

Windows Metafile

Windows Metafile (**WMF**) is an image file format originally designed for Microsoft Windows in the 1990s. The original Windows Metafile format was not device-independent (though could be made more so with placement headers) and may contain both vector graphics and bitmap components. It acts in a similar manner to SVG files. WMF files were later superseded by **Enhanced Metafiles** (EMF files) which did provide for device-independence. EMF files were then themselves enhanced via **EMF+** files.

Essentially, a metafile stores a list of records consisting of drawing commands, property definitions and graphics objects to display an image on screen.^[1] The drawing commands used are closely related to the commands of the Graphics Device Interface (GDI) API used for drawing in Microsoft Windows.

There are three major types of metafiles – a WMF is a 16-bit format introduced in Windows 3.0. It is the native vector format for Microsoft Office applications such as Word, PowerPoint, and Publisher. As of 2017 revision 14 of the Windows Metafile Format specification is available for online reading or download as PDF.^[2] EMF files, which replaced WMF files, work on the same principle only it is a 32-bit file format that also allows for the embedding of private data within "comment" records.^[3] EMF+ is an extension to EMF files and embedded in these comment records, allowing for images and text using commands, objects and properties that are similar to Windows GDI+.^[4]

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History

The original 16 bit WMF file format was fully specified in volume 4 of the 1992 Windows 3.1 SDK documentation^[5] (at least if combined with the descriptions of the individual functions and structures in the other volumes), but that specification was vague about a few details. These manuals were published as printed

books available in bookstores with no click through EULA or other unusual licensing restrictions (just a general warning that if purchased as part of a software bundle, the software would be subject to one).

Over time the existence of that historic specification was largely forgotten and some alternative implementations resorted to reverse engineering to figure out the file format from existing WMF files, which was difficult and error prone.^[6] In September 2006, Microsoft again published the WMF file format specification in a more complete form^[7] in the context of the Microsoft Open Specification Promise, promising to not assert patent rights to file format implementors.^[8]

Microsoft later deprecated WMF files in favour of 32-bit EMF files as WMF files had real issues with device independence, despite the use of a "placeable" file header which provided basic device independence. Microsoft found that developers who use the format were "[embedding] application, location, or scaling comments in the metafiles... Others added headers to the metafile that provided various application-specific information", causing major compatibility issues.^[9] Thus, in 1992 with Windows NT 3.1, Microsoft introduced the Enhanced Metafile format (EMF)^[10] — a format which was based on the Win32 API and with which they built-in device independence.^{[11][9]} — these were also known as NT metafiles.^[12] With the release of Windows XP and GDI+, the set of records had to be significantly increased and so Microsoft released EMF+ as an extension to the existing EMF file format.^{[10][13]}

Metafile structure

WMF, EMF and EMF+ files all consist of a series of records that are played back to produce graphical output. Some records define objects which can specify graphical objects used to determine how graphics should be drawn (e.g. pens specify the color and width of lines). Each of these objects are stored in metafiles and are placed into an object table, which tracks the usage of graphic objects while processing the metafile. The object table is an associative array of indexes to graphical object structures defined within the metafile.

WMF and EMF files handle object processing differently to EMF+ records in EMF files. As a WMF and EMF file is being processed, the records are read into an object table once an object is defined. If an object is deleted then the object is released from the table and the identifier can be reused. Notably an object will not be used until it is specifically selected during record playback.^{[14][15]} This differs for EMF+ files, which also use an associative array via a hashmap which records the object along with an object identifier. However, unlike WMF and EMF files which can delete an object, when a new object is created that has the same index as an existing object, the entry in the table is replaced with the new object. An EMF file also does not need to specifically select an object before it is used.^[16]



Comparison of Windows Metafiles – note that WMF files can include EMF+ records

WMF

WMF files were not originally designed to be device independent, meaning that you could not playback the file on output devices that differed from the original device on which the file was recorded. A partial solution to this issue was invented by Aldus Corporation, who added an additional "placeable" header, called the "APM header",^[18] which added a bounding rectangle, a metafile version, metafile size, number of objects in the metafile and the size of the largest single record in the metafile.^{[19][20]} This was later incorporated into the WMF format by Microsoft, starting in Windows 2000.^[21]



Structures of original and placeable Windows metafiles^[17]

WMF files are structured by a series of records, starting with a number of control records: the header record,^{[19][22]} the aforementioned optional placeable record,^[23] and finished by an end of file record.^{[19][24]}

Encapsulated by the control records are the records that make up the image itself. These records work within what is known as the *playback device context*, which is the collection of properties and objects that make up a device's graphical environment as the metafile is being "played back" onto this output device.^[25]

Records other than control records can be largely grouped into bitmap records, drawing records, object records, state records and escape records.

Bitmap records

Bitmap records manage and output bitmap images.

Name	Description
META_BITBLT	Specifies how to do a <u>bit block transfer</u> . These records can specify a bitmap to use as the source, or a region. ^[26]
META_DIBBITBLT	Specifies how to do a bit block transfer of a <u>device-independent bitmap</u> image. These records can specify a bitmap to use as the source, or a region. ^[27]
META_DIBSTRETCHBITBLT	Specifies how to do a bit block transfer of a device-independent bitmap image, but allows for expansion or contraction of the image. These records can specify a bitmap to use as the source, or a region. ^[28]
META_SETDIBTODEV	Specifies color to set a block of pixels in a device-independent bitmap image. These records can specify a bitmap to use as the source, or a region. ^[29]
META_STRETCHBLT	Specifies how to do a bit block transfer, but allows for expansion or contraction of the image. ^[30]
META_STRETCHDIB	Specifies how to do a bit block transfer of a device-independent bitmap image, but allows for expansion or contraction of the image. These records can specify a bitmap to use as the source, or a region. ^[31]

Drawing records

Drawing records produce graphics output.

Name	Description
META_ARC	Draws an elliptical <u>arc</u> . ^[32]
META_CHORD	Draws a <u>chord</u> . ^[33]
META_ELLIPSE	Draws an elliptical <u>arc</u> . ^[34]
META_EXTFLOODFILL	Fills an area with a brush. ^[35]
META_EXTTEXTOUT	Draw text with font, background color and text color of the playback device context. ^[36]
META_FILLREGION	Fills a region with a specified brush. ^[37]
META_FLOODFILL	Fills an area with a brush. ^[38]
META_FRAMEREGION	Draws a border around a region of the page with a brush. ^[39]
META_INVERTREGION	Paints a region of the graphic with inverted colors. ^[40]
META_LINETO	Draws a half-open line from the drawing position defined in the playback device context to a specified point. ^[41]
META_PAINTREGION	Paint a region with the current brush specified in the playback device context. ^[42]
META_PATBLT	Paint a region with the current brush specified in the playback device context and then combine the brush color and surface color(s) using a <u>raster operation</u> . ^[43]
META_PIE	Draw a pie-shaped wedge bounded by the intersection of an ellipse and two radials — the line is set via the pen set via the playback device context, and the area bounded by the pie shape is filled in by the current brush of the playback device context. ^[44]
META_POLYLINE	Draws a series of line segments by connecting the points in a specified array. ^[45]
META_POLYGON	Paints a <u>polygon</u> consisting of two or more vertices connected by straight lines. The polygon is outlined by using the pen and filled by using the brush and polygon fill mode that are defined in the playback device context. ^[46]
META_POLYPOLYGON	Paints a series of closed polygons, which may overlap. Each polygon is outlined by using the pen and filled by using the brush and polygon fill mode that are defined in the playback device context. ^[47]
META_RECTANGLE	Paints a rectangle, which is outlined by using the pen and filled by using the brush and is filled by using the brush that is defined in the playback device context. ^[48]
META_ROUNDRECT	Paints a rectangle with rounded corners. The rectangle is outlined by using the pen and filled by using the brush and is filled by using the brush that is defined in the playback device context. ^[49]
META_SETPIXEL	Sets the pixel at the specified coordinates to the specified color. ^[50]
META_TEXTOUT	Outputs a character string at the specified location by using the font, background color, and text color that are defined in the playback device context. ^[51]

Object records

Object records create and manage graphics objects. In WMF files there are two broad categories of objects – graphics objects and structure objects. Structure objects are not explicitly created or deleted in a WMF, they are instead of complex structures. For example, the BitmapCoreHeader contains information about the dimensions and color format of a device-independent bitmap,^[52] which is itself part of a DeviceIndependentBitmap object.^[53] A graphics object, however, specifies parameters for graphics output and during playback of the WMF it sets up the playback device context.^[54]

Graphics objects can be *brushes* (defines the style, color and pattern of a brush which defines how to paint an area of the graphic), *fonts* (defines properties that affect how text is displayed), *palettes* (specifies colors as device-independent values, defined by an application), *pens* (specifies the graphical attributes of a line), and *regions* (which specify line and curve segments that define a shape).^[54]

Name	Description
META_CREATEBRUSHINDIRECT	Creates a brush object from a LogBrush (logical brush) object. ^[55]
META_CREATEFONTINDIRECT	Creates a brush object from a font object. ^[56]
META_CREATEPALETTE	Creates a palette object.
META_CREATEPATTERNBRUSH ^[57]	Creates a brush object from a LogBrush (logical brush) object. ^[58]
META_CREATEPENINDIRECT	Creates a pen object. ^[59]
META_CREATEREGION	Creates a region object. ^[60]
META_DELETEOBJECT	Delete a object. ^[61]
META_CREATEBRUSHINDIRECT	Creates a brush object from a LogBrush (logical brush) object. ^[62]
META_DIBCREATEPATTERNBRUSH	Creates a brush object from a device-independent bitmap. ^[63]
META_SELECTCLIPREGION	Specifies the region object that will be the current <u>clipping region</u> . ^[64]
META_SELECTOBJECT	Selects the object that will be the current object for the playback device context, which works on all graphics objects except palette objects, which must be set with META_SELECTPALETTE. ^[65]
META_SELECTPALETTE	Selects the logical palette for the playback device context. ^[66]

State records

State records manage the graphics properties of the playback device context.^[67]

Name	Description
META_ANIMATEPALETTE	Redefines entries in the logical palette that is defined in the playback device context with a specified Palette Object. ^[68]
META_EXCLUDECLIPRECT	Sets the clipping region that is defined in the playback device context to the existing clipping region minus a specified rectangle. ^[69]
META_INTERSECTCLIPRECT	Sets the clipping region that is defined in the playback device context to the intersection of the existing clipping region and a specified rectangle. ^[70]
META_MOVETO	Sets the output position in the playback device context to a specified point. ^[71]
META_OFFSETCLIPRGN	Moves the clipping region that is defined in the playback device context by specified offsets. ^[72]
META_OFFSETVIEWPORTORG	Moves the viewport origin in the playback device context by specified horizontal and vertical offsets. ^[73]
META_OFFSETWINDOWORG	Moves the output window origin in the playback device context by specified horizontal and vertical offsets. ^[74]
META_REALIZEPALETTE	Maps entries from the logical palette that is defined in the playback device context to the system palette. ^[75]
META_RESIZEPALETTE	Redefines the size of the logical palette that is defined in the playback device context. ^[76]
META_RESTOREDC	Restores the playback device context from a previously saved device context. ^[77]
META_SAVEDC	Saves the playback device context for later retrieval. ^[78]
META_SCALEVIEWPORTEXT	Scales the horizontal and vertical extents of the viewport that is defined in the playback device context using the ratios formed by specified multiplicands and divisors. ^[79]
META_SCALEWINDOWEXT	Scales the horizontal and vertical extents of the output window that is defined in the playback device context using the ratios formed by specified multiplicands and divisors. ^[80]
META_SETBKCOLOR	Sets the background color in the playback device context to a specified color. ^[81]
META_SETBKMODE	Sets the background mix mode in the playback device context. ^[82]
META_SETLAYOUT	Defines the layout orientation in the playback device context. ^[83]
META_SETMAPMODE	Defines the mapping mode in the playback device context. ^[84]
META_SETMAPPERFLAGS	Defines the algorithm that the font mapper uses when it maps logical fonts to physical fonts. ^[85]
META_SETPALENTRIES	Defines RGB color values in a range of entries in the logical palette that is defined in the playback device context. ^[86]
META_SETPOLYFILLMODE	Defines polygon fill mode in the playback device context for graphics operations that fill polygons. ^[87]
META_SETRELABS	Unused record. ^[88]
META_SETROP2	Defines the foreground raster operation mixing mode in the playback device context. ^[89]
META_SETSTRETCHBLTMODE	Defines the bitmap stretching mode in the playback device context. ^[90]
META_SETTEXTALIGN	Defines text-alignment values in the playback device context. ^[91]
META_SETTEXTCHAREXTRA	Defines inter-character spacing for text justification in the playback device

	context. ^[92]
META_SETTEXTCOLOR	Defines the text foreground color in the playback device context. ^[93]
META_SETTEXTJUSTIFICATION	Defines the amount of space to add to break characters in a string of justified text. ^[94]
META_SETVIEWPORTEXT	Defines the horizontal and vertical extents of the viewport in the playback device context. ^[95]
META_SETVIEWPORTORG	Defines the viewport origin in the playback device context. ^[96]
META_SETWINDOWEXT	Defines the horizontal and vertical extents of the output window in the playback device context. ^[97]
META_SETWINDOWORG	Defines the output window origin in the playback device context. ^[98]

Escape records

Escape records are a means to extend metafile functionality via records that are not otherwise defined as a WMF record type. Each escape record contains a record function, an escape function and potentially escape data.

The following escape records make up a WMF file.

1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	
RecordSize																															
RecordFunction																EscapeFunction															
ByteCount																EscapedData (variable)															
...																															

WMF generic escape record

Name	Description
ABORTDOC	Stops processing the current document. ^[99]
BEGIN_PATH	Opens a path. ^[100]
CHECK_JPEGFORMAT	Determines whether it can handle the given <u>JPEG</u> image. ^[101]
CHECK_PNGFORMAT	Determines whether it can handle the given <u>PNG</u> image. ^[102]
CLIP_TO_PATH	Applies a function to the current <u>PostScript</u> clipping path. ^[103]
CLOSE_CHANNEL	Same as ENDDOC. ^[104]
DOWNLOAD_FACE	Sets the font face name on the output device. ^[105]
DOWNLOAD_HEADER	Downloads sets of PostScript procedures. ^[106]
DRAW_PATTERNRECT	Draws a rectangle with a defined pattern. ^[107]
ENCAPSULATED_POSTSCRIPT	Sends arbitrary encapsulated PostScript (EPS) data directly to the printer driver. ^[108]
END_PATH	Ends a path. ^[109]
ENDDOC	Notifies the printer driver that a new print job is ending. ^[110]
EPS_PRINTING	Indicates the start and end of EPS printing. ^[111]
EXTTEXTOUT	Draws text using the currently selected font, background color, and text color. ^[112]
GET_COLORTABLE	Gets color table values from the printer driver. ^[113]
GET_DEVICEUNITS	Gets the device units currently configured on the output device. ^[114]
GET_EXTENDED_TEXTMETRICS	Gets the extended text metrics that are currently configured on the printer driver. ^[115]
GET_FACENAME	Gets the font face name currently configured on the output device. ^[116]
GET_PAIRKERNTABLE	Gets the <u>font kern</u> table currently defined on the output device. ^[117]
GET_PHYSPAGE_SIZE	Retrieves the physical page size currently selected on the output device. ^[118]
GET_PRINTINGOFFSET	Retrieves the offset from the upper-left corner of the physical page where the actual printing or drawing begins. ^[119]
GET_PS_FEATURESETTING	Queries the printer driver for information about PostScript features supported on the output device. ^[120]
GET_SCALINGFACTOR	Retrieves the scaling factors for the x-axis and the y-axis of a printer. ^[121]
META_ESCAPE_ENHANCED_METAFILE	Used to embed an EMF metafile within a WMF metafile. ^[122]
METAFILE_DRIVER	Queries the printer driver about its support for metafiles on the output device. ^[123]
NEWFRAME	Notifies the printer driver that the application has finished writing to a page. ^[124]
NEXTBAND	Notifies the printer driver that the application has finished writing to a band. ^[125]
PASSTHROUGH	Passes through arbitrary data to the printer driver. ^[126]
POSTSCRIPT_DATA	Sends arbitrary PostScript data to the output device. ^[127]

POSTSCRIPT_IDENTIFY	Sets the printer driver to either PostScript-centric or GDI-centric mode. ^[128]
POSTSCRIPT_IGNORE	Notifies the output device to ignore PostScript data. ^[129]
POSTSCRIPT_INJECTION	Inserts a block of raw data into a PostScript stream. ^[130]
POSTSCRIPT_PASSTHROUGH	Sends arbitrary data directly to a printer driver, which is expected to process this data only when in PostScript mode. ^[131]
OPEN_CHANNEL	Acts the same as STARTDOC, with a NULL document and output filename, and data in raw mode. ^[132]
QUERY_DIBSUPPORT	Queries the printer driver about its support for DIBs on the output device. ^[133]
QUERY_ESCSUPPORT	Queries the printer driver to determine whether a specific WMF escape function is supported on the output device. ^[134]
SET_COLORTABLE	Sets color table values. ^[135]
SET_COPYCOUNT	Sets the number of copies. ^[136]
SET_LINECAP	Specifies the line-ending mode to use in drawing to the output device. ^[137]
SET_LINEJOIN	Specifies the line-joining mode to use in drawing to the output device. ^[138]
SET_MITERLIMIT	Sets the limit for the length of miter joins to use in drawing to the output device. ^[139]
SPCLPASSTHROUGH2	Enables documents to include private procedures and other arbitrary data in documents. ^[140]
STARTDOC	Notifies the printer driver that a new print job is starting. ^[141]

There was a major vulnerability found in escape records around the Abort escape record, which stores the abort procedure code within the record itself. This affected Windows systems (see [CVE-2005-4560](https://cve.mitre.org/cgi-bin/cvename.cgi?name=CVE-2005-4560)) and the Wine project (see [CVE-2006-0106](https://cve.mitre.org/cgi-bin/cvename.cgi?name=CVE-2006-0106)). According to Secunia, "The vulnerability is caused due to an error in the handling of Windows Metafile files ('.wmf') containing specially crafted SETABORTPROC 'Escape' records. Such records allow arbitrary user-defined function to be executed when the rendering of a WMF file fails."^[142] According to the Windows 3.1 SDK documentation, the SETABORTPROC escape was obsoleted and replaced by the function of the same name in Windows 3.1, long before the WMF vulnerability was discovered.^[143] However the obsoleted escape code was retained for compatibility with 16 bit programs written for (or at least backwards compatible with) Windows 3.0. This change happened at approximately the same time as Microsoft was creating the 32 bit reimplementations of GDI for Windows NT, and it is likely that the vulnerability occurred during this effort.

After Steve Gibson from Gibson Research Corporation accused Microsoft of deliberately implementing a backdoor into their code,^{[144][145]} Mark Russinovich provided a rebuttal, and stated that:

...things were different when the format was architected. In the Windows 3.1 "large" memory model code is inherently location-independent and Windows was never patched, so both Windows and an application could simply copy an application function into the WMF file and assume it would work when played back by the same application in a later run session. In any case, it's not clear that the developers envisioned applications creating on-disk metafiles with abort procedures. Also, as Microsoft's Stephen Toulouse pointed out in Microsoft's rebuttal (<https://we>

b.archive.org/web/20060116042756/http://blogs.technet.com/msrc/archive/2006/01/13/417431.aspx) to Steve's claims, the security landscape in the early 1990s was very different than today and all code, including that stored in a WMF file, was inherently trusted.^[146]

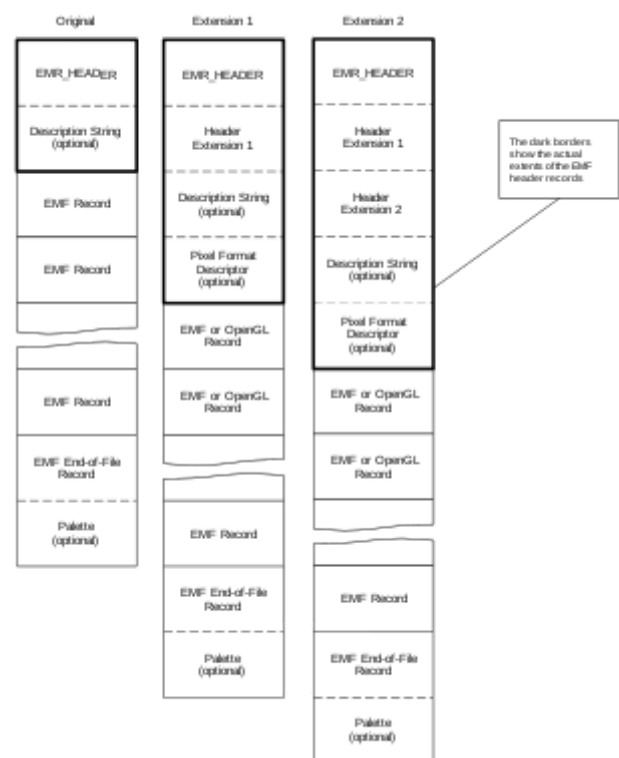
Peter Ferrie of Symantec Security Response, USA also disagreed with Gibson, noting that:

Gibson claimed that a thread is created to run the SetAbortProc handler. In fact, no thread is created to run the handler – it is a callback, which is called by the parser, and the parser has to wait until the callback returns, otherwise the whole point of the function (to abort the printing) is lost. By his own admission, Gibson did not read the documentation (in fact, he claimed that he couldn't find it, although it is freely available on Microsoft's Web site), and he claimed that the device context is not available to the function handler. Of course the device context is available to the function handler — it is one of the two parameters that is passed to it (see above), and it is required in order to abort the printing. Finally, Gibson claimed that the control flow could not return to Windows. It is simply a matter of the function returning and discarding the parameters that were passed on the stack. If the record is well formed, Windows will continue to parse the file, as before. ... Gibson admits that he was guessing about a number of things. Unfortunately, he guessed poorly. I guess we know better now.^[147]

EMF

EMF files have three possible versions of headers. The original headers is just a container for images, the second and third version encapsulates the original header and contains a pixel format record and support for OpenGL records, and the third version encapsulates the second header extension and increases EMF accuracy and scalability of EMFs as it adds the ability to measure distances of device surfaces using the metric system.^[148]

Each EMF header starts with an EMR_HEADER record, and records the relevant properties of the device on which the metafile image was recorded. The original EMF header has an 80 byte header and an optional variable length description string.^[149] Other metafiles contain extension fields, which encapsulate the original header. EmfMetafileHeaderExtension1 is a record that is inserted directly after the original EMF header, specifies whether there is a pixel format descriptor and the offset to the descriptor object within the header, as well as a field that specifies if OpenGL records exist in the metafile.^[150] The pixel format descriptor specifies the capabilities of the drawing surface and whether a pixel is encoded in RGBA or is an index into a color table.^[151] EmfMetafileHeaderExtension2 is a record that is inserted directly after the EmfMetafileHeaderExtension1 record, and it contains two fields with the X and Y values to measure the device surface in micrometers.^[152]



Windows Enhanced Metafile headers

Like WMF files, records can be classified by function, however there are more record types in EMF files than there are in WMF files. Records can be classified as control, bitmap, clipping, comment, drawing, escape, object creation, object manipulation, OpenGL, path bracket, state and transform records.

EMF+

With the release of Windows XP, the *Enhanced Metafile Format Plus Extensions* (EMF+) format was introduced. EMF+ provides a way to serialize calls to the GDI+ API in the same way that WMF/EMF stores calls to GDI.

There are also compressed versions of Windows Metafiles known as *Compressed Windows Metafile* (WMZ) and *Compressed Windows Enhanced Metafile* (EMZ),^[153] which are basically gzip compressed WMF and EMF files correspondingly.

Implementations

The WMF format was designed to be executed by the Windows GDI layer in order to restore the image, but as the WMF binary files contain the definition of the GDI graphic primitives that constitute this image, it is possible to design alternative libraries that render WMF binary files or convert them into other graphic formats.

See also

- PostScript
- Vector Markup Language
- Scalable Vector Graphics

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External links

- [Windows Metafile Format Specification from Microsoft](https://docs.microsoft.com/en-us/openspecs/windows_protocols/ms-wmf/4813e7fd-52d0-4f42-965f-228c8b7488d2) (https://docs.microsoft.com/en-us/openspecs/windows_protocols/ms-wmf/4813e7fd-52d0-4f42-965f-228c8b7488d2)
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