low power	Texas Instruments
165	TLV1544	ADC	10Bit 4/8 channel	Texas Instruments
166	TLV1570	ADC	10Bit 1.25Msps	Texas Instruments
167	TLV1572	ADC	10Bit 1.25Msps	Texas Instruments
168	TLC1514 TLC1518	ADC	10Bit, 400ksps DSP-compatible 20MHz	Texas Instruments
169	TLV2541 TLV2542 TLV2545	ADC	12Bit, 200ksps low power DSP-compatible 20MHz	Texas Instruments
170	TLV2544 TLV2548	ADC	12Bit 200ksps 4/8 channel low power	Texas Instruments

171	TLC2554 TLC2558	ADC	12Bit 400ksps 4/8 channel low power	Texas Instruments
172	TLV5604	DAC	10Bit	Texas Instruments
173	TLV5606	DAC	10Bit low power	Texas Instruments
174	TLV5616 TLV5616	DAC	12Bit low power	Texas Instruments
175	TLV5617 TLV5617A	DAC	10Bit dual DAC programmable settling time	Texas Instruments
176	TLV5618A	DAC	12Bit dual DAC low power	Texas Instruments
177	TLV5623 TLV5623	DAC	8Bit	Texas Instruments
178	TLV5624	DAC	8Bit internal reference	Texas Instruments
179	TLV5627	DAC	8Bit 4 channel	Texas Instruments
180	TLV5636	DAC	12Bit internal reference programmable reference	Texas Instruments
181	TLV5637	DAC	10Bit	Texas Instruments
182	X25020	EEPROM	2K 256x8Bit clock 1MHz	XICOR

183	X25040	EEPROM	4K 512x8Bit clock 1MHz	XICOR
184	X25160	EEPROM	16k 2048x8Bit clock 2MHz	XICOR
185	X25F008 X25F016 X25F032 X25F064	FLASH	1.8V to 3.6V data retention 100 years clock 1MHz	XICOR
186	X25F128	FLASH	Block Lock Protection	XICOR
187	X5001	CPU Supervisor	5 Reset-Schwellspannungen	XICOR
188	X5043	CPU Supervisor	4K EEPROM	XICOR
189	X5163 X5165	CPU Supervisor	16K EEPROM	XICOR
190	X5323	CPU Supervisor	32K EEPROM	XICOR

Literature

[1] Motorola MC68HC11 Reference Manual, Prentice Hall 1989
[2] Motorola MC68332 User Manual
[3] Various application notes
[4] Data sheets

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