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# DIRAC

**The video compression family using open technology**

# DIRAC

**Are you in search of the ideal video compression format? Do you find that one of your biggest challenges is the myriad of proprietary media formats? Does the stringent and complex licensing environment put you off making decisions? Do your customers operate on a range of different platforms? Are you paying out very large amounts of money for codec license fees? If so the Dirac video codecs developed by the BBC are for you.**

## Dirac

Dirac is a general-purpose video compression family suitable for everything from internet streaming to HDTV.

Dirac achieves state of the art performance – good quality at low bit rates, leading to lower costs.

Dirac is an open technology – removing licensing costs on software, hardware and content flow. Dirac's technical flexibility offers a versatile package, facilitating ease of operation over many applications and therefore saving money.

## Dirac Pro

Dirac Pro is a version of the Dirac family of video compression tools, optimised for professional production and archiving applications.

It is designed for simplicity, efficiency, and speed, and intended for high quality applications with lower compression ratios.

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# INTRODUCTION TO THE DIRAC FAMILY

The use of video compression is ubiquitous within the broadcast industry. Almost everywhere video is handled digitally so some form of video compression is involved. As the transition to digital technologies matures video compression will become ever more critical in all aspects of programme making and distribution. Many video compression options are available, such as the MPEG series of standards, but these do not meet all our needs. Building on our long experience of video compression, dating back to the 1960's, we have continued to develop innovative compression solutions to meet our specific needs. Furthermore the BBC, as a publicly funded body, is in a unique position to produce open technology that may be freely used by all.

## Dirac

Over the past few years the BBC has developed an advanced video compression system, called "Dirac", which is comparable with the latest standards, H264/MPEG-4 AVC and VC-1. Potential uses of this codec (coder/decoder) include Internet distribution such as web clips, video on demand and IPTV. With industry plans for "On Demand" TV and streaming over the Internet open platforms technologies like Dirac have become more significant. The way Dirac has been developed allows it to be used on any platform and without the payment of royalties. These attributes will also support the BBC in supplying free video tools to Schools and educational bodies to allow them to use the free content made available by the BBC's Creative Archive and Open Archive. And the freedom from royalties should reduce our costs allowing more money to be used for programme making.

Dirac has continued to mature with improved performance both in terms of compression and implementation. The technology behind Dirac and Dirac Pro is now robust, effective and easy to implement. An extensive and detailed specification has been created and published to allow anyone to develop their own products. Software implementations of the Dirac Family codec are freely available for download at [www.sourceforge.net/projects/dirac](http://www.sourceforge.net/projects/dirac).

Dirac may be used for a wide range of applications from low resolutions for mobile phones and the Internet through HDTV and to ultra high resolution Digital Cinema. Dirac's wavelet technology has proved particularly well matched to high resolutions.

The BBC is working with industry bodies such as the SMPTE (Society of Motion Picture and Television Engineers) to standardise the technology. We first publicly demonstrated compression of HDTV using Dirac in 2005.

## Dirac Pro

The Dirac technology has been extended for high quality production use including transportation of signals between studios and production areas. In addition it can be utilised for desktop production over IP networks, file storage and video editing. This development, called Dirac Pro, is an extension to the Dirac Family and shares many traits. Between them they provide a family of codecs that work well together on a wide range of bit rates from below 100kbit/s to more than 1Gbit/s, with Dirac Pro being most suitable above 100Mbit/s.

The initial application for Dirac Pro, defined as Dirac Pro 1.5, was for use in transporting full HDTV (1080P50/60). The high frame rate of full HDTV conveys a more fluid motion than the conventional 24/25 frames/s video. The BBC plans to move to this higher quality standard, particularly suitable for sport such as the 2012 Olympic Games, over the next few years. Without a technology like Dirac Pro it would be necessary to re-engineer studio cabling, at significant cost. Dirac Pro provides 2:1 compression, with almost no loss in quality, allowing the full HDTV video to be carried on the same cables and infra structure used for conventional HDTV.

A second application of Dirac Pro (defined as Dirac Pro 270) is to allow the transmission of HDTV signals using the cables and infrastructure formerly used for standard definition television. This requires more compression of HDTV signals than Dirac Pro 1.5 but Dirac Pro is sufficiently flexible to allow this to be achieved with little loss in quality.

As part of our commitment to standardisation we have initiated proceedings with the SMPTE to formulate Dirac Pro's specification under the name VC-2.



# WHAT IS DIRAC?

Dirac is a very versatile compression family. It includes a range of tools which gives flexibility in performance to match the environment.

Dirac has the capability of compressing high resolution files for production, compression for broadcast content, and compression for web 2.0 applications. Compression can be either lossless or visually lossless, or it can exploit lossy compression using long-GOP formats for distribution. The compression efficiency is similar to that of AVC/H264 but without the encoding complexity or licence burden.

- Direct support of multiple picture formats 4 K E-Cinema through to QCIF
- Supports I-frame only up to long GOP structures
- Direct support of multiple chroma formats, e.g. 4.4.4/4.2.2/4.2.0
- Direct support of multiple bit depths, e.g. 8 bit to 16 bit
- Direct support of interlace via metadata
- Direct support of multiple frame rates from 23.97 fps to 60 fps
- Definable pixel aspect ratios
- Definable 'Clean Area' for inputs within larger containers
- Definable signal ranges and offsets
- Multiple colour spaces with metadata to describe:
  - Colour Primaries
  - Colour Matrices
  - Transfer Functions
- 32 bit frame numbers (more than two years at 60 fps) in both I frame only and Long-GOP
  - Definable wavelet depth
- A choice from multiple wavelet filters (including filters optimised for down-conversion)

## Applications

Dirac suits a wide range of applications from 2 K formats used for E-Cinema through to QSIF found on hand-held devices.

Dirac Pro offers high quality and low latency, with the high bandwidth operations found in production and post production, archiving and contribution links.

Dirac offers high compression for narrow bandwidth environments such as broadcasting and internet downloads, podcasting, peer-to-peer distribution and access services.

Whatever the application, it is possible to select parameters which offer the solution you need.

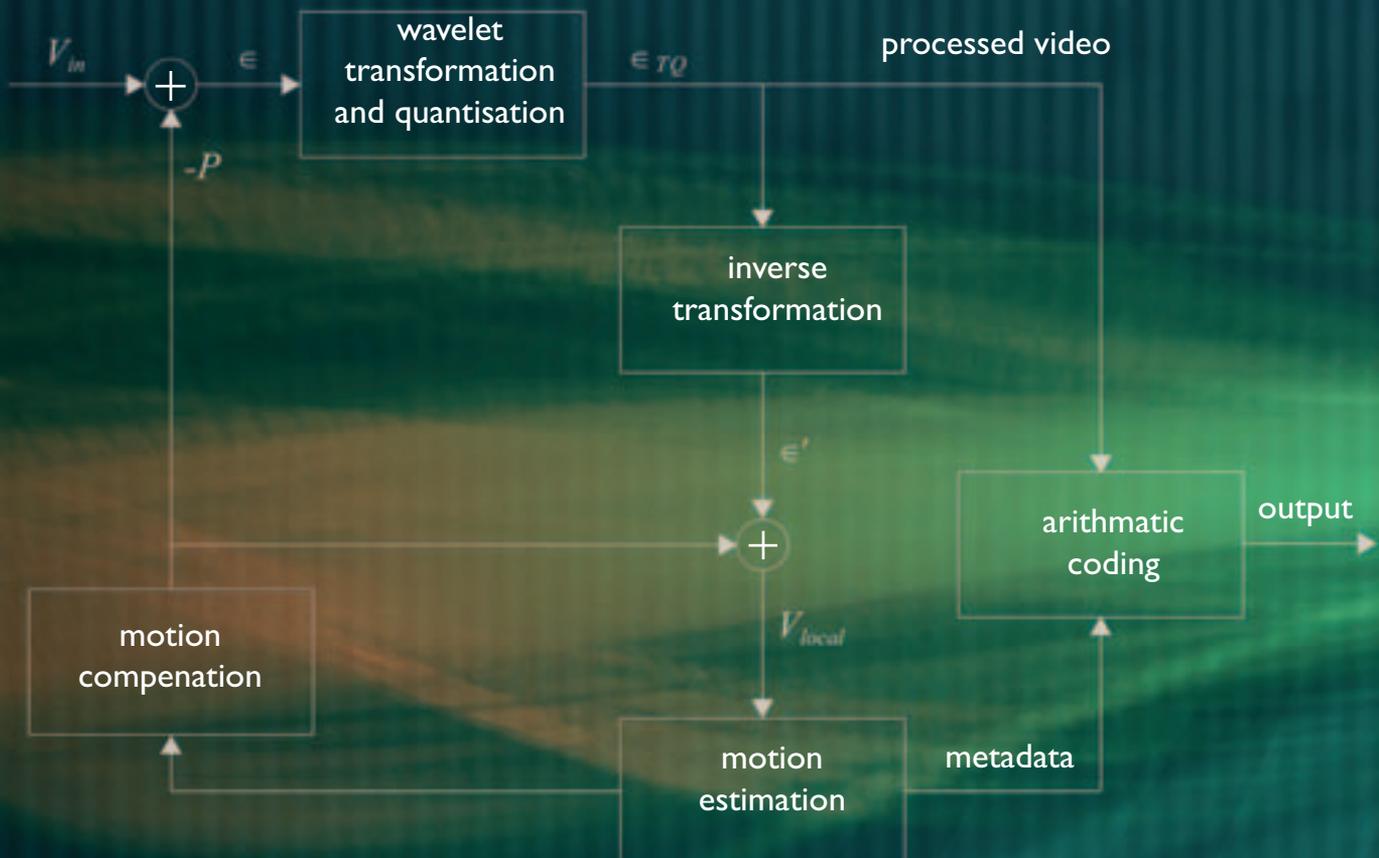
- Clip Distribution
- Live Streaming Video
- Pod Casting
- Creative Archive
- Peer to Peer transfers
- HDTV with SD Simulcast capability
- Higher density channel packing
- Desktop Production
- News links
- Archive Storage
- Digital Intermediate Film Out file storage
- PVRs
- Multilevel Mezzanine 3 GBit/s into 1.5 GBit/s, 1.5 GBit/s into 270 MBit/s, etc



# TECHNOLOGY

Dirac development has three main strands:

- A compression specification for the bytestream and the decoder
- Software for compression and decompression
- Algorithms designed to support simple, and efficient hardware implementations



## Dirac Architecture

Dirac is similar to many of the established video coding systems. However we have adopted established technologies which combine effectiveness, efficiency and simplicity. Together these features give us a quality system which is not encumbered with patents.

First we use motion compensation to make use of the correlation between picture frames. Good motion compensation can dramatically reduce the amount of data required to code a picture.

Then we use wavelets (not the more conventional DCT) to transform the residual error signal.

## Motion Compression

Dirac like other modern codecs has a flexible GOP (Group of Pictures) structure. This allows it to be used for a wide range of applications trading off latency against compression efficiency. In addition to the standard block base motion vectors Dirac can also use global motion parameters e.g. pan, tilt, zoom and rotate to achieve efficient compression.

## Transform coding

Wavelets are commonly used for still image compression e.g. JPEG2000. We are now using wavelets for video compression. These wavelets repeatedly transform and filter the signals into low and high frequency parts. This repeated splitting concentrates the important data in one subband, which can then be efficiently encoded. We apply different degrees of quantisation to the transformed data as the human eye is insensitive to coarse quantisation in some of the high wavelet bands. We exploit this to achieve high compression efficiency.

One of the weaknesses of MPEG-2 is the way that the picture goes all blocky when the coder is being worked hard. The use of the Discrete Cosine Transform (DCT) limits the flexibility of the blocks used in the processing. By using wavelets, we can achieve more flexibility and prevent blocking, improving picture quality.

## Entropy coding

The transformed data still has redundancy. Entropy coding is used to reduce the data size, a process similar to computer Zip files. Dirac uses two entropy coding techniques, 1) A variable length code called exp-Golomb and 2) arithmetic coding. Arithmetic coding separates statistical modelling from the compression process itself and results in better compression quality.

Dirac applies entropy coding to both the motion vectors and the output of the wavelet transform process.

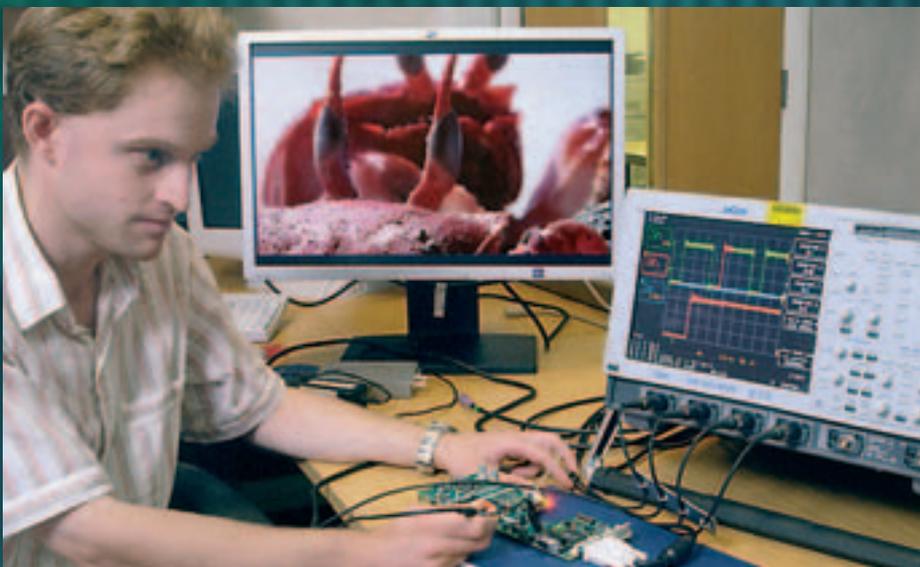
## Bytestream

The whole of the compressed data is packaged in a simple bytestream. This includes synchronisation information, permitting access to any frame quickly and efficiently – making editing simple. The structure is such that the whole bytestream can be packaged in many of the existing transport streams, such as MPEG, MXF, Ogg, etc.

## Dirac Pro

There are three differences between Dirac and Dirac Pro:

1. I-Frame coding - which means that each frame is coded independently, making editing and production easier
2. Dirac Pro – only uses exp-Golomb coding, which makes hardware and software implementation simple, efficient and low cost
3. The data is repackaged to achieve low latency, down to very few picture lines.



# THE OPEN ENVIRONMENT

## So, Dirac is free – what does that mean in practice?

Given the surfeit of other codecs why is there a need for another codec, such as Dirac, and what does it provide to broadcasters that the others don't? The key feature of Dirac, in contrast to the other codecs, is that it is Open Technology. Dirac has been designed to avoid patent infringement. This means it may freely be used by anyone without the payment of royalties. This may seem like a minor issue but it could have a profound impact on the uptake of digital technology and, particularly the way it is used by public service broadcasters.

It is worth clarifying the difference between 'Open Standards' and 'Open Technology'. The two concepts are often confused. Public service broadcasters have always preferred open standards to vendor-specific technology. They provide interoperability and a competitive market place. Open standards are published and may be read by anyone, but implementers and users typically pay royalties to the owners of patents embodied in the standard. So open standards can still be proprietary in the sense that the technology is owned and you may have to pay to use it. Open Technology, on the other hand, takes openness a stage further and gives you the right to use the technology, for any purpose, without royalty payment.

## What are the license conditions?

Dirac software is released under the Mozilla triple licence (MPL). This is an Open Source licence. The licence gives completely open access to the technology to all comers.

## Are you going to charge for Dirac?

No. The terms of the licence mean that as far as the BBC is concerned, there will be no charges or royalties for the Dirac software. As with all Open Source software, you can access the tools freely. However, independent vendors are free to charge.

## Does the BBC have patents in Dirac?

Yes. We have patent applications pending for some of the techniques involved in Dirac, and others that we intend to put into Dirac in the future. There has been some criticism about this, so we'll be clear: this does not affect the Open Source status of Dirac, nor does it affect its royalty-free status. The conditions of the MPL mean that we're licensing these patents for use within the Dirac software for free.

## Do you infringe any patents? Are there any royalties to pay?

The short answer is that we don't know for certain, but we don't think so. We haven't employed armies of lawyers to trawl through the tens of thousands of video compression techniques. That's not the way to invent a successful algorithm. Instead we have tried to use techniques of long standing in novel ways. Where we think we're novel, we're in the process of getting patent protection ourselves, which will invalidate others' claims of priority. There are some areas that are more heavily patented than others. Arithmetic coding is one such, even though the technique itself has been around for 25 years. We're using a basic version, based on considerable prior art dating back many years, which we don't believe is patented.

## What is the BBC's attitude towards Open Source?

The BBC is public body, whose funding comes from a television license fee paid by the British public. The BBC's remit is defined by its legal Charter and associated Framework Agreement with the British Government. One of the most relevant provisions is that the BBC 'must pay particular attention to the desirability of supporting actively in national and international forums the development of open standards'.

With this political guidance, many of the BBC's latest developments have been released as Open Source projects. This gives everyone an opportunity to experience the benefits of the technology, and has benefits as others have been joining in the development work, helping to create products which are much more functional, and less experimental.

# WHY DIRAC?

**Dirac offers you a state of the art video compression system.**

**Our demonstrations show that**

- **Dirac is here.**
- **Dirac works.**
- **Dirac is ready for deployment.**

But there are many video compression systems; you may want to know what is special about Dirac. If you are the sort of person that hopes that your content has a long lifetime, consider the upgrade policy of your existing suppliers. Can you handle a format conversion on a regular basis? Can you handle the lack of support for 'obsolescent' technologies? If you cannot, then Dirac offers a long-term solution for you. Because the source code for the software is available for operation on a variety of platforms, you can have confidence that Dirac can stand the test of time.

If you want quality, in your own specialist area, Dirac provides a simple, but powerful range of options which can be selected to fine tune the performance for your content. If you want a cost effective solution, then the Open Source licence means that you are a customer who has to be considered respectfully by your suppliers. You will have a choice of supplier, so you can select one who offers a service which you need, not which they want you to buy.

## Why is it called Dirac?

The Dirac codec is named after the British physicist Paul Dirac. Dirac (1902–1984) was one of the most influential scientists of the 20th century. In 1933 he shared the Nobel Prize for physics with Erwin Schrödinger for his contributions to quantum mechanics.

## What are the origins of Dirac?

Although named after Dirac, there is no direct connection between Dirac the scientist and Dirac the video coding algorithm. Dirac was originally developed at BBC Research at Kingswood Warren in the UK. The BBC have specialists in compression technology, having been working on digital television and its ramifications since the 1960s.

The ideas behind Dirac were originally developed as part of an idea to deliver high definition services as a layered addition to conventional broadcasts. This rapidly developed into a much broader system which became today's Dirac.

Within the BBC, Tim Borer is the project leader for the Dirac Project, and Thomas Davies is the guru who understands the algorithm in more depth than most.

# SOURCES OF INFORMATION

## Products

### Schrödinger

[sourceforge.net/projects/schrodinger](http://sourceforge.net/projects/schrodinger)

In parallel to the Dirac pages on SourceForge, there is also Schrödinger: This is a project led by one of our collaborators, Fluendo, implementing the Dirac video codec in ANSI C code. It is meant to be highly optimized and portable to a wide range of platforms.

This software is therefore a good source for the technologist interested in the practical application of Dirac.

### NuMedia Technology Ltd

[www.numediatechnology.com](http://www.numediatechnology.com)

Numedia Technology Ltd is a manufacturer of high-technology electronic equipment for the broadcast and digital cinema markets. The Chameleon Image Processing Platform developed by Numedia is very well suited to the application of Dirac algorithms that require real-time processing at high-definition and D-Cinema rates. Numedia have also developed a new range of cost-effective modules to support Dirac Pro.

### High Definition & Digital Cinema Ltd

[www.hddc.co.uk](http://www.hddc.co.uk)

HDDC are consultants in high end Digital Cinema, E-Cinema and the HDTV production and distribution process. Their role is assisting the BBC with extended roadmap planning and dissemination of information. HDDC have over twenty year experience in HDTV and eight years experience of Digital and Electronic Cinema applications. HDDC have recognised that Dirac provides solutions to Commercial and Technical problems which no other coding system can match.

## The website for Dirac is: [sourceforge.net/projects/dirac](http://sourceforge.net/projects/dirac)

This site has the new specification, and working software to try out the system. Many of the original ideas for Dirac came from the BBC Research & Development Department. This department has just undergone a reorganisation and is now being branded BBC Research within BBC Technology Group. The website [www.bbc.co.uk/rd](http://www.bbc.co.uk/rd) is a mine of information about broadcast technology and video processing in particular. As well as links to the Dirac project, you can find information about video coding and motion compensation in reports and white papers there.

### Licences

The Dirac software and code are licensed under the Mozilla Public License, Version 1.1. A plain text version of this is available in [dirac.sourceforge.net/licenses.html](http://dirac.sourceforge.net/licenses.html)

## I would really like to contact someone about Dirac

If you have any questions, the best route to ask questions is through the SourceForge pages. It may be that your question has already been answered there, or if not, others might be interested in knowing the answer too. Routing your query through SourceForge makes the process more inclusive and efficient.

In addition enquiries can also be addressed by mailing: [diracenquiries@bbc.co.uk](mailto:diracenquiries@bbc.co.uk)

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