Converting between AES/EBU and S/PDIF interfaces

There are differences in the electrical characteristics of AES/EBU and S/PDIF interfaces:

- AES/EBU uses a balanced differential line based on XLR connectors and the signal levels are 5 volts
- S/P-DIF uses a coaxial unbalanced line with RCA connectors and the signal levels are around 0.5 volts

You can convert one electrical interface to another with a small amount of off-the-shelf hardware and a little time as you can see in the circuit below.
But the protocol used in AES/EBU and S/PDIF is not exactly the same and that can cause sometimes problems. The basic data format of AES and S/P-DIF are identical. There is a bit in the channel status frame that tells which is which. Depending upon the setting of that bit, some bits have different meanings. For example, the bits used to describe de-emphasis in the AES/EBU protocol overlap the bits used to implement the SCMS protocol in S/P-DIF land.
The big problem comes in the fact that MANY products out there are VERY picky about what they see in the bits, and even though a given signal may fall within the letter of the standard, some equipment will absolutely refuse to talk to it. Many equipments are reasonably flexible and tolerant of slight foos in the signal so the simple converters cna work on those. But a simple converter that works fine with one piece will as likely not work with another.

What are different types of IEC 958-interface

There are 2 implementations of IEC 958: consumer and professional. Those are referred in standard as IEC958 Types I and II. IEC958 professional format is same as AES/EBU but is carried over same type of coaxial or optical interface as consumer S/PDIF. IEC958 consumer format is the S/PDIF format used in CD-players. You can put an S-PDIF data stream on an AES/EBU physical balanced cable, or vice versa, and still have it be valid IEC958 data. Professional and consumer formats (Types I and II) differ only in the subcode information. In order to do track indexing, you must have a consumer format data stream (ie. an S/PDIF style data).

Jitter specifications of AES/EBU interface

The AES/EBU standard for serial digital audio uses typically 163 ns clock rate and allows up to +-20 ns of jitter in the signal. This peaks to peak value of 40 ns is aroun 1/4 of the unit interval. D/A conversion clock jitter requirements are considrably tighter. A draft AES/EBU standard specifies the D/A converter clock at 1 ns jitte; however, a theoretical value for 16-bit audio could be as small as 0.1 nsec. Small jitter D/A conversion is implemented by using separate PLL clocks for data recover and DAC and by using a buffering between data recovery and DAC.

Conversion circuits

Here are some AES/EBU and S/PDIF circuit collected from various sources. The following circuit will only convert the signal levels, not other protocol details.

Remeber that although the audio data is the same in both AES/EBU and S/PDIF interfaces, they are indeed different formats, at least in their subcode. AES converted to coax is NOT S/PDIF, and S/PDIF converted to XLR balanced is NOT AES. They are still their native format, just the transmission medium has changed. Whether they will work in your application depends on the equipment chosen.
Some DATs have a switch that selects one format or the other regardless of the physical interface, some just ignore what they don't understand (usually resulting in the generally positive benefit of ignoring SCMS encoding), and some indeed gag on the "other" format. But simply fixing the physical interface works far more often than it doesn't.

How to do different conversions using the circuit below

Here are some ideas how to make the most common conversions using the circits described below. Note: there is no guarantee that the information in this or the circuit are correct (they are believed to be correct but note tested by the author).

- AES/EBU to S/PDIF: There is complete circuit for this
- S/PDIF to AES/EBU: There is complete circuit for this
- S/PDIF to optical: S/PDIF coax input circuit followed with optical TOSLINK output
- Optical to S/ODIF: Optical TOSLINK receiver followed with S/PDIF output buffer circuit
- CD-ROM digital output to normal S/PDIF: S/PDIF output buffer circuit does this
- CD-ROM digital output to optical: Connect optical TOSLINK output circuit to CD-ROM output

For every other conversion combination you can think of you can find circuits on the lis below. To build an dapter you need two parts connected after each other.

- First you need an input circuit which converts the input you want (coax,optical or AES/EBU) to TTL format (if the input is in TTL format you don't need any input circuitry)
- Connect a suitable output circuit with TTL input after the receiving electronics to give you the output format you want (coax,optical,AES/EBU,TTL)

After you have slected the suitable circuit parts, built them an attached them together you get the conversion circuit you want. If you need more than one output, you can connect few (1-4) output modules to one input circuitry to have more then one output.

AES/EBU to S/PDIF signal level converter

```
AES out:   2-------330 ohm-----+-------------   SPDIF in
                               |
           3--+             91 ohm
              |                |
           1--+------+---------+-------------
                     |
                     -
                ground
```

The idea for this circuit is taken from articles posted to Usenet News.

If you are looking for a professional components for 110 ohm to 75 ohm interconnection then check Canare web site where they have 110 OHM-75 OHM IMPEDANCE TRANSFORMERS.

S/PDIF to AES/EBU

```
                                            _
                   + 5 volt                | \
SPDIF out:           |                   +-|  O-+
                     _ +--4,7k-+         | |_/  |
               diode ^ |  _    |     _   |  _   |
       10 u (+)      | | | \   |    | \  | | \  |      100 n
O--+--+-||-+---------+-+-|  O--+--+-|  O-+-|  O-+-120 r-||-+----+-- 2
   |  |    |         |   |_/   |  |  |_/    |_/             |    |
   |  +-||-+ 100n    _      2,2k  |                       1 k   |
  75r                ^ diode   |  |    IC                  |    |   AES in
   |                 |        ---  |                       ---   |
  ---               ---           |       _                    220r
                                  |      | \           100 n    |
                                  +--+---|  O---+--120 r-||-+---+--- 3
 Diode = 1N914 or 1N4148             |   |_/    |           |
                                     |    _     |         1 k   +--- 1
                                     |   | \    |           |   |
    IC = 74HC04 or CMOS 4049         +---|  O---+          --- ---
                                         |_/
```

S/PDIF conversion circuit building blocks

This is a collection of S/PDIF circuits found from various sources. The circuits are presented as building blocks which have one end on S/PDIF standard signal and other end an TTL level signal. The TTL levle signal end of the circuits is designed to be the the interface which you can use to wire different modules together to make whatever S/PDIF converter circuit you want. The circuit are presented as building blocks because with this approacs you can most easily build a suitable circuit for all conversion needs.

Here are tips for building a conversision circuits for different uses:

- Coaxial S/PDIF to optical: Select any S/PDIF coaxial input circuit and connect it's TTL output to one optical S/PDIF (Toslink) output circuit.
- Optical S/PDIF to coaxial: Select one optical S/PDIF input circuit and connet it's TTL output to any coaxial S/PDIF output circuit.
- CD-ROM digital out to coaxial: CD-ROMs output TTL level S/PDIF, so get it to caoxial you just need a coaxial output circuit where you directly connect the digital signal from your CD-ROM drive.

For other conversion needs do a little thinking and you should find quite easily the answer what blocks to connect to each other.

S/PDIF output buffer circuits

Here is set of output circuit which take in TTL level S/PDIF signal in and output standard S/PDIF coax cable output signal. Those output circuit are very useful building blocks for all kinds of S/PDIF related electronics projects. All the circuits do basically the same thing. They just use different components, so use the one where uou can easily get components.

S/PDIF output buffer circuit

```
                                                          S/PDIF output
                                                          (RCA or BNC)
                            |\
TTL level signal -----+-----| O-----680R--+---------+    +------- center pin
                      |     |/            |         |    |
                      |                   |          )||(
                      |     |\            |          )||(
                      +-----| O-----680R--+          )||(
                            |/            |          )||(
                                        100R        |    |
                          74HC04          |         |    +------- ground
                                          +----+----+ T1
                                               |
                                              ---
```

Idea for this circuit is taken from "A digital Output for the CD720" web page (was at http://www.spiceisle.com/homepages/brian/audiodiy/mods/digi-out.htm). The transformer T1 is high quality 1:1 pulse transformer (can be salvaged from old broken network interface card or similar source).

Another S/PDIF output circuit

```
                            |\
                      +-----| O-----------+
                      |     |/            |               S/PDIF output
                      |                   |  100nF        (RCA or BNC)
                      |     |\            |   ||      T1
TTL level signal -----+-----| O-----------+---||----+    +-------+--75R---
center pin
                      |     |/            |   ||    |    |       |
                      |                   |          )|| |       |
                      |     |\            |     15   )||(  3    220R
                      +-----| O-----------+    turns )||( turns  |
                      |     |/            |          )|| |       |
                      |                   |         |    |       |
                      |     |\04          |         |    +-------+--------
ground
                      +-----| O-----------+         |
                            |/                     ---

                          74HCU04
```

This circuit is part of circuit "Splitter for S/PDIF coax/optical output" by T. Giesberts from Elektor Electronics magazine July/August 1995 pages 78-79. The transformer T1 is made to G2.3-FT12 ferrite ring core. Primary coil is 15 turns of 0.5 mm diameter enamelled copper wire and secondary is 3 turns of 0.5 mm diameter enamelled copper wire. The chip 74HCU04 is manufactured by Philips

The circuit in the magazine had 3 outputs. The two extra output were made by adding two more output coils to T1 and the output resistors.

Output circuit with transformer used as impedance matcher

This circuit is taken from Digital One V. 1.1 documentation. Digital One is from NET-Labs and is designed by by Enland Unruh.

```
                                                               S/PDIF output
```

```
                            IC1              0.1 uF        0.1 uF
                            |\                ||            ||
TTL level signal -----------| +-----750R--+---||----+    +--||--- center pin
                            |/            |   ||    |    |  ||
                                          |          )||(
                                          |          )||(
                                          |          )||(
                                          |          )||(
                                        499R        |    |
                                          |         |    +------- ground
                                          +----+----+ T1
                                               |
                                              ---
```

T1 is a HF-transformer which has 2:1 turns ratio. Transformer type used in example circuit is SC944-05. IC1 in this circuit consists of 8 parallel connected buffer ports from 74ACQ244 IC.

Output with 1:1 pulse transformer

This is the recommended S/PDIF output circuit from Crystal Semiconductor CD4237 single chip multimedia audio system IC datasheet page 71.

```
                                                               S/PDIF output
                            IC1
                            |\
TTL level signal -----------| +-----374R--+---------+    +------- center pin
                            |/            |         |    |
                                          |          )||(
                                          |          )||(
                                          |          )||(
                                          |          )||(
                                       90.9R        |    |
                                          |         |    +------- ground
                                          +----+----+ T1
                                               |
                                              ---
```

The transformer used in this circuit is 1:1 pulse transformer (the original application note suggested pulse transformer from Pulse Engineering or Schott Corporation). IC1 is a buffer IC which must be capablw to supply enough current to drive the 75 ohm S/PDIF interface to full votlage swing specified (capable of loading 415 ohm load or capable of supplying 12 mA current).

Simple S/PDIF output without galvanic isolation

```
                            |\
                      +-----| O-----------+
                      |     |/            |               S/PDIF output
                      |                   |  150nF        (RCA or BNC)
             |\       |     |\            |   ||
TTL level ---| o------+-----| O-----------+---||-----374R---+----- center pin
signal       |/       |     |/            |   ||            |
                      |                   |                 |
                      |     |\            |                93R1
                      +-----| O-----------+                 |
                      |     |/            |                 +----- ground
                      |                   |                 |
                      |     |\            |                ---
                      +-----| O-----------+
                      |     |/            |
                      |                   |
                      |     |\            |
                      +-----| O-----------+
                            |/

                          74HTU04
```

This circuit does not provide any isolation on the output. The TTL level signal form 74HCT04 buffer is attenuated to the levels specified in S/PDIF optical interface by using the voltage divider made of 374 ohm and 93.1 ohm resistors. This circuit is based on S/PDIF converter circuit diagram from Elektor Electronics magazine issue 4/1997 page 66.

Simplest TTL to S/PDIF coax interface

```
        100nF
  TTL ----||-----330ohm--+--------- coax S/PDIF signal out
  in                     |
                       100ohm
                         |
 Ground -----------------+--------- coax signal ground
```

This ricuit interfaces directly to the TTL level output provided by some sound equipment (CD-ROM or soundcard). This circuit works if the equipment which gives out TTL level has powerful enough TTL output to run this circuit (enough current output capability). If this simple circuit does not work reliably, then you need to build a circuit which includes the buffering electronics.

Isolation transformer for S/PDIF output

If your equipment (for example sound cards) has an S/PDIF output which does not have an isolation transformer at the output, you can easily add the transformer to it by putting a suitable transformer afther the original output. Elector Electronics magazine issue 7-8/1999 recommend building the transformer for S/PDIF isolation in the following way:
The transformer must have good coupling factor, so the transformer core must be a toroidal core made of high permiability material. The prototype described in the magazine uses Philips Type TN13/7.5/5-3E25 core which has permiability rating (yt) of 4500. THe primary and secondary windongs consisted of 6 turns of 0.5 mm diameter enamelled copper wire laid on opposite sides of toroid. The transformer used in this prototype was described to have a bandwidth raged from 50 kHz to 17 MHz, which is more than adequate for an S/PDIF link.

The transformer should be fitted directly to the source and the receiving end must be protperly terminated for reliable operation. The reason for this is that the transformer input and output impedances are not exactly 75 ohm.

S/PDIF input circuits

The following circuits can be used to convert S/PDIF signals to TTL level signals which can be connected to any suitable output circuit or directly to digital electronics.

S/PDIF coax input circuit

```
                                   +----10K--+
                      10 nF        |         |
                       ||          |    |\   |        |\
S/PDIF input ------+---||----100R--+----| O--+---+----| O----- TTL out
                   |   ||               |/       |    |/
                  75R                           10K
                   |                 74HCU04     |
                  ---                           ---
```

This circuit is part of circuit "Splitter for S/PDIF coax/optical output" by T. Giesberts from Elektor Electronics magazine July/August 1995 pages 78-79. The chip 74HCU04 is manufactured by Philips

Another input circuit

```
                            +----10K----- +5V
                            |     /\
                           ---     |
                     4700 pF       |
                       ||          |    |\            |\
S/PDIF input ----------||----------+----| O-----------| O----- TTL out
(+/-500mV)             ||               |/            |/

                                         7404
```

The capacitor works as DC blocking capacitor. 10 kohm trimpot signal raises its ground potential to the point that Hex Inverter IC1 recognizes the difference between a digital 1 and 0 input. When you firt test the circuit then first addjust 10 kohm trimmer to the center and then adjust it so that the circuit receivers the S/PDIF signal well. If you have a voltmeter, you can adjust the trimpot to show around 2.6V at pin 1 of the IC. The inverter buffers the input and produces TTL 0-5V output signal. This circuit does not provivide the 75 ohm termination resistor, so you need to add it if you have problems because of cable signal reflections. This circuit is ppart of Coax Digital Out to MD circuit design.

Optical S/PDIF output circuit

Optical TOSLINK output

```
                        ________________
                      4|               ___|
 TTL signal -----------|              /
                       |             |
                      3|             |
 +5V--4R7--+-----------|             |
           |          2|   TOTX173   |
           +---8k2-----|             |
           |           |             |
          === 100 nF   |             |
           |          1|             \___
           +-----------|________________|
           |
          ---
```

The 4.7 ohm resistor and 100 nF capacitor make a filter against digital noise in +5V power source. The Toslink transmitting module used in this circuit is TOTX173 from Toshiba. This circuit is a part of circuit diagram from Elektor Electronics magazine issue 4/1997 page 65.

TORX173 and TOTX173 module pinouts

Toshiba optical receiver & transmitter modules used for S/P-DIF TORX173, TOTX173 top view:

```
    opto
   +----+
  6.    .5
   +....+
    1234
```

```
Pin  TORX173     TOTX173
1    out         GND
2    GND         R
3    Vcc         Vcc
4    GND         in
5    case(GND)   case(GND)
6    case(GND)   case(GND)

Vcc  +5V (use 0.1 uF decoupling to GND)
         (use 47 uH choke to connect Pin 3 to Vcc for TORX)
R    8.2 kOhm to Vcc
```

TORX and TOTX are both high active and are CMOS/TLL logic compatible. More information and datasheets is available at Toshiba optoelectronics components web page TOSLINK section.

Very cheap optical S/PDIF output

With TOSLINK modules available for as low as $10 it hardly seems worth it to bother with the trouble of making your own TOSLINK module due to the fact that the ones from Sharp have a built-in connector and are much easier to interface. But if you really want to make your own optical output interface, you can do it because S/PDIF optical (Toslink) transmitter is just basically a red LED coupled to the optical fiber. So to build a very basic output circuit you only need a red LED and a resistor, both available from any place where electronic components are sold.

The circuit is very simple:

```
                    _____
TTL signal -------|_____|---------+
```

```
                                   |
                                  ---
                                   V  LED
                                  ---
                                   |
    Ground -----------------------+
```

The idea of the circuit is that the digital data is fed through a series current limiting resistor to the LED (typically LEDs only require 5-30mA). A digital 0 is 0V and the LED is off. A digital 1 is +5V and the LED is on. That's it!
If for some reason the circuit does not work, try to change the LED and also try to connecting it better to the optical fiber. NOTE: Not all LEDs will work, so you may have to experiment a bit. Optimally, you want a high-brightness RED LED with a typical wavelength of 660nm.
If swapping the LED doesn't work, you might want to try using a hex inverter (7404 or similar IC) to buffer the signal. This might be good practice too, just in case the TTL SPDIF output of your source device isn't designed to handle a 20~30mA load this circuit generates.

Optical S/PDIF output circuit

Optical TOSLINK receiver

```
       _____________
      |___          |1
          \         |----------------- TTL output
           |        |
           |TORX173 |3
           |        |----+----coil47uH----- +5V
           |        |    |
           |        |   === 100 nF
           |        |2   |
           |        |----+
           |        |4   |
           |        |----+
           |        |5   |
           |        |----+
           |        |6   |
        __/         |----+
       |____________|    |
                        ---
```

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   +----+
  6.    .5
   +....+
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```

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5    case(GND)    case(GND)
```

```
6    case(GND)   case(GND)

Vcc  +5V (use 0.1 uF decoupling to GND)
         (use 47 uH choke to connect Pin 3 to Vcc for TORX)
R    8.2 kOhm to Vcc
```

TORX and TOTX are both high active and are CMOS/TLL logic compatible. More information and datasheets is available at Toshiba optoelectronics components web page TOSLINK section.

Other related information

Who makes AES/EBU digital audio transceiver chips ?

DSP FAQ mentions that Sony, Crystal Semiconductor, Motorola and Yamaha have all AES/EBU tranceiver chips available. DSP FAQ contain more information about AES/EBU chips at http://tjev.tel.etf.hr/josip/DSP/FAQ/42.html. Same companies which have AES/EBU chips have also SPDIF chips and some chips can handle both formats.

Information sources

- About SP-DIF by DJ Greaves
- DSP FAQ
- Elektor Electronics magazine July/August 1995 pages 78-79
- Public domain S/PDIF document found in in the net (that article did not mention the author name)
- David K. Fibush, Jitter Effect and Measurement in Serial Digital Television Signals, SMPTE Journal, August 1993, pages 693-698
- Various articles from usenet newsgroups sci.electronics.design, rec.audio.pro and rec.audio.tech
- Super-Cheap TOSLINK Module web page