

# Technical Report

## **Application Notes** Integrated Discrettes for Cellular Usage

2003 September 25





## Integrated Discretes for Cellular Usage

### Summary

The Cellular handset industry is facing two very different challenges; firstly to compete in the low-end market for high volumes of limited feature models and secondly in the mid to high end where features are one of the key elements in brand marketing.







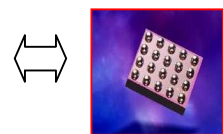
#### Low End Handsets

For the low end, reduction of cost has the highest importance. Integration is a major benefit in both, reduction in size of the overall phone and also in reducing the component count. The continuing trend for miniaturization combined with the drive for more product features makes packaging components into electronic devices increasingly difficult. This is further compounded by requirements to limit EMI/RFI interference and to provide ESD protection.

An obvious solution to space constraints is to integrate several components into a single package; Philips Semiconductor Integrated Discretes use thin film on silicon techniques to combine active and passive components in single packages. These devices range from simple ESD protection arrays to complex audio interfaces incorporating many functions. The use of Chip Scale packaging maximizes the space utilization; space savings of up to 95% are achievable compared to discrete parts.

Comparison of pcb area utilised:

 Area using discrete 0603 components	 0402 Equivalent
 Equivalent QSOP area	 5x5 CSP package



A further benefit of the combination of thin film integration and Chip Scale packing is the effect on filter performance. Devices using this combination and a multi layer board give the maximum broadband attenuation of unwanted frequencies.

#### Mid and High End Handsets

Whilst cost remains an important metric for any phone model the introduction of value added services require high and midrange phones to pack increased electronics into the same case sizes as preceding models. Here miniaturization and performance are the leading requirements. The performance improvements of Integrated Discretes are of added benefit to a layout that has to be optimised for space possibly at the expenses of filtering.



## Integrated Discretets for Cellular Usage

### Introduction

Philips Integrated Discretets has developed devices for use in many areas of cellular phone design focussing on 3 key requirements:

1. ESD protection.
2. EMI/RFI filtering.
3. Termination.

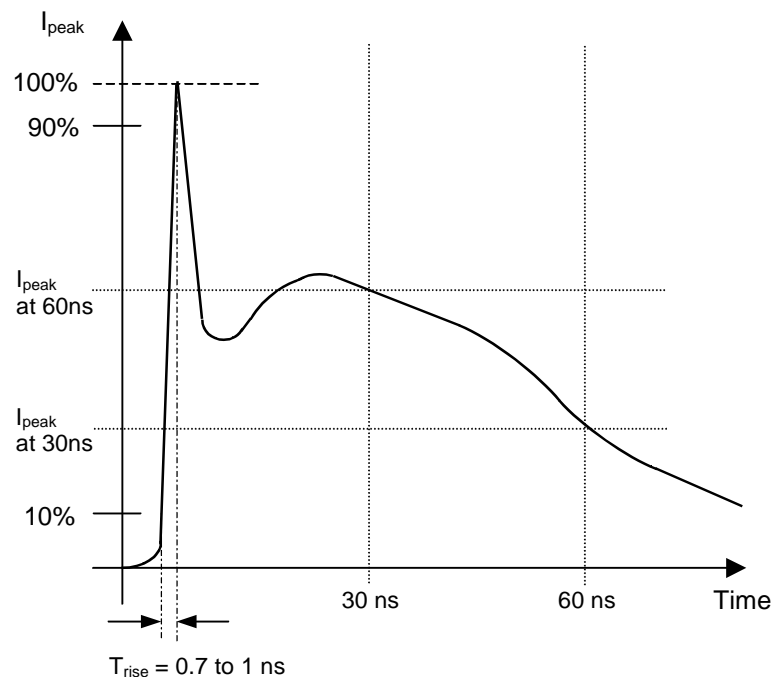
By the use of Integrated Discretets all of these requirements can be fulfilled by use of a single piece of silicon.

### ESD Protection

There are several system level tests required for phone certification; one of these is IEC61000-4-2 for Electrostatic Discharge protection.

Level 4 of this specification is one of the most stringent and requires the device to withstand contact discharges of up to 8kV and air discharges of 15kV.

These discharges generate very high instantaneous currents that require special devices to withstand these surges. The peak current for IEC61000-4-2 at 8kV is between 27 and 33 amps.

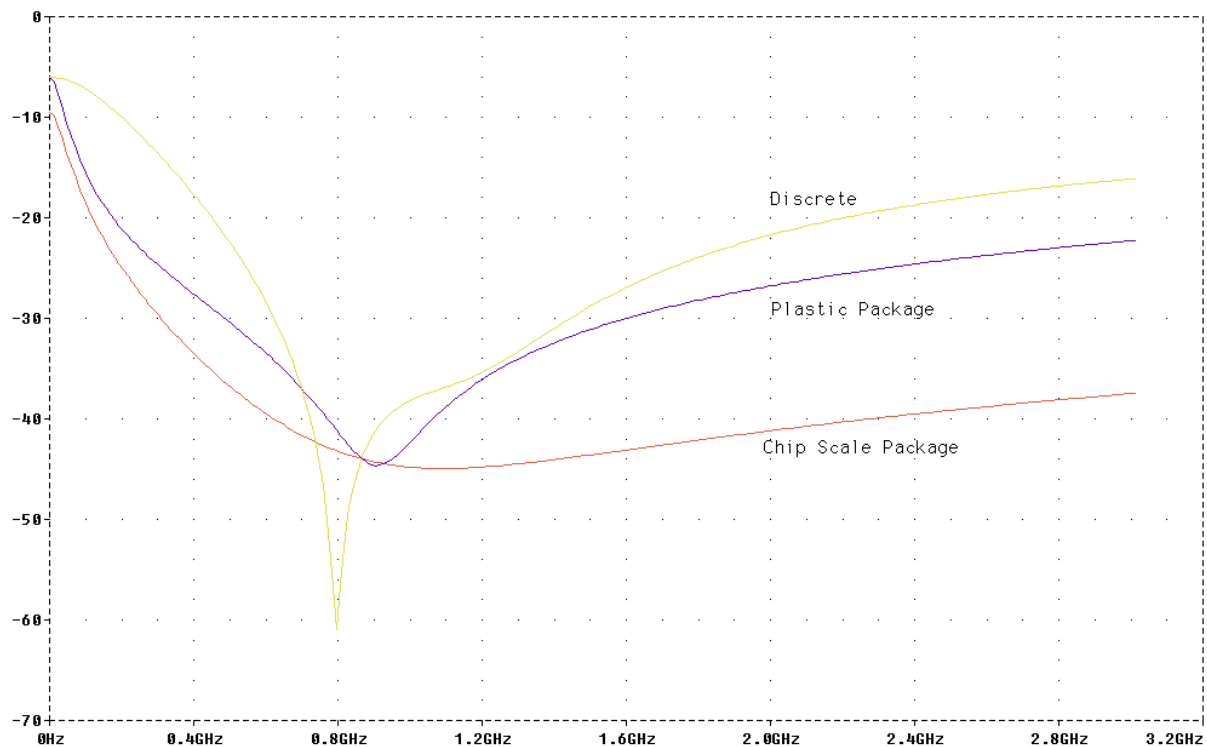




## Integrated Discretres for Cellular Usage

### EMI/RFI Filtering

Another area measured for certification is the amount of unwanted radiation from the phone and accessories connected to it. This is particularly important for the oscillator output and its harmonics. This also has relevance for the audio circuits where the induced voltages can cause audible interference if not filtered sufficiently. The values quoted in this report represent typical figures when the devices are used as recommended in the datasheet; for full information please refer to the individual datasheet.



The Chip Scale Package shows an excellent filter performance even in the GHz range, because of the low lead inductance of 0.09nH and low parasitics.

### Termination

In addition to providing the above functions the filter components may be used for impedance matching between the baseband controller and the external devices. Further components may also be integrated to provide bias voltages.

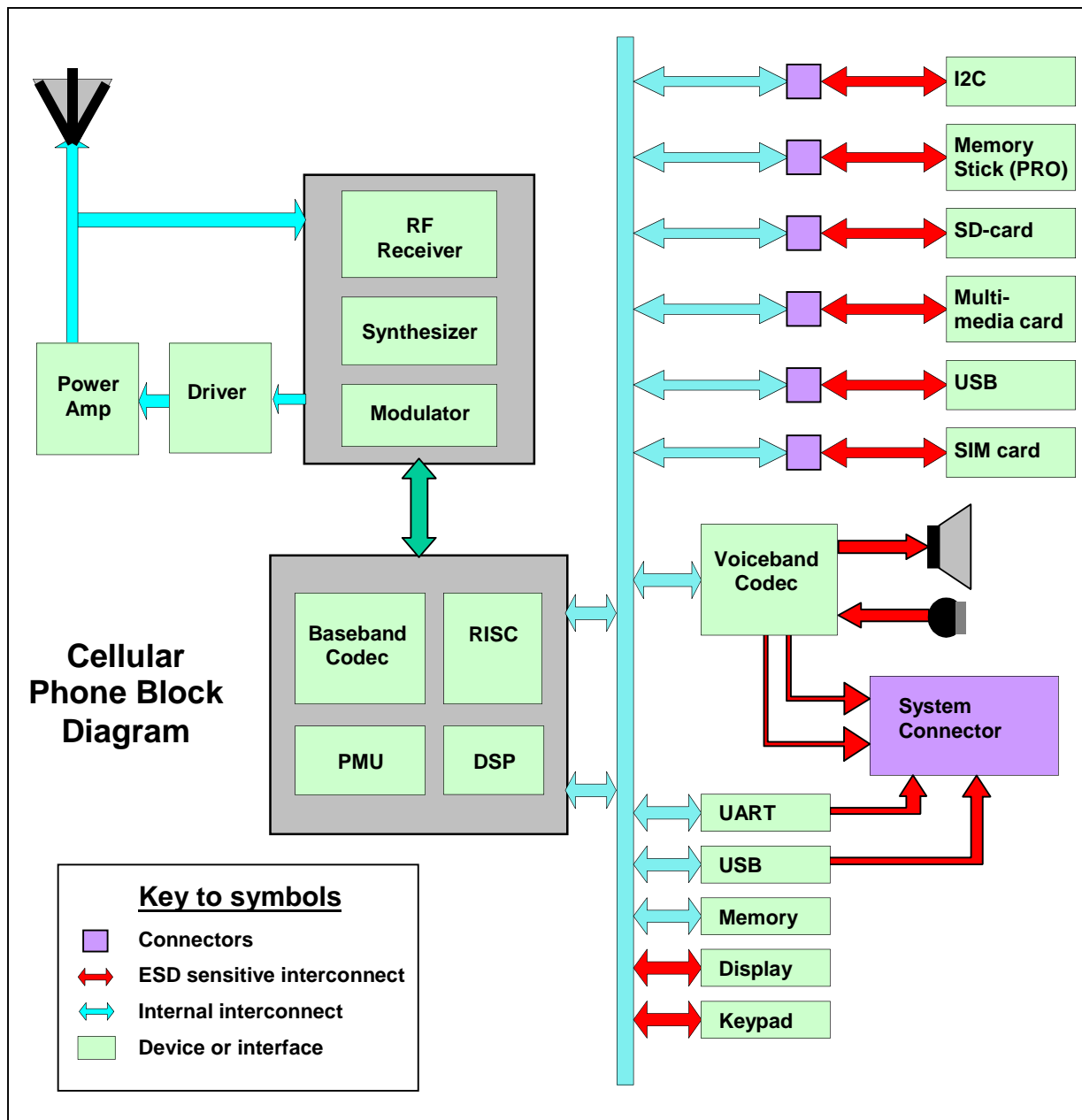
Based on the above features the ideal usages of Integrated Discretres are interfaces between the baseband processing and external devices or connectors.



Integrated Discretes for Cellular Usage

Application Areas

Here is a typical block diagram of a mobile phone. Some of these blocks are present in every handset, like the microphone, others are only present in the top of the range models. The areas indicated in red are potential interfaces that can benefit from Integrated Discretes products; these areas are described in more details below.





Integrated Discretes for Cellular Usage

Application Areas

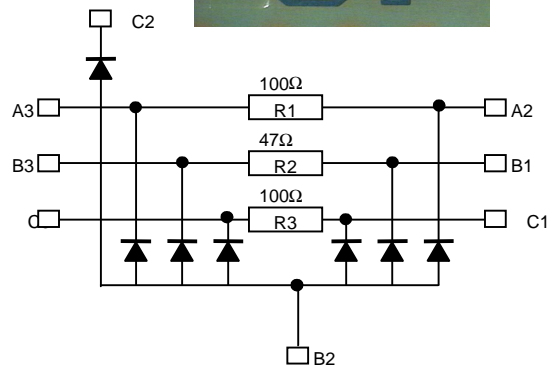
External Memory IP4044CX8, IP4051CX11, IP4052CX20 & IP4067CX9

External memory requires correct termination of the data and clock connections to ensure data integrity. The connectors used are normally accessible to the user either directly or indirectly when the memory is inserted, this makes ESD discharges a significant risk.

IP4044CX8

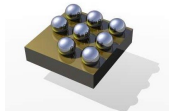
SIM Card Interface

This device provides the necessary components for protection and filtering of the **Subscriber Identity Module**, which requires 3 digital lines and an additional protection for the supply rail. An important feature of the digital lines is the matching of the resistors and the low capacitance to maintain the rise times within the specified limit of 50ns and to avoid group delay. ESD protection at the input and output provide a high level of surge limitation due the two stage ESD protection build from the pi-filter structure with ESD protection/clamping diodes at both sides of each data channel. In comparison discrete implementations need close matching of the resistor values and special diodes to provide low capacitance to allow a fast rise time.



IP4044CX8 Used in typical mobile phone

R = 47Ω, 100Ω  
 C<sub>line</sub> = 35pF

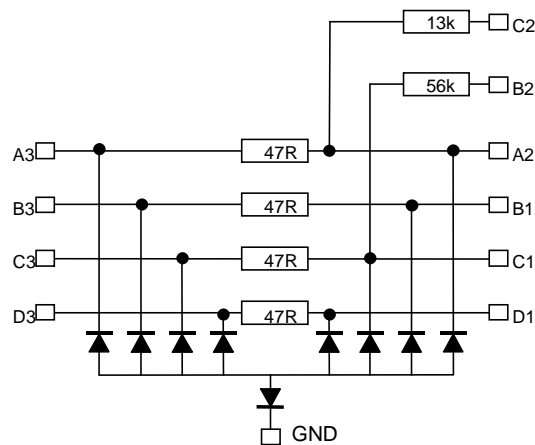


IP4051CX11

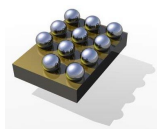
Multi Media Card Interface

Another external state of the art memory device is the **Multi Media Card** for storage and transfer of downloaded data. This has the same requirements as the SIM Card but due to the higher data rate transfer the device capacitance is even more critical; because of this the IP4051 has been carefully optimized to achieve the balance between ESD performance and channel capacitance to allow fast rise-times.

The extremely close channel-to-channel matching inherent in wafer level integration provides the optimum performance for this interface.



C<sub>line</sub> = 25pF





Integrated Discretes for Cellular Usage

**IP4052CX20**

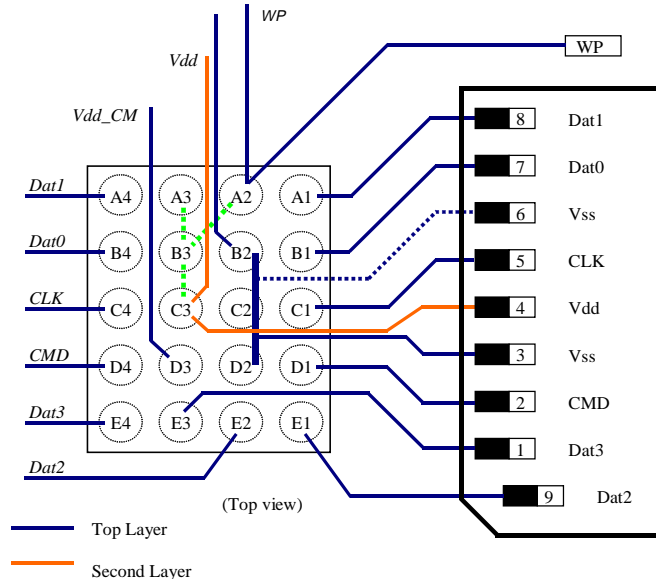
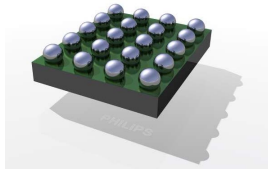
**SD-Card Interface**

Mechanically similar to the Multi-Media Card, the SD card (Secure Digital) is also used for data transfer and storage. It offers a fast 4-bit (nibble-wise) data transmission and also a 1-bit serial SPI compatible operation mode. While the similarity in size allows using one slot for both types, the interface looks different, so that the SD-Card requires different filters.

The line capacitance is lower than the one integrated in the IP4051CX11 and all required pull-up resistors for the SD-card are integrated.

$R1-R7 = 40\Omega$

$C_{line} = 18pF$  (typ.)

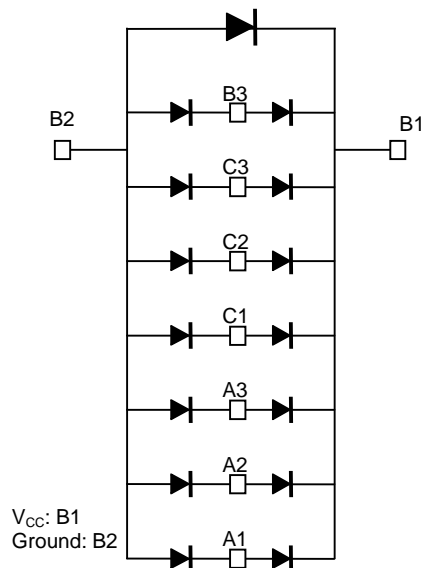
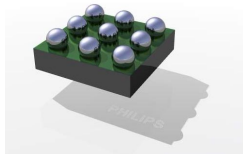


**IP4067CX9**

**Memory Stick Interface Protection**

The Sony Memory Stick™ and especially the Memory Stick PRO™ storage card require a very low additional capacitance for the ESD-protection due to the restricted specification of 26pF total capacitance. The IP4067CX9 is optimized to protect the full Memory Stick PRO interface without exceeding the maximum capacitance in an average design. Due to the single Zener diode connected between supply and ground, the IP4067CX9 provides bi-directional ESD protection also in if no supply is available.

$C_{jo} \leq 5.0 pF$  (typ.)





## Integrated Discretes for Cellular Usage

### Audio Interfaces IP4047CX6, IP4048CX5, IP4049CX5, IP4055CX6, IP5001CX11 & IP5002CX8

In addition to providing all the normal interface requirements the design of an audio interface has to consider the following:

- Filtering of induced signals from long cables (which act like aerials).
- Demodulation of induced signals by non-linear elements.
- Extra ESD protection because of the positioning of the transducers upstream of the protection element.
- Channel resistance, matching of differential channels
- Biasing

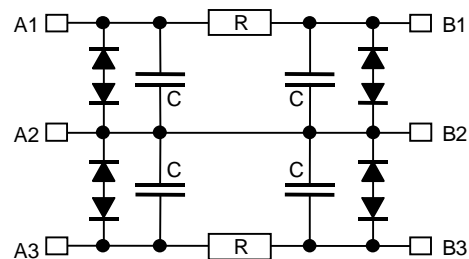
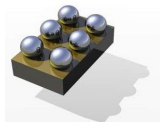
Overview of use-cases for the various audio interfaces:

	Low-Ohmic Speaker (<~ 8Ω)	High-Ohmic Speaker (>~8Ω)	Single-Ended Microphone	Differential Microphone	Integrated Resistors for Biasing
IP4047CX6	X				
IP4048CX5		X			
IP4049CX5			X	X	
IP4055CX6			X	X	
IP5001CX11				X	X
IP5002CX8			X		X

#### IP4047CX6

The IP4047CX6 is small 6 ball device used for low-ohmic speakers and/or head-sets intended to provide all the necessary interface and protection components in the smallest space possible, only Xmm x Ymm, area. The small size allows the maximum placement flexibility. The very low series resistance enables usage of the connected loudspeaker not only for voice but also for hand-free and ringing functionality.

$R = 0.8\Omega$ ,  $C_{line} = 300pF$



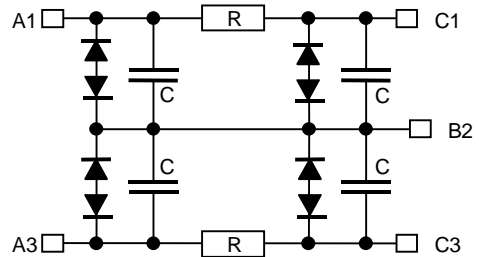
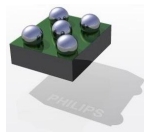


Integrated Discretes for Cellular Usage

**IP4048CX5 & IP4049CX5**

These are two small 5 ball devices used for speaker (IP4048) and microphone (IP4049) intended to provide all the necessary interface and protection components in the smallest space possible, only 1.38mm x 0.92mm. The small size allows the maximum placement flexibility.

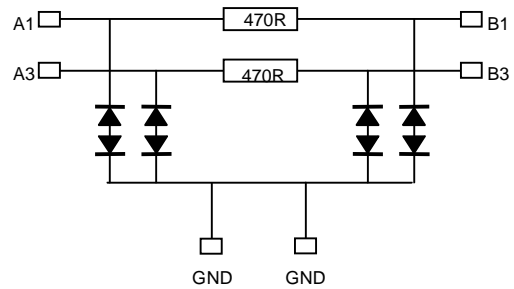
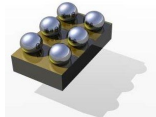
IP4048CX5:  $R = 10\Omega$ ,  $C_{line} = 100pF$   
 IP4049CX5:  $R = 68\Omega$ ,  $C_{line} = 33pF$



**IP4055CX6**

This device has been especially developed to offer higher levels of filtering of induced interference; the re-dimensioning of the filter components and the addition of an extra ground ball provide broadband filtering of 35dB. This is particularly useful for CDMA applications where the oscillator multiplex rate falls within the audio band. Alternatively this device is useful for adding 2 additional data lines to an existing data interface due to the low line capacitance of 35pF.

$C_{line} = 35pF$



**IP5001CX11 & IP5002CX8**

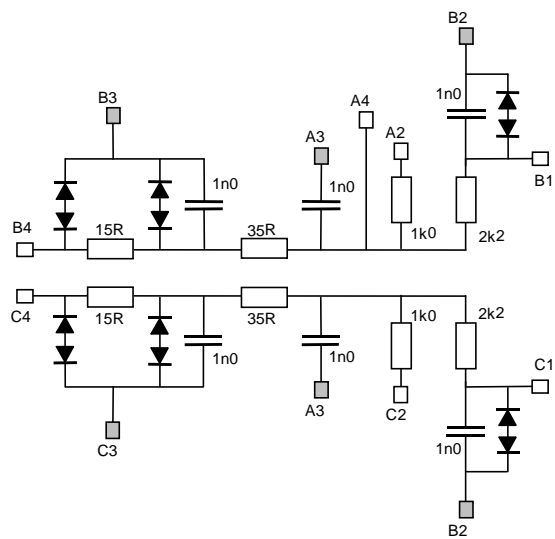
These are devices specifically for microphones and provide audio and RF filtering together with bias components. A feature of the IP5001/2 series is the high capacitance density of approximately 5nF/mm<sup>2</sup>. The only connections required are a bias voltage, the microphone output(s), the ASIC inputs and ground; all other components are included in the devices including 1nF filter capacitors. The IP5001 is for a balanced microphone and the IP5002 is for a single ended microphone.



IP5001CX11



IP5002CX8



The IP5001CX11 is shown as an example



Integrated Discretres for Cellular Usage

USB Interfaces

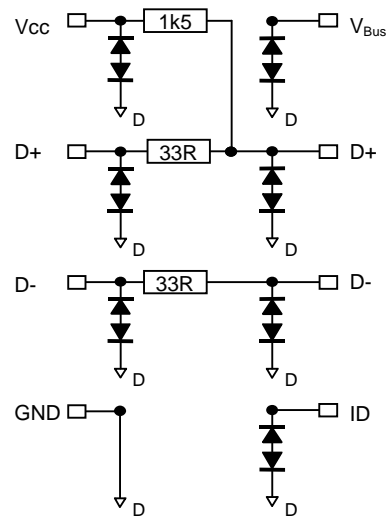
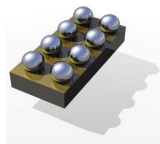
USB 1.1 & USB2.0OTG ( at Full Speed) IP4058CX8

The IP4058CX8 is a very small device measuring only 2mm<sup>2</sup> with a footprint specifically matching to the USB connector. Suitable for low speed and full speed data rates as well as for USB *On The Go* (OTG) with external pull down resistor switching.

Refer to Application-USB\_IP4058 for further details. The ESD protection capability of a diode is proportional to the area of the diode.

For USB, line capacitance is a critical parameter; this is also proportional to diode area. In order to achieve a low line capacitance and meet the capacitance requirements of the USB specification Philips Integrated Discretres has developed a wide range of different protection devices.

$C_{line} = 35pF$   
 $R_{datalines} = 33\Omega$

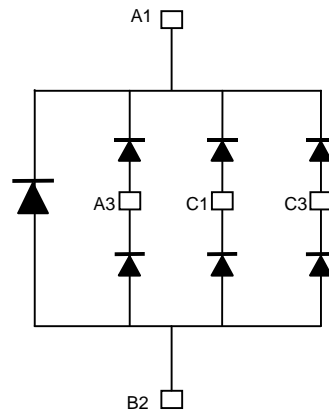


IP4058CX8 Schematic view

USB2.0 (High Speed, Full Speed & LowSpeed) IP4059CX5

The latest development in the field of physical transmission in the USB technology is the USB2.0 High Speed (HS) standard. This operation mode requires as low as possible line capacitances, especially for protection devices and allows no series resistors in the data lines. Therefore, the IP4059CX5 consist of three ultra low capacitive protection channels to take care of both data lines and the ID pin for USB-OTG applications.

$C_{line} = 4.5pF$





## Integrated Discretes for Cellular Usage

### General Purpose Multi-Channel Interfaces (e.g. Data I/O, Keypad, LCD)

#### IP4040CX25<sup>1</sup>, IP4041CX25, IP4035CX24, IP4032CX25, IP4053CX15, IP4054CX15

The typical application area for these device are busses of 8-bit width or more that are often used for Data I/Os, LCD-Displays and other short range, high speed data transmissions or to protect e.g. the keypad input pins.

Depending on the application area, parameters such as channel resistance and line capacitance are the most important.

For average Data I/Os IP4032CX25 or IP4041CX25 are the devices of choice, whereas for high-speed data busses up to 40MHz and more, the IP4040CX25 is the appropriate solution.

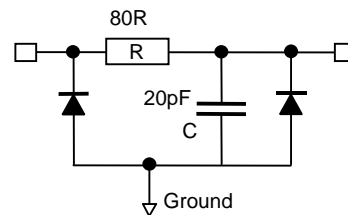
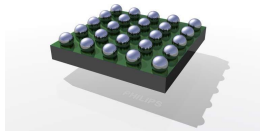
When it comes to low-speed I/Os, such as the keypad, IP4035CX24 offers the maximum filter performance. Smaller busses can easily be protected from ESD and EMI by use of either IP4053CX15 or IP4054CX15 for up to 6 respectively 4 channels, depending on the bus width.

#### IP4032CX25

A device featuring 10 identical channels with a low impedance of 80Ω per channel only. The lower impedance allows higher speed data to be transmitted; it will also allow data and audio functions to be combined for a system connector.

$$R = 80\Omega$$

$$C_{\text{line}} = 43.4\text{pF}$$



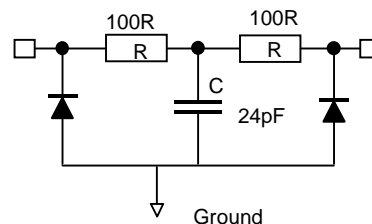
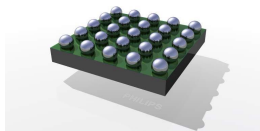
Schematic of 1 channel

#### IP4041CX25

Another device featuring 10 identical channels with an identical pinning to the IP4032CX25 but a slightly different filter. The higher impedance and channel capacitance results in a stronger attenuation for non high-speed data transmitting interfaces such as (monochrome) LCD displays. It will also allow data and audio functions to be combined for a system connector.

$$R = 2 \times 100\Omega$$

$$C_{\text{line}} = 63\text{pF}$$



Schematic of 1 channel

<sup>1</sup> IP 4032CX25, IP4040CX25 and IP4041CX25 have an identical footprint and pinning. All three devices are suited to protect according the IEC61000-4-2 method, level4, ±15kV air discharge and ±8kV contact discharge

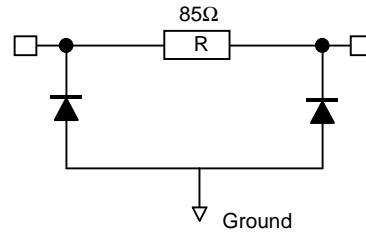
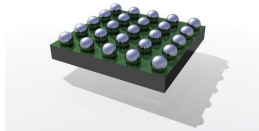


## Integrated Discretes for Cellular Usage

### IP4040CX25

Yet another 10 channel filter, pin compatible to the IP4041CX25 and IP4032CX25 but with a very low channel capacitance to be used in digital high-speed interfaces (e.g. LCD control). The lower impedance allows higher speed data to be transmitted; it will also allow data and audio functions to be combined for a system connector.

$R = 85\Omega$   
 $C_{line} = 14pF$



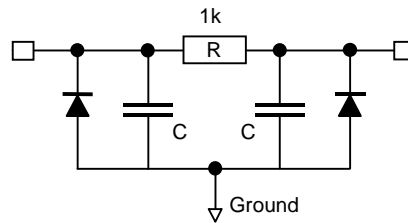
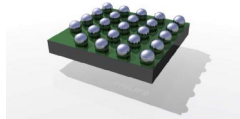
Schematic of 1 channel

### IP4035CX24

Featuring 10 identical channels with  $1k\Omega$  series resistance, EMI filtering and ESD protection. The IP4035CX24 contains 50 components in an area of only  $6.4mm^2$  and can be placed with normal high speed placement equipment. The package has been optimized to meet all reliability tests without the need for underfill.

Suitable for low speed interfaces e.g. keyboard.

$R = 1k\Omega$   
 $C_{line} = 25pF$

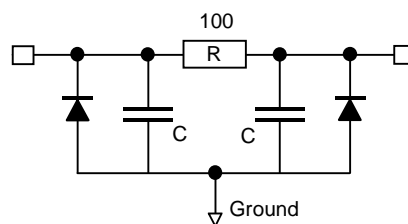
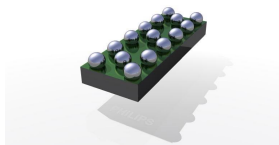


Schematic of 1 channel

### IP4053CX15 & IP4054CX15

Featuring 6 identical channels (IP5053CX15) respectively 4 identical channels plus 4 single ESD-protection diodes (IP4054CX15) with  $100\Omega$  series resistance per channel, EMI filtering and ESD protection. both devices are ideal for EMI-filtering and ESD-protection of smaller busses. The package has been optimized to offer an as simple as possible routing.

$R = 100\Omega$   
 $C_{line} = 60pF$



Schematic of 1 channel



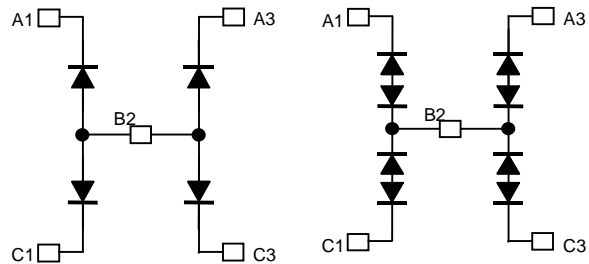
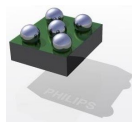
Integrated Discretes for Cellular Usage

Multi Purpose Diode Arrays IP4042CX5, IP4043CX5

IP4042CX5, IP4043CX5

Two general-purpose ESD arrays suitable for local protection of devices. The IP4042CX5 has 4 single diodes in an extremely small 1.38 x 0.92mm package. The IP4043CX5 has 4 pairs of back to back diodes to allow AC-signals. This has further benefits of not demodulating large induced signals. The back-2-back diode pairs also reduce the capacitance to less than 20pF.

IP4042CX5:  $C_{jo} = 30\text{pF}$ ,  $V_{BR} = 7.5\text{V}$   
 IP4042CX5:  $C_{jo} < 20\text{pF}$ ,  $V_{BR} = 16.5\text{V}$



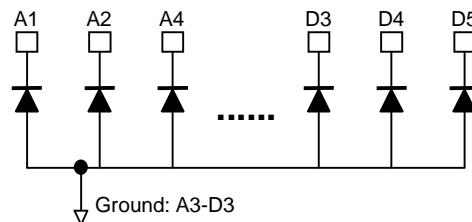
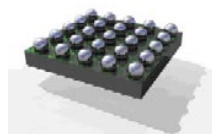
Schematic of IP4042CX5

Schematic of IP4043CX5

IP4080CX20

A large general-purpose ESD-protection array suitable for local protection of devices. The IP4080CX20 contains 16 single diodes with 15pF at 0V only. Due to the very small device size of only 1.96mm by 2.52mm, the IP4080CX20 offers a ratio between number of protected pins and device size that is unique. The implemented ESD-protection diodes are IEC61000-4-2, Level 4, ±8kV contact and ±15kV air discharge compliant.

$C_{jo} = 15\text{pF @0V}$



Schematic of IP4080CX20



## Integrated Discretes for Cellular Usage

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### Active Devices

#### Summary

Philips Integrated Discretes offers a variety of different integrated active functions. Depending on the customer requirements, such as operating voltage, power consumption requirements and functionality, different technologies can be used.

Available are:

- Bipolar
- High-Voltage CMOS ( $U_{BR} \sim 55\text{Volt}$ )
- BiMOS

Examples of integrated functional blocks:

- Switches
- Level-Shifters
- Temperature Sensors
- Reference Sources (Voltage and Current)
- Logic
- Voltage and Current clamping

Besides the active functions as described above, passive filters and ESD-protection diodes are also available. An ESD-protection level compliant to IEC61000-4-2, level 4 standard ( $\pm 8\text{kV}$  contact and  $\pm 15\text{ kV}$  air discharge) can be reached.



## Integrated Discretes for Cellular Usage

### APPLICATION

As with any device used for filtering or protection, board layout and device placement are very important. Data given in this report is based on using a multi layer printed wiring board with ground connections made directly to a ground plane within the PCB using micro vias.

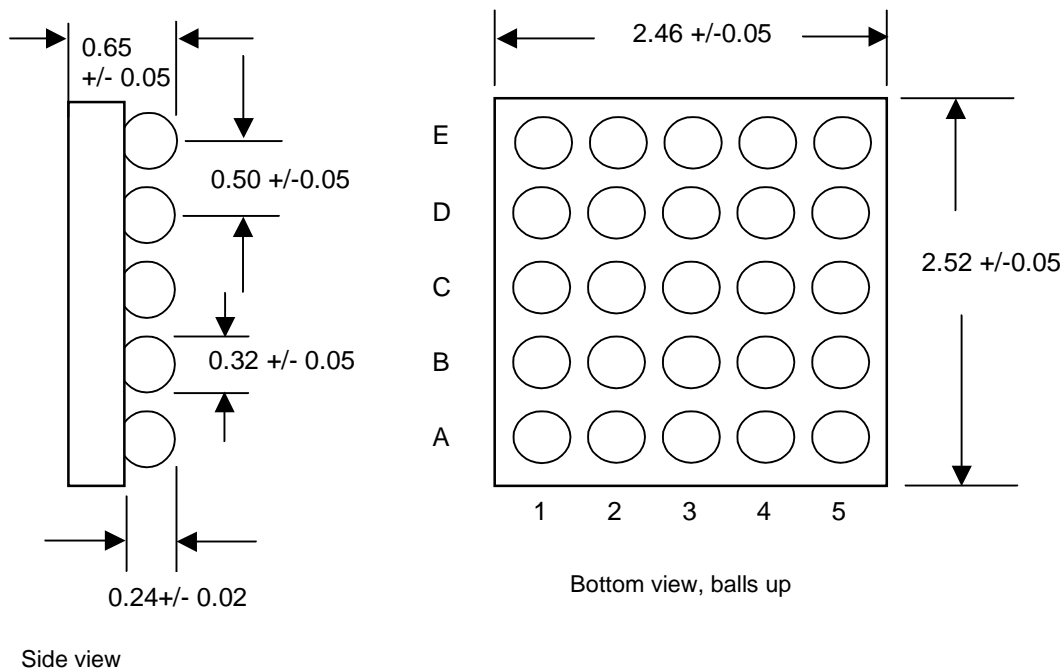
The small footprints of the devices allow them to be placed in the optimum position close to the external connector or device. This provides the maximum filtering of unwanted signals. In devices for specific applications the pinning is chosen to match with the standard connector for that application e.g. SIM card or USB.

### Grounding

For maximum efficiency of filtering and ESD protection the devices should be connected to a ground plane with a micro via. If this is not possible the connection to the ground plane should be as direct as possible to minimize the inductance; the ground should be directly connected to e.g. the USB connector ground. It should not be on a "spur".

### Chip Scale Package

Example of a 5x5  $\mu$ CSP package outline





## Integrated Discretes for Cellular Usage

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### Reliability

Chip Scale packaging has been available for several years. Philips has been supplying these packages since 1998, they have been extensively tested by suppliers and leading customers and by ourselves at our Centre for Manufacturing Technology centre in Eindhoven. These tests have determined the optimum parameters for p.w.b. design, placement and soldering to ensure all applicable reliability tests can be met. It has been proven that all Philips Integrated Discretes devices in *UltraCSP* up to 6x6 solder balls do not require any underfill.

Philips Integrated Discrete products can already be used with lead free soldering processes and most devices are available as lead-content and also as lead-free devices with an identical electrical performance.

### References

#### Philips Semiconductors Integrated Discretes:

ESD and Filter guidelines for Integrated Discretes ( Application - ESD&Filter )  
Filter considerations ( Application - Using ID's Filters and PCB )  
Chip Scale Package ( Application - Chip Scale Packaging )  
Application Notes USB Chip Scale Interface Device IP4058CX8  
Relevant datasheet for each product

#### Philips Semiconductors

##### Connectivity:

ISP1105/1106/1107 Datasheet

##### International Test Standards:

IEC 61000-4-2

MIL-883E Methode 3015.7



## Integrated Discretes for Cellular Usage

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