



Interface Requirements Specification for FLIR TIFF File Format

Document number: 102-9012-01
Version: 1.0.7
2016-01-06

Table of Contents

Revisions	4
1.0 - Scope	4
1.1 - Identification	4
1.2 - System Overview	4
1.3 - Document Overview	5
2.0 - Applicable Documents	5
2.1 - Official FLIR Resources	5
2.2 - External Resources	5
2.2.1 - Specifications and Standards	5
2.2.2 - Vendor Specifications	5
2.2.3 - Useful Software	5
2.2.4 - Other Resources	5
3.0 - File Format Interface Specification	6
3.1 - Interface Diagrams	6
3.2 - FLIR TIFF Image Format	6
3.2.1 - FLIR TIFF Interface Requirements	6
3.2.2 - FLIR TIFF Data Requirements	7
3.2.3 - TIFF Header	8
3.2.4 - TIFF IFD Tables	8
3.2.5 - TIFF Metadata	10
3.2.6 - TIFF Image Data	12
3.2.7 - TIFF Extension Mechanisms	12
3.3 - Exif Metadata	13
3.3.1 - Exif Location inside TIFF File	13
3.3.2 - Exif Metadata Syntax	13
3.4 - XMP Metadata	14
3.4.1 - XMP Location inside TIFF File	14
3.4.2 - XMP Metadata Syntax	15
3.5 - Multiple-Image TIFF Files	17
3.6 - Full List of Metadata	18
3.6.1 - Image metadata: baseline TIFF tags	18
3.6.2 - Image metadata: XMP tags in FLIR namespace	19
3.6.3 - Camera metadata: baseline TIFF tags and Exif tags	19
3.6.4 - Positioning metadata: Exif GPS tags	20
3.6.5 - Positioning metadata: XMP tags in FLIR namespace	22

3.6.6 - Timing metadata: Exif tags	22
4 - Quality Assurance	23
5 - Preparation for delivery	23
6 - Notes	23
Canonical Examples	23
Appendix A - example file	25
Baseline TIFF section	25
XMP extension section	27
Exif extension section	28
Image data section	30

Revisions

Document revision history.

Revision	Author	Date	Description
0.1	SJLC/SLA	2015-09-08	Initial draft
0.2	SJLC/SLA	2015-09-12	Add some figures, add table of contents, reformat tables
0.3	SJLC	2015-09-15	Switch XMP namespace to "Camera", cover multiple images per file
0.4	SJLC	2015-09-28	Split XMP tags into "Camera" and "FLIR" namespaces
1.0	SJLC	2015-10-06	Reconcile various details with actual contents of example file
1.0.1	SJLC/SLA	2015-10-29	Allow lossless compression, add FrameRate, separate section for multiple-image files
1.0.2	SJLC	2015-11-03	Add SamplesPerPixel for wider viewer compatibility
1.0.3	SLA	2015-11-24	Update MAVLink-related tags and fix some typos.
1.0.4	SLA	2015-12-16	Add/update tag tables for complete navigation tags, update requirement statements.
1.0.5	SLA	2015-12-17	Added related FLIR reference docs, updated GPS tag tables, updated text discussion for required vs. optional tags (user-defined vs. standard).
1.0.6	SLA	2015-12-21	Update tag reqs and section numbering, move camera namespace to separate document
1.0.7	SLA	2016-01-06	Add (required) GPSVersionID tag to tables (analogous to new MAVLinkVersionID tag). Also added corresponding note to MAVLink SIRS. Updated rational and time format examples.

1.0 - Scope

1.1 - Identification

1.2 - System Overview

A FLIR TIFF image file is a TIFF file holding an IR image and corresponding metadata. The TIFF standard does not explicitly cover many types of metadata useful for IR images, but it does provide a flexible extension mechanism. The Exif (EXchangable Image File) format defines a TIFF extension that adds metadata common among many digital cameras, including FLIR IR cameras. The XMP (Extensible Metadata Platform) format also defines a TIFF extension to add metadata to TIFF files; as hinted by the word "Extensible", XMP was specifically designed to support custom types of metadata, which makes it suitable for IR-specific and manufacturer-specific metadata not defined by Exif.

1.3 - Document Overview

This document covers TIFF files with IR images and advanced metadata, in particular GPS data. Older FLIR cameras produced TIFF files with a minimal set of metadata that is mandatory for baseline TIFF files; please check product documentation to see if a particular camera supports the "FLIR TIFF" format discussed in this document or only baseline TIFF.

2.0 - Applicable Documents

- Interface Requirements Specification (IRS) Data Item Description, DI-MCCR-80026A, 29 Feb 1988

2.1 - Official FLIR Resources

1. TIFFMAVLINK_ICDv00001 - ICD for TIFF Image File / MAVLink Command Interface
2. MAVLINK_SIRSV00001 - SIRS for FLIR MAVLink Command Set Interface
3. Example reference image files for FLIR TIFF v1.0
4. FLIR Applications Engineering Support <techsupport@flir.com>

2.2 - External Resources

Includes Specifications, Standards, Drawings, Other publications.

2.2.1 - Specifications and Standards

1. [TIFF 6.0 Specification](#) - TIFF Revision 6.0 Specification, Final — June 3, 1992, Adobe Developers Association.
2. [Exif 2.3 Specification](#) - Exchangeable image file format for digital still cameras: Exif Version 2.3, Revised on December, 2012, Camera & Imaging Products Association.
3. [XMP 1.0 Specification](#) - XMP Specification, [Part 1](#) (April, 2012), [Part 2](#) (November 2014), [Part 3](#) (November 2014), Adobe Developers Association.

2.2.2 - Vendor Specifications

1. [Camera XMP Namespace Specification](#) - XMP Namespace published for additional camera properties not covered by Exif
2. [CinemaDNG 1.0.0.0 Specification](#) - CinemaDNG Image Format Specification, Version 1.0.0.0, September 2009, Adobe Systems Incorporated.

2.2.3 - Useful Software

1. [LibTiff](#) - Upstream development and maintenance of libtiff software.
2. [Exiv2](#) - Upstream development and maintenance of exiv2 software.
3. [ExifTool](#) - Upstream development and maintenance of exiftool software.

2.2.4 - Other Resources

1. [Searchable TIFF tag reference](#) - Third party (independent developer) TIFF image references and TIFF related topics. It includes a freeware TIFF Tag Viewer application, the LibTiff mailing list archive, and a TIFF-specific links page.

2. [Exif tags list](#) - Complete list of Exif tags supported by Exiv2.

3.0 - File Format Interface Specification

3.1 - Interface Diagrams

The FLIR TIFF file format makes use of 3 image file and metadata standards to store the required image data and accompanying metadata:

- TIFF 6.0 - overall file layout, storage of image data and basic image properties
- Exif 2.3 - standard digital camera properties and GPS measurements
- XMP 1.0 - IR-camera-specific and/or manufacturer-specific metadata

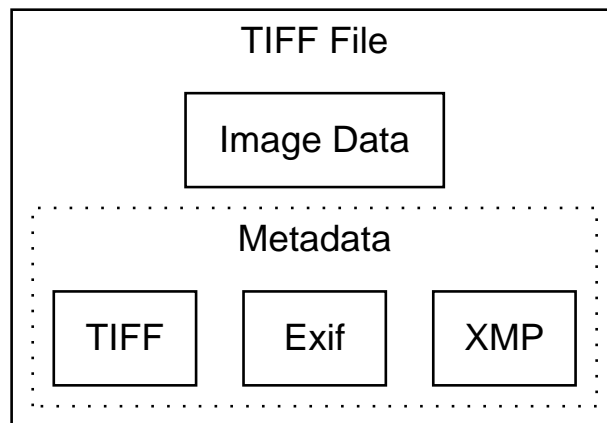


Figure 1: TIFF with Exif and XMP extensions

With this arrangement, all image data and basic image properties are accessible to software with Baseline TIFF 6.0 compatibility, though proper image handling requires support for 16-bit grayscale images (which is an advanced feature, beyond the Baseline TIFF 6.0 standard). Camera properties and GPS measurements stored according to the Exif 2.3 standard are accessible to software with Exif compatibility, which includes most photo-editing applications. The remaining metadata not covered by either TIFF or Exif specifications is stored in the XMP format, using either the existing "Camera" namespace or a custom "FLIR" namespace defined in this document. Software with XMP support provides access to these properties, with basic support for retrieving properties as a full set or by property name possible out-of-the-box. Advanced interpretation of XMP metadata values would require customized software aware of the "Camera" and/or "FLIR" XMP namespaces.

3.2 - FLIR TIFF Image Format

The purpose of the FLIR TIFF Image Format is to define the file format and metadata structure for the storage of 14-bit thermal data from FLIR imaging systems in a "standard" TIFF file.

3.2.1 - FLIR TIFF Interface Requirements

ID	Requirement Text
F010	This file format Shall_F010 use standard EXIF Tags for Timestamp, Camera Model, etc as used by consumer cameras. See Section 3.6 - Full List of Metadata for a complete list of required tags.

F020	This file format Shall_F020 include detailed camera position and attitude data beyond the standard EXIF GPS tags. See Sections 3.6.4 - Positioning metadata: Exif GPS tags and 3.6.6 - Timing metadata: Exif tags for a list of required tags.
F022	Any new autopilot geo-tags not part of the EXIF specification Shall_F022 first be created in the XMP FLIR namespace (some values may also be converted for use with other vendor namespaces). See Sections 3.6.5 - Positioning metadata: XMP tags in FLIR namespace and 3.6.6 - Timing metadata: Exif tags for a list of required tags.
F025	The structure for non-standard metadata Shall_F025 be completely defined in this and the XMP specifications.
F030	The end user of the file format specification Shall_F030 be internal and external firmware and software developers.
F040	Example reference image file(s) Shall_F040 be provided for inspection and test purposes.

3.2.2 - FLIR TIFF Data Requirements

A TIFF file contains 3 major classes of elements:

- file header
- fixed-width tables containing a mixture of data and pointers to other data (including other tables)
- data objects pointed to by the tables

There is exactly one TIFF file header, located at the start of the file. This header includes a pointer to the singly-linked list of tables that organize all other data in the file; these tables are called IFD (Image File Directory) in the TIFF standard. The location of the IFD tables is not fixed - the first IFD table *may* follow immediately after the file header, but frequently it does *not*. The only way to reliably interpret a TIFF file is to navigate using its pointers (i.e. file offsets): use the TIFF header to find the first IFD table, then use the first IFD table to find its child data objects and the next IFD table (if present).

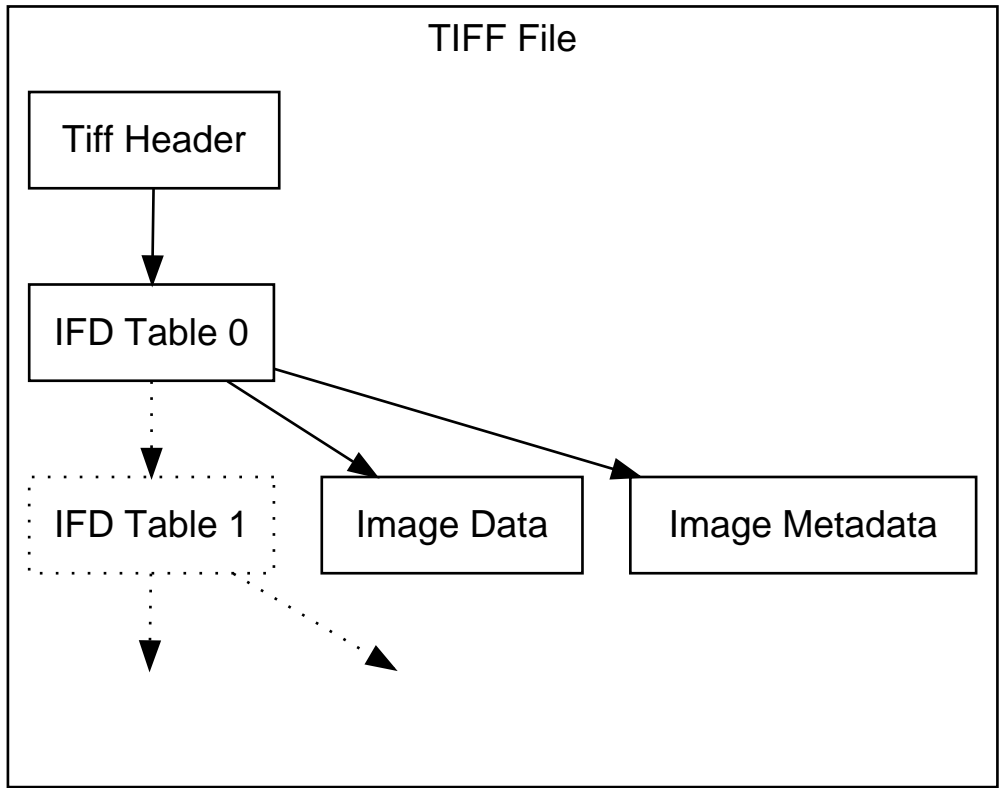


Figure 2: TIFF navigation

3.2.3 - TIFF Header

A TIFF header is 8 bytes long and consists of:

- 2-byte endian specifier: 0x4949 for little-endian byte order for all data in file, 0x4d4d for big-endian byte order
- 2-byte constant: 0x002a
- 4-byte file offset pointing to the first IFD table

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x4949 or 0x4d4d		0x002a		file offset of first IFD table			

Figure 3: TIFF header bytes

3.2.4 - TIFF IFD Tables

A TIFF IFD table consists of:

- 2-byte count of table entries
- one or more 12-byte table entries
- 4-byte pointer to next IFD table (or zero, if this is the end of the linked list)

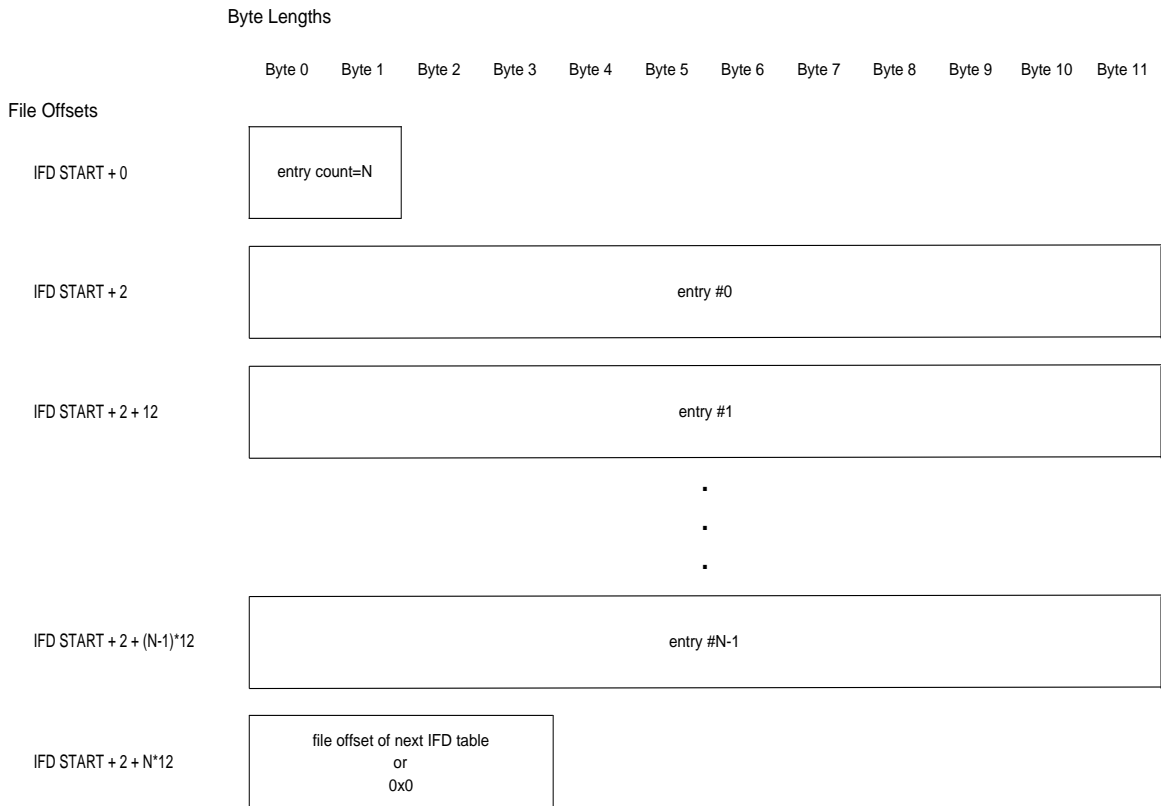


Figure 4: TIFF IFD table layout

Each IFD table entry consists of a Tag, a Type, a Count, and a Value-or-Offset, where this last part is either the Tag's actual value *or* an offset pointing to the Tag's value located outside the IFD table. The Tag value determines the meaning of the table entry; the specific Tags used in FLIR TIFF files will be defined in following sections. Entries inside an IFD table are sorted in ascending order according to their Tags. The Count refers to the number of values of the given Type, rather than the total length in bytes. Thus, the total data length in bytes for a table entry is (Count * length of Type).

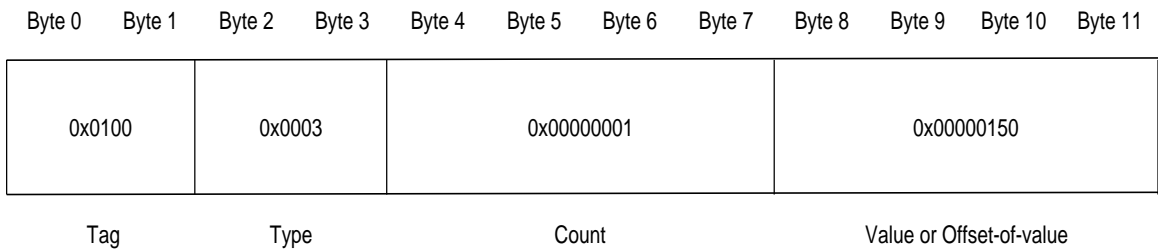


Figure 5: TIFF IFD table entry

TIFF 6.0 defines the following set of Types:

Type ID	Name of type	C language equivalent	Data length for count=N
0x1	byte	unsigned char	N bytes
0x2	ascii	null-terminated ascii string	N bytes (N must include null)
0x3	short	unsigned short	N * 2 bytes

0x4	long	unsigned long	N * 4 bytes
0x5	rational	pair of unsigned longs	N * 8 bytes
0x6	sbyte	char	N bytes
0x7	undefined	--	N bytes
0x8	sshort	short	N * 2 bytes
0x9	slong	long	N * 4 bytes
0xa	rational	pair of longs	N * 8 bytes
0xb	float	float	N * 4 bytes
0xc	double	double	N * 8 bytes

Note: above C language equivalents assume a 32-bit platform

Note that the "undefined" Type is the literal name of a valid Type, rather than indicating that the Type was uninitialized. Although many Tags manage fixed size blocks of data, with both Type and Count fully specified, certain Tags use the "undefined" type and no restriction on Count (other than fitting into the space allocated for Count) to point to a data block which can vary in length and has internal structure that is not simply an array of the other listed Types.

3.2.5 - TIFF Metadata

Metadata is stored using 2 different methods, depending length of the metadata value

- 4 bytes or less: inline metadata - stored inside an IFD table entry
- longer than 4 bytes: external metadata - pointed at by an IFD table entry

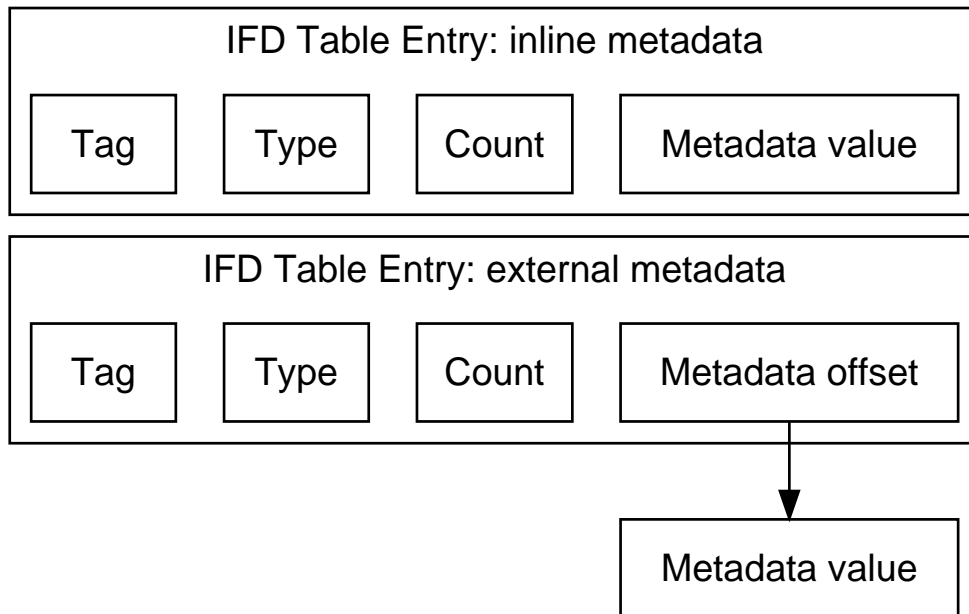


Figure 6: Inline metadata vs external metadata

If a metadata value is smaller than 4 bytes, and thus does not take up the full Value/Offset area of its IFD table entry, it is stored in the lower bytes of this area.

TIFF header endian specifier = 0x4949: Little-endian byte order

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8	Byte 9	Byte 10	Byte 11
0x00	0x01	0x03	0x00	0x01	0x00	0x00	0x00	0x50	0x01	0x00	0x00
Tag=0x0100		Type=0x0003		Count=0x00000001				Value=0x0150			

TIFF header endian specifier = 0x4d4d: Big-endian byte order

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8	Byte 9	Byte 10	Byte 11
0x01	0x00	0x00	0x03	0x00	0x00	0x00	0x01	0x01	0x50	0x00	0x00
Tag=0x0100		Type=0x0003		Count=0x00000001				Value=0x0150			

Figure 7: Storing metadata shorter than 4 bytes

FLIR TIFF files include the following properties defined as "mandatory" by the TIFF specification:

Tag	Name (from TIFF specification)
0x0100	ImageWidth
0x0101	ImageLength
0x0102	BitsPerSample
0x0103	Compression
0x0106	PhotometricInterpretation
0x0111	StripOffsets
0x0116	RowsPerStrip
0x0117	StripByteCounts
0x011a	XResolution
0x011b	YResolution
0x0128	ResolutionUnit

FLIR TIFF files also include the following properties defined as "optional" by the TIFF specification:

Tag	Name (from TIFF specification)
0x010f	Make
0x0110	Model
0x0115	SamplesPerPixel
0x0129	PageNumber
0x0131	Software
0x0153	SampleFormat

and also the following properties defined in the CinemaDNG specification (an extension to TIFF):

Tag	Name (from DNG specification)
0xc62f	CameraSerialNumber
0xc764	FrameRate

See corresponding entries under "Full List of Metadata" for definitions of these standard TIFF metadata Tags, and the Appendix for an example of their usage.

Note:

FrameRate shall be present in TIFF files containing multiple images, but not in single-image TIFF files.

3.2.6 - TIFF Image Data

The TIFF standard provides for splitting images across multiple buffers called "strips", each containing the same number of image rows (except for possibly the last strip, if the image height is not evenly divided by chosen size of strips). In this general case, each strip can be separately compressed. Thus, the standard set of TIFF metadata specifies the location of image data with the following properties:

Tag	Name (from TIFF specification)
0x0111	StripOffsets
0x0116	RowsPerStrip
0x0117	StripByteCounts

In the general case, the StripOffsets and StripByteCounts properties are arrays, respectively containing a start offset and a byte length for each image strip. StripByteCounts is individually given for each strip because each strip may be compressed, in which case the lengths will likely vary. RowsPerStrip is just a single value indicating the typical number of rows, which applies to all strips (except the last one, which may be a smaller number of leftover rows).

However, FLIR TIFF files do not take advantage of this generality:

- each image is stored consecutively, as a single "strip"

Therefore, in a FLIR TIFF file

- StripOffsets degenerates from an array to just a single value, the image offset
- RowsPerStrip is always the total number of rows in the image

```
RowsPerStrip = ImageWidth
```

- StripByteCounts degenerates from an array to a single value, total image size in bytes

Image data in FLIR TIFF files may be either uncompressed or compressed with a lossless compression scheme: either LZW or PackBits. The JPEG compression scheme is lossy and is *not* supported in FLIR TIFF files.

3.2.7 - TIFF Extension Mechanisms

The TIFF 6.0 specification allows the following methods of adding extensions to the TIFF format:

- Private Tag of 'undefined' type pointing to a single block of data, with structure inside that block defined by the extension
- Private Tag of 'unsigned long' type pointing to a custom IFD table, with tags inside that IFD table defined by the extension

The former mechanism, a single block of custom data, is used by the XMP standard; Exif uses the latter mechanism, custom IFD tables which can point to custom data values as needed.

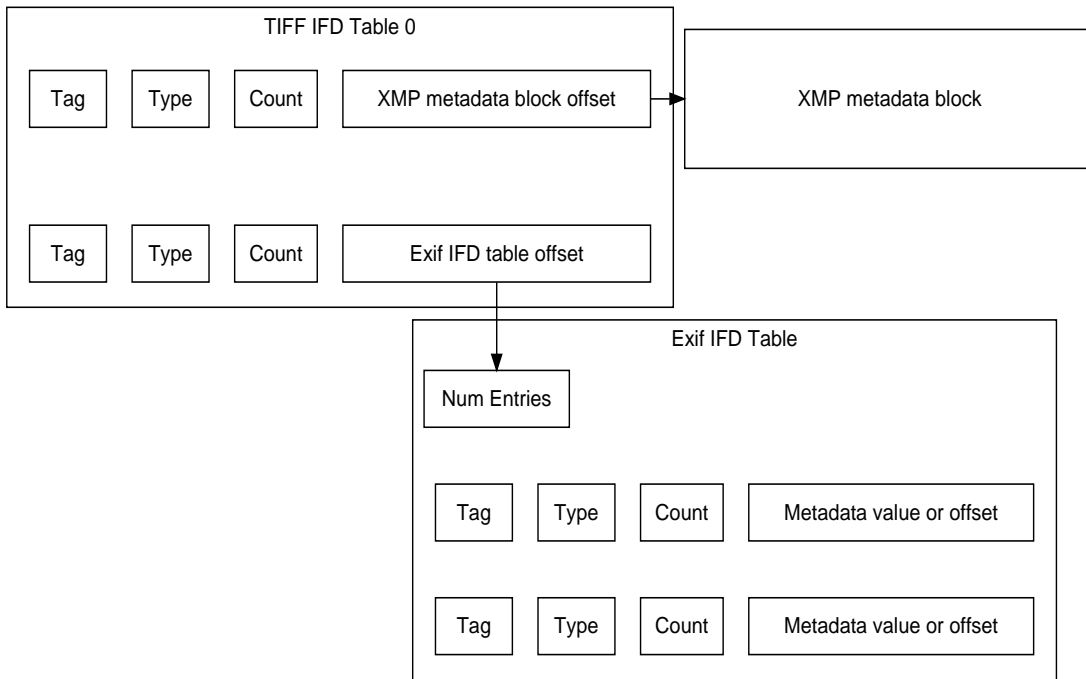


Figure 8: TIFF IFD table pointing to Exif and XMP areas

3.3 - Exif Metadata

3.3.1 - Exif Location inside TIFF File

The Exif format adds metadata to TIFF files using the "custom IFD table" extension mechanism. The Exif 2.3 specification defines two types of private IFD, one referred to as "Exif" and the other called "GPS". Unlike a primary TIFF IFD table, an extension IFD tables is not part of the linked list formed by pointers at the tail end of each TIFF IFD, and instead is pointed to by a normal IFD entry (as if it were a normal piece of metadata).

These are the Tags defined by the Exif specification to point to custom IFD tables:

Tag	Type	Count	Value-or-Offset
0x8769	unsigned long	1	offset to beginning of an Exif IFD table
0x8825	unsigned long	1	offset to beginning of a GPS IFD table

Note that the entries in the main TIFF IFD table only indicate the start of the Exif IFD tables and not their sizes; the count value of 1 must be ignored in favor of parsing the Exif IFD tables to discover lengths (i.e. handle them in the same manner as primary TIFF IFD tables).

3.3.2 - Exif Metadata Syntax

Exif metadata is stored in a completely analogous manner to primary TIFF metadata, with both IFD tables and their entries laid out according to the TIFF standard. The key difference is that each type of Exif extension IFD table, "Exif" and "GPS", has its own unique set of defined metadata tags. The rest of the IFD entry (type, count, and value-or-offset) conforms to the main TIFF standard, including use of the same set of pre-defined types, and the same rules for storing data inline or as an external reference.

FLIR TIFF files include the following properties contained in an Exif IFD table:

Tag	Name (from Exif specification)
-----	--------------------------------

0x829d	FNumber
0x9003	DateTimeOriginal
0x920a	FocalLength
0x9291	SubSecTimeOriginal
0xa20e	FocalPlaneXResolution
0xa20f	FocalPlaneYResolution
0xa210	FocalPlaneResolutionUnit

FLIR TIFF files also include the following properties contained in a GPS IFD table:

Tag	Name (from Exif specification)
0x0000	GPSVersionID
0x0001	GPSLatitudeRef
0x0002	GPSLatitude
0x0003	GPSLongitudeRef
0x0004	GPSLongitude
0x0005	GPSAltitudeRef
0x0006	GPSAltitude
0x0007	GPSTimeStamp
0x0010	GPSTimeStamp
0x000C	GPSSpeedRef
0x000D	GPSSpeed
0x000E	GPSTrackRef
0x000F	GPSTrack
0x0010	GPSTrack
0x0010	GPSImgDirectionRef
0x0011	GPSImgDirection
0x0012	GPSMapDatum
0x001B	GPSProcessingMethod
0x001D	GPSDateStamp

See corresponding entries under "Full List of Metadata" for definitions of these standard Exif metadata Tags, and the Appendix for an example of their usage.

3.4 - XMP Metadata

3.4.1 - XMP Location inside TIFF File

The XMP format adds metadata to TIFF files using the "block of custom data" extension mechanism.

TIFF IFD table entry for an XMP metadata block:

Tag	Type	Count	Value-or-Offset
-----	------	-------	-----------------

0x02bc	Undefined	total number of bytes in XMP metadata	offset to beginning of XMP metadata
--------	-----------	---------------------------------------	-------------------------------------

Note that, in contrast to Exif, the total size of XMP metadata is stored in the main TIFF IFD table.

3.4.2 - XMP Metadata Syntax

Inside the custom data block, XMP metadata is stored in an XML format -- a fully text representation of all metadata, in contrast to TIFF and Exif formats with binary tags and binary values for numeric data types.

The minimum contents of a FLIR XMP extension block are, in order from the outermost element to the innermost elements:

- xpacket wrapper
- rdf:RDF element referencing:
 - the "RDF" namespace
 - the "FLIR" namespace
- metadata tag elements
 - one instance of each tag in the "FLIR" namespace (see list below)

Here is the XML representation of this block, with a single FLIR:MAVYaw" metadata tag serving as placeholder for the full set of XMP metadata tags:

```
<?xpacket begin=" " id="W5M0MpCehiHzreSzNTczkc9d"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:Camera="http://pix4d.com/camera/1.0/"
xmlns:FLIR="http://ns.flir.com/xmp/1.0/">
<rdf:Description rdf:about="">

<FLIR:MAVYaw>-30.1</FLIR:MAVYaw>

</rdf:Description>
</rdf:RDF>
<?xpacket end="w"?>
```

Note that XMP metadata tags in a FLIR TIFF file may come from both the custom FLIR namespace and an externally-defined Camera namespace.

Following section 1.3.1 of XMP Specification Part 2, the FLIR namespace is defined in this document by providing the following pieces of information:

- the custom namespace URI: <http://ns.flir.com/xmp/1.0/>
- the custom namespace preferred namespace prefix: FLIR
- a table containing the name of each property, the value type, and the descriptions of the property: see custom metadata tables under "Full List of Metadata" section

The "FLIR" XMP namespace contains the following sets of tags:

```
FLIR:ImageOffsetX
FLIR:ImageOffsetY
FLIR:ImageValidStartX
FLIR:ImageValidEndX
FLIR:ImageValidStartY
FLIR:ImageValidEndY
FLIR:ImageUpsampleMode
FLIR:SpotmeterMinRadius

FLIR:MAVVersionID
FLIR:MAVRateOfClimb
FLIR:MAVRelativeAltitude
FLIR:MAVPitch
FLIR:MAVRoll
FLIR:MAVYaw
FLIR:MAVPitchRate
FLIR:MAVRollRate
FLIR:MAVYawRate
```

See corresponding entries under "Full List of Metadata" for definitions of these custom XMP metadata Tags, and the Appendix for an example of their usage.

Both "Camera" and "FLIR" XMP namespaces use the following set of types from section 8.2.1 "Basic value types" of Part 1 of the XMP specification:

Text

A possibly empty Unicode string.

Example XMP Tag with Text value:

```
<ex:someText>Something about rain and planes</ex:someText>
```

Boolean

Boolean values shall be "True" or "False".

Example XMP Tags with Boolean values:

```
<ex:someBoolean>True</ex:someBoolean>
<ex:otherBoolean>False</ex:otherBoolean>
```

Integer

A signed or unsigned numeric string used as an integer number representation. The string consists of an arbitrary-length decimal numeric string with an optional leading "+" or "-" sign.

Example XMP Tags with Integer values:

```
<ex:someInteger>1234321234</ex:someInteger>
<ex:otherInteger>-4500</ex:otherInteger>
```

Real

A string denoting a floating point-numeric value, written using decimal notation of an optional sign followed by an integer part and a fraction part. Either the integer part or the fraction part, but not both, may be omitted.

Example XMP Tags with Real values:

```
<ex:someReal>2.1234</ex:someReal>
<ex:otherReal>-.1234</ex:otherReal>
```

In addition "Camera" and "FLIR" namespaces use the Rational type, which is defined in section 3.2.3.3 of Part 3:

Rational

A string representing a fraction in *numerator/denominator* form.

Example XMP Tags with Rational values:

```
<ex:someRational>123/456</ex:someRational>
<ex:otherRational>-11/54</ex:otherRational>
```

The "Camera" namespace also makes use of ordered arrays composed of some of the basic types, per section 7.7 "Array valued XMP properties" of Part 1 of the XMP specification:

ordered array of Text

Value is a sequence element containing one or more list elements containing Text values

Example ordered array of Text:

```
<ex:someTextArray>
  <rdf:Seq>
    <rdf:li>First text</rdf:li>
    <rdf:li>Second text</rdf:li>
  </rdf:Seq>
</ex:someTextArray>
```

ordered array of Integer

Value is a sequence element containing one or more list elements containing Integer values

Example ordered array of Integer:

```
<ex:someIntegerArray>
  <rdf:Seq>
    <rdf:li>99</rdf:li>
    <rdf:li>-15</rdf:li>
  </rdf:Seq>
</ex:someIntegerArray>
```

3.5 - Multiple-Image TIFF Files

FLIR TIFF files *may* contain multiple images. These images would be multiple frames captured from the same detector as a video sequence. If multiple frames are present, each has its own TIFF IFD table in the linked list of IFD tables, with IFD table 0 corresponding to the first captured frame, IFD table 1 corresponding to the second captured frame, and so forth.

Each of the additional IFD tables, IFD 1 and later, contain the baseline TIFF tags listed below as "Image metadata". These tags locate image data for subsequent frames in the same manner described in section "TIFF Image Data". However, they do not contain other types of metadata, nor do they point to additional Exif and XMP metadata sections. There is only a single copy each of Exif and XMP metadata for the whole image

sequence, both pointed to by IFD table 0 as shown in Figure 8. Restricting Exif and XMP properties to the first image frame improves compatibility, because multiple Exif and XMP areas is not a widely supported feature for reader software.

In multiple-image files, IFD Table 0 contains one additional tag not found in single-image files: the *FrameRate* tag. This tag gives the rate of image capture in frames-per-second, and thus can be used to determine the time spacing between the frames.

3.6 - Full List of Metadata

3.6.1 - Image metadata: baseline TIFF tags

TagID	Tag name	Type	Example Value	Meaning
0x0100	Tiff.Image.ImageWidth	unsigned long	336	Width of image in pixels
0x0101	Tiff.Image.ImageLength	unsigned long	256	Height of image in pixels
0x0102	Tiff.Image.BitsPerSample	unsigned short	16	Number of bits per pixel
0x0103	Tiff.Image.Compression	unsigned short	1	Compression algorithm: 1=none, 5=LZW, 32773=PackBits
0x0106	Tiff.Image.PhotometricInterpretation	unsigned short	1	Color space: 0=WhitelsZero, 1=BlackIsZero, 2=RGB, 3=ColorPalette
0x0111	Tiff.Image.StripOffsets	unsigned long	8	See section "TIFF Image Data"
0x0115	Tiff.Image.SamplesPerPixel	unsigned short	1	number of color components per pixel - will be 1 for grayscale
0x0116	Tiff.Image.RowsPerStrip	unsigned long	256	See section "TIFF Image Data"
0x0117	Tiff.Image.StripByteCounts	unsigned long	172032	See section "TIFF Image Data"
0x011a	Tiff.Image.XResolution	rational	1/1	Pixels per Resolution Unit in X direction
0x011b	Tiff.Image.YResolution	rational	1/1	Pixels per Resolution Unit in Y direction
0x0128	Tiff.Image.ResolutionUnit	unsigned short	1	Unit for for image resolution: 1=none, 2=inch, 3=cm

0x0129	Tiff.Image.PageNumber	unsigned short * 2	0,1	word 0 is the number of corresponding image, word 1 the total number of images in file
0x0153	Tiff.Image.SampleFormat	unsigned short	1	1 = unsigned integer data

Note:

the exiv2 metadata library/tool names all TIFF tags "Exif", e.g. it calls tag 0x0100 "Exif.Image.ImageWidth"

3.6.2 - Image metadata: XMP tags in FLIR namespace

TagID	Type	Example Value	Meaning
FLIR:ImageOffsetX	Integer	0	X coordinate for upper left corner in original image, in case saved image was cropped from larger source image
FLIR:ImageOffsetY	Integer	0	Y coordinate for upper left corner in original image, in case saved image was cropped from larger source image
FLIR:ImageValidStartX	Integer	0	X coordinate for first pixel of valid data, in case of camera mode with padding at sides
FLIR:ImageValidEndX	Integer	335	X coordinate for last pixel of valid data, in case of camera mode with padding at sides
FLIR:ImageValidStartY	Integer	0	Y coordinate for first pixel of valid data, in case of camera mode with padding at top/bottom
FLIR:ImageValidEndY	Integer	255	Y coordinate for last pixel of valid data, in case of camera mode with padding at top/bottom
FLIR:ImageUpsampleMode	Integer	2	Type of upsampling of raw data from detector to image pixels: 0=none 1=copyX&Y 2=interpolateX&Y 3=interpolateX,copyY 4=copyX,InterpolateY

3.6.3 - Camera metadata: baseline TIFF tags and Exif tags

TagID	Tag name	Type	Example Value	Meaning
0x010f	Tiff.Image.Make	ascii string	FLIR	The camera manufacturer name
0x0110	Tiff.Image.Model	ascii string	Vue Pro 336 13mm	The model name of the camera
0x0131	Tiff.Image.Software	ascii string	12.3.4	Camera firmware version string

0x829d	Exif.Photo.FNumber	rational	125/100	Aperture F number
0x9211	Exif.Image.ImageNumber	unsigned long	16200	Frame counter for this image, incremented for each still frame captured (eventually wraps back to 0)
0x920a	Exif.Photo.FocalLength	rational	13/1	Focal length (mm)
0x9217	Exif.Image.SensingMethod	unsigned short	15	Type of detector
0xa20e	Exif.Photo.FocalPlaneXResolution	rational	40/7	Pixels per unit - for sensor/pixel size
0xa20f	Exif.Photo.FocalPlaneYResolution	rational	100/23	Pixels per unit - for sensor/pixel size
0xa210	Exif.Photo.FocalPlaneResolutionUnit	unsigned short	4	Unit for FocalPlane[XY]Resolution: 2=in, 3=cm, 4=mm
0xc62f	Tiff.Image.CameraSerialNumber	ascii string	141691	The serial number of the camera
0xc764	Tiff.Image.FrameRate	signed rational	9/1	The frame rate in FPS (Frames Per Second) for the captured image sequence (only applies to files containing multiple images)

Notes:

the exiv2 metadata library/tool names all TIFF tags "Exif", e.g. it calls tag 0x010f "Exif.Image.Make"

Tiff.Image.CameraSerialNumber and Tiff.Image.FrameRate are private TIFF tags which appear in a primary TIFF IFD table, not an Exif IFD table

Tiff.Image.FrameRate is only present if TIFF contains multiple images

3.6.4 - Positioning metadata: Exif GPS tags

TagID	Tag name	Type	Example Value	Meaning
0x0000	Exif.GPSInfo.GPSVersionID	byte (4)	2.3.0.0	Indicates the version of GPSInfoIFD. Current version is 2.3.
0x0001	Exif.GPSInfo.GPSLatitudeRef	ascii string	N	GPS reference north or south N=north, S=south
0x0002	Exif.GPSInfo.GPSLatitude	list of rational	34/1 25/1 15/1	GPS degrees, minutes, and seconds ¹
0x0003	Exif.GPSInfo.GPSLongitudeRef	ascii string	W	GPS reference east or west E=east, W=west
0x0004	Exif.GPSInfo.GPSLongitude	list of rational	119/1 41/1 10000/187	GPS degrees, minutes, and seconds ¹

0x0005	Exif.GPSInfo.GPSAltitudeRef	byte	0	GPS altitude reference: 0=altitude is above sealevel and is given relative to sealevel, 1=altitude is below sealevel and is given as absolute value
0x0006	Exif.GPSInfo.GPSAltitude	rational	121500/1000	GPS altitude (AMSL) in meters
0x0010	Exif.GPSInfo.GPSMeasureMode	ascii string	3	Indicates the GPS measurement mode. '2' means two-dimensional measurement and '3' means three-dimensional measurement.
0x000C	Exif.GPSInfo.GPSSpeedRef	ascii string	K	Units used to express the GPS receiver speed of movement. 'K' 'M' and 'N' represents kilometers per hour, miles per hour, and knots.
0x000D	Exif.GPSInfo.GPSSpeed	rational	62	(Horizontal) speed of GPS receiver movement.
0x000E	Exif.GPSInfo.GPSTrackRef	ascii string	T	Reference for giving the direction of GPS receiver movement. 'T' denotes true direction and 'M' is magnetic direction.
0x000F	Exif.GPSInfo.GPSTrack	rational	247.83	(Horizontal) direction of GPS receiver movement. The range of values is from 0.00 to 359.99.
0x0010	Exif.GPSInfo.GPSImgDirectionRef	ascii string	T	Reference for giving the direction of the image when it is captured. 'T' denotes true direction and 'M' is magnetic direction.
0x0011	Exif.GPSInfo.GPSImgDirection	rational	256.32	Direction of the image when it was captured. The range of values is from 0.00 to 359.99.

0x0012	Exif.GPSInfo.GPSMapDatum	ascii string	WGS-84	GPS coordinate system
0x001B	Exif.GPSInfo.GPSProcessingMethod	Undefined (character encoding, method name, no NULL)	MAVLINK	A character string recording the name of the method used for location finding.

¹ IFD entry has type = rational, count = 3; its externally-stored data array of rational values has value[0] = degrees, value[1] = minutes, value[2] = seconds

3.6.5 - Positioning metadata: XMP tags in FLIR namespace

Tag Name	Type	Example Value	Meaning
FLIR.MAVVersionID	Byte (4)	0.3.0.0	Version ID of MAVLink protocol (same format as Exif.GPSInfo.GPSVersionID)
FLIR.MAVRelativeAltitude	Rational	120500/1000	Vehicle altitude above ground in meters
FLIR.MAVRateOfClimbRef	ASCII	M	Units used to express the vehicle speed of vertical movement. M, S, and F represents meters per second, feet per second and feet per minute, respectively. Keep consistent with speed units.
FLIR.MAVRateOfClimb	Rational	123/10	The vertical speed of vehicle movement.
FLIR.MAVYaw	Rational	4304/100	Orientation data degrees +/- 180
FLIR.MAVPitch	Rational	51/10	Orientation data degrees/sec +/- 180
FLIR.MAVRoll	Rational	18/1	Orientation data degrees +/- 180
FLIR.MAVYawRate	Rational	4/10	Angular speed data degrees/sec
FLIR.MAVPitchRate	Rational	21/10	Angular speed data degrees/sec
FLIR.MAVRollRate	Rational	18/10	Angular speed data degrees/sec

3.6.6 - Timing metadata: Exif tags

TagID	Tag name	Type	Example Value	Meaning
-------	----------	------	---------------	---------

0x0007	Exif.GPSInfo.GPSTimeStamp	rational	5/1 24/1 51930/1000	Time as UTC (Coordinated Universal Time). TimeStamp is expressed as three rational values giving the hour, minute, and second.
0x001D	Exif.GPSInfo.GPSDateStamp	ASCII	YYYY:MM:DD	Character string recording date and time information relative to UTC (Coordinated Universal Time). The format is "YYYY:MM:DD." The length of the string is 11 Bytes including NULL.
0x9003	Exif.Photo.DateTimeOriginal	ascii string	2011:02:10 14:11:27	Time of image acquisition. The character string length is 20 Bytes including NULL for termination.
0x9291	Exif.Photo.SubSecTimeOriginal	ascii string	798	A tag used to record fractions of seconds for the DateTimeOriginal tag.

Note

Please see the additional Note about length of SubSecTime on page 49 of Exif Version 2.3 Specification.

4 - Quality Assurance

None.

5 - Preparation for delivery

None.

6 - Notes

Software and application notes/examples for internal/external developers.

Canonical Examples

Reference files available as a companion for this spec:

spilled_water.tiff

FLIR TIFF file containing a single 336x256 image frame

spilled_water.raw

raw 16-bit pixel data from *spilled_water.tiff* to aid in verifying that image data has been successfully extracted from the FLIR TIFF format

spilled_water.png

same raw data converted down to 8-bit grayscale and stored in PNG image format for a quick check of what the image should look like (most image viewers do not support 16-bit grayscale images)

Appendix A uses the contents of *spilled_water.tiff* to illustrate interpretation of all metadata present in a FLIR TIFF file. Note that, as is conventional for TIFF formats, the ordering among different subsections of the file is left as an implementation detail; only the header has a fixed position at the start of the file. For instance, a different but equally valid file might have image data follow immediately after the header, in which case the StripOffsets value would point backwards to a lower file offset -- rather than pointing forwards to image data placed after all metadata.

Appendix A - example file

Baseline TIFF section

offsets 0-305

TIFF Header

```
offset
  0 4949 002a ByteOrder: 0x4949 = little-endian, Constant: 0x002a
  4 0008 0000 IFD0 Pointer: 0x00000008 = 8
```

TIFF_IFD_0 first (and in this case, only) TIFF IFD

```
offset
  8 0014 EntryCount: 0x14 = 20 entries

type 1 = undefined (raw bytes)
type 2 = ascii
type 3 = unsigned short
type 4 = unsigned long
type 5 = rational (pair of unsigned long)

offset  tag  type cnt      value/offset
-----  ---  ----  -
  10 0100 0004 00000001 00000150 ImageWidth:
                                unsigned long 0x150 (336)
  22 0101 0004 00000001 00000100 ImageLength:
                                unsigned long 0x100 (256)
  34 0102 0003 00000001 00000010 BitsPerSample:
                                unsigned short 0x10 (16)
  46 0103 0003 00000001 00000001 Compression:
                                unsigned short 1 (no-compression)
  58 0106 0003 00000001 00000001 PhotometricInterpretation:
                                unsigned short 1 (black-is-zero)
  70 010f 0002 00000005 000000fe Make - EXTERNAL VALUE:
                                5 ascii bytes @ offset 0xfe (254)
  82 0110 0002 0000000d 00000104 Model - EXTERNAL VALUE:
                                0xd (13) ascii bytes @ offset 0x104 (260)
  94 0111 0004 00000001 00000ef4 StripOffsets:
                                unsigned long 0xef4 (3828)
 106 0116 0004 00000001 00000100 RowsPerStrip:
                                unsigned long 0x100 (256)
 118 0117 0004 00000001 0002a000 StripByteCounts:
                                unsigned long 0x2a000 (172032)
 130 011a 0005 00000001 00000112 XResolution - EXTERNAL VALUE:
                                rational (2 longs) @ offset 0x112 (274)
 142 011b 0005 00000001 0000011a YResolution - EXTERNAL VALUE:
                                rational (2 longs) @ offset 0x11a (282)
 154 0128 0003 00000001 00000001 ResolutionUnit:
                                unsigned short 1 (no-unit)
 166 0129 0003 00000002 00010000 PageNumber:
                                unsigned shorts 0, 1 (page0 of total 1)
 178 0131 0002 00000007 00000122 Software - EXTERNAL VALUE:
```

```

7 ascii bytes @ offset 0x122 (290)
190 0153 0003 000000001 000000001 SampleFormat:
unsigned short 1 (unsigned-integer-data)
202 02bc 0001 00000c8d 00000132 XMP metadata - XMP EXTENSION:
0xc8d (3212) bytes @ offset 0x132 (306)
214 8769 0004 000000001 00000dc0 Exif_IFD table - EXIF EXTENSION:
offset 0xdc0 (3520)
226 8825 0004 000000001 00000e5a GPS_IFD table - EXIF EXTENSION:
offset 0xe5a (3674)
238 c62f 0002 000000007 0000012a CameraSerialNumber - EXTERNAL VALUE:
7 ascii bytes @ offset 0x12a (298)

offset
250 0000 0000 NextIFD: 0 (TIFF_IFD_1 does not exist in this example file)

```

External Values

```

Tiff.Image.Make value
offset  value
-----
254 46 4c 49 52 00  ascii "FLIR"

Tiff.Image.Model
offset  value
-----
260 56 75 65 20 33 33 36 20 31 33 6d 6d 00  ascii "Vue 336 13mm"

Tiff.Image.XResolution value
offset  value
-----
274 00000001 00000001  rational 1/1

Tiff.Image.YResolution value
offset  value
-----
282 00000001 00000001  rational 1/1

Tiff.Image.Software
offset  value
-----
290 31 32 2e 33 2e 34 00  ascii "12.3.4"

Tiff.Image.CameraSerialNumber
offset  value
-----
298 31 34 31 36 39 31 00  ascii "141691"

```

XMP extension section

offsets 306-3519

```
<?xpacket begin=" " id="W5M0MpCehiHzreSzNTczkc9d"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:Camera="http://pix4d.com/camera/1.0/"
  xmlns:FLIR="http://ns.flir.com/xmp/1.0/">

  <rdf:Description rdf:about="">

    <Camera:BandName>
      <rdf:Seq>
        <rdf:li>LWIR</rdf:li>
        <rdf:li>MWIR</rdf:li>
      </rdf:Seq>
    </Camera:BandName>

    <Camera:CentralWavelength>
      <rdf:Seq>
        <rdf:li>10000</rdf:li>
        <rdf:li>4000</rdf:li>
      </rdf:Seq>
    </Camera:CentralWavelength>

    <Camera:WavelengthFWHM>
      <rdf:Seq>
        <rdf:li>4500</rdf:li>
        <rdf:li>1000</rdf:li>
      </rdf:Seq>
    </Camera:WavelengthFWHM>

    <Camera:Yaw>-30</Camera:Yaw>
    <Camera:Pitch>5</Camera:Pitch>
    <Camera:Roll>18</Camera:Roll>
    <Camera:GPSXYAccuracy>10.4</Camera:GPSXYAccuracy>
    <Camera:GPSZAccuracy>15.6</Camera:GPSZAccuracy>
    <Camera:GyroRate>139.6</Camera:GyroRate>
    <Camera:DetectorBitDepth>16</Camera:DetectorBitDepth>

    <FLIR:ImageOffsetX>0</FLIR:ImageOffsetX>
    <FLIR:ImageOffsetY>0</FLIR:ImageOffsetY>
    <FLIR:ImageValidStartX>0</FLIR:ImageValidStartX>
    <FLIR:ImageValidEndX>335</FLIR:ImageValidEndX>
    <FLIR:ImageValidStartY>0</FLIR:ImageValidStartY>
    <FLIR:ImageValidEndY>255</FLIR:ImageValidEndY>
    <FLIR:ImageUpsampleMode>2</FLIR:ImageUpsampleMode>

  </rdf:Description>
</rdf:RDF>
<?xpacket end="w"?>
```

Exif extension section

offsets 3520-3827

Exif_IFD table

```
offset
  3520 0008 EntryCount: 8 entries

type 1 = undefined (raw bytes)
type 2 = ascii
type 3 = unsigned short
type 4 = unsigned long
type 5 = rational (pair of unsigned long)

offset  tag  type  cnt      value/offset
-----  ---  ----  -
 3522  829d  0005  00000001  00000e26 FNumber - EXTERNAL VALUE:
                                     rational (2 longs) @ offset 0xe26 (3622)
 3534  9003  0002  00000014  00000e2e DateTimeOriginal - EXTERNAL VALUE:
                                     0x14 (20) ascii bytes @ offset 0xe2e (3630)
 3546  920a  0005  00000001  00000e42 FocalLength - EXTERNAL VALUE:
                                     rational (2 longs) @ offset 0xe42 (3650)
 3558  9211  0004  00000001  00003f48 ImageNumber:
                                     unsigned long 0x3f48 (16200)
 3570  9291  0002  00000003  00003937 SubSecTimeOriginal:
                                     3 ascii bytes "79" with null-termination
 3582  a20e  0005  00000001  00000e4a FocalPlaneXResolution - EXTERNAL VALUE:
                                     rational (2 longs) @ offset 0xe4a (3658)
 3594  a20f  0005  00000001  00000e52 FocalPlaneYResolution - EXTERNAL VALUE:
                                     rational (2 longs) @ offset 0xe52 (3666)
 3606  a210  0003  00000001  00000004 FocalPlaneResolutionUnit: unsigned short 4 (mm)

offset
  3618 0000 0000 NextIFD: 0 (no IFD table follows this one in linked list)
```

External Values

```
Exif.Photo.FNumber value

offset  value
-----  -
 3622  0000007d 00000064 rational 0x7d/0x64 (125/100)

Exif.Photo.DateTimeOriginal value

offset  value
-----  -
 3630  32 30 31 31 3a 30 32 3a 31 30
      20 31 34 3a 31 31 3a 32 37 00 ascii "2011:02:10 14:11:27"

Exif.Photo.FocalLength value

offset  value
```

```

-----
3650 0000000d 00000001 rational 0xd/1 (13/1)

Exif.Photo.FocalPlaneXResolution value

offset  value
-----
3658 00000028 00000007 rational 0x28/7 (40/7)

Exif.Photo.FocalPlaneYResolution value

offset  value
-----
3666 00000064 00000017 rational 0x64/0x17 (100/23)

```

GPS_IFD table

```

offset
 3674 0007 EntryCount: 7 entries

type 1 = undefined (raw bytes)
type 2 = ascii
type 3 = unsigned short
type 4 = unsigned long
type 5 = rational (pair of unsigned long)

offset  tag  type cnt      value/offset
-----  -
 3676 0001 0002 00000002 0000004e GPSLatitudeRef:
                               2 ascii bytes "N" with null-termination
 3688 0002 0005 00000003 00000eb4 GPSLatitude - EXTERNAL VALUE:
                               3 rationals (6 longs) @ offset 0xeb4 (3764)
 3700 0003 0002 00000002 00000057 GPSLongitudeRef:
                               2 ascii bytes "W" with null-termination
 3712 0004 0005 00000003 00000ecc GPSLongitude - EXTERNAL VALUE:
                               3 rationals (6 longs) @ offset 0xecc (3788)
 3724 0005 0001 00000001 00000000 GPSAltitudeRef:
                               byte 0 (altitude-relative-to-sealevel)
 3736 0006 0005 00000001 00000ee4 GPSAltitude - EXTERNAL VALUE:
                               rational (2 longs) @ offset 0xee4 (3812)
 3748 0012 0002 00000007 00000eec GPSMapDatum:
                               7 ascii bytes @ offset 0xeec (3820)

offset
 3760 0000 0000 NextIFD: 0 (no IFD table follows this one in linked list)

```

External Values

Exif.GPSInfo.GPSLatitude value

offset value

```
-----  
3764 00000022 00000001 rational 0x22/1 (34/1)  
3772 00000019 00000001 rational 0x19/1 (25/1)  
3780 0000000f 00000001 rational 0xf/1 (15/1)
```

Exif.GPSInfo.GPSLongitude value

offset value

```
-----  
3788 00000077 00000001 rational 0x77/1 (119/1)  
3786 00000029 00000001 rational 0x29/1 (41/1)  
3804 00002710 000000bb rational 0x2710/0xbb (10000/187)
```

Exif.GPSInfo.GPSAltitude value

offset value

```
-----  
3812 000004b5 00000064
```

Exif.GPSInfo.GPSMapDatum

offset value

```
-----  
3820 57 47 53 2d 38 34 00 ascii "WGS-84"
```

Image data section

offsets 3828-175859

offset value

```
-----  
3828 0cd0 0cd8 0cc2 0cd8 0cd9 0cd6 0cd9 0cd8 16-bit grayscale image data:  
... 256 rows of 336 pixels each  
175844 0d36 0d32 0d3b 0d38 0d44 0d36 0d33 0d44
```