

Windows NT Registry File (REGF) format specification

Analysis of the NT Registry File format

By Joachim Metz <joachim.metz@gmail.com>

Summary

A Windows NT Registry File is used by Microsoft Windows NT (or later) to store a part of the Windows Registry. This specification is based on earlier work on the format and was complimented by reverse engineering.

This document is intended as a working document for the Windows NT Registry File (REGF) format specification. Which should allow existing Open Source forensic tooling to be able to process this file type.

Document information

Author(s): Joachim Metz <joachim.metz@gmail.com>

Abstract: This document contains information about the Windows NT Registry File format.

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Version

Version	Author	Date	Comments
0.0.1	J.B. Metz	July 2009	Initial version.
0.0.2	J.B. Metz	October 2009	Additional information.
0.0.3	J.B. Metz	January 2010	Small changes
0.0.4	J.B. Metz	June 2010	Additional information regarding data blocks.
0.0.5	J.B. Metz	October 2010	Small changes
0.0.6	J.B. Metz	March 2012	Added information about key and value names.
0.0.7	J.B. Metz	April 2012	Update regarding hash algorithm.
0.0.8	J.B. Metz	May 2012	Updates for Windows 8 Consumer Preview.
0.0.9	J.B. Metz	August 2012	Small changes.
0.0.10	J.B. Metz	September 2012	Small changes.
0.0.11	J.B. Metz	February 2013	Small changes.
0.0.12	J.B. Metz	April 2013	Additional information regarding value data.
0.0.13	J.B. Metz	April 2013	More information on corruption scenarios.

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1. Overview

A Windows NT Registry File (REGF) is used by Microsoft Windows NT (or later) to store a part of the Windows Registry. These parts are referred to as hives. The Registry uses the following hives:

Hive name	Description
HKEY_CLASSES_ROOT	TODO Used by Windows NT 4 and later Refers to the class key in HKEY_LOCAL_MACHINE
HKEY_CURRENT_USER	Information regarding the current active user Used by Windows NT 4 and later Refers to the active user key in HKEY_USERS
HKEY_CURRENT_CONFIG	TODO Used by Windows NT 4 and later Refers to the active control set in HKEY_LOCAL_MACHINE\CONTROL\
HKEY_USERS	Information about all active users Used by Windows NT 4 and later
HKEY_LOCAL_MACHINE	Local settings Used by Windows NT 4 and later

There are REGF with different names for parts of the Registry, some are:

Filename	Windows	Description
default	NT4 and later	TODO
NTUSER.DAT	NT4 and later	User specific part of the registry Location: %UserProfile%\ Registry key: HKEY_CURRENT_USER
NTUSER.MAN	NT4 and later	Mandatory user specific part of the registry Location: %UserProfile%\
SAM	NT4 and later	Security Account Manager (SAM) part of the registry Location: %SystemRoot%\System32\Config\
SOFTWARE	NT4 and later	Software specific part of the registry Location: %SystemRoot%\System32\Config\ Registry key: HKEY_LOCAL_MACHINE\Software
SYSTEM	NT4 and later	System specific part of the registry Location: %SystemRoot%\System32\Config\ Registry key: HKEY_LOCAL_MACHINE\System
userdiff	NT4 and later	Location: %SystemRoot%\System32\Config\
UsrClass.dat	2000 and later	File associations and COM registry entries Location: %UserProfile%\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
UsrClass.dat	Vista and later	File associations and COM registry entries %UserProfile%\Local Settings\Application

Filename	Windows	Description
		Data\Microsoft\Windows\Usrclass.dat

1.1. Test version

The following version of programs were used to test the information within this document:

- Windows NT 4
- Windows 2000
- Windows XP (SP2, SP3)
- Windows 2003
- Windows Vista
- Windows 2008
- Windows 7
- Windows 8

1.2. Overview

A REGF consist of the following distinguishable elements:

- file header
- hive bins
- trailing empty blocks

Characteristics	Description
Byte order	little-endian
Date and time values	Filetime in UTC
Character string	ASCII strings are stored in extended ASCII with a codepage. Unicode strings are stored in UTF-16 little-endian without the byte order mark (BOM).

According to [MSDN]:

- a key name has a limit of 255 characters
- a value name has a limit of 16383 characters (for Windows 2000 this is limit is 260 ASCII or 16383 Unicode characters)
- a Registry tree can be 512 levels deep

Both key and values names are case insensitive. The \ character is used as the key separator. Note that the \ character can be used in value names. The / character is used in both key and value names. Some examples of which are:

Key:	HKEY_LOCAL_MACHINE\SYSTEM\ControlSet002\Services\NetBT\Parameters\
Value:	Size/Small/Medium/Large

Key:	HKEY_LOCAL_MACHINE\SYSTEM\ControlSet001\Control\Terminal
Value:	\Device\Video0

Key:	
------	--

```
HKEY_LOCAL_MACHINE\SYSTEM\ControlSet002\services\xmlprov\Parameters\SchemaGroups\User\http://www.microsoft.com/provisioning/eaptlsuserpropertiesv1\
Value:      SchemaFile
```

Note it seems that duplicate key and value names are possible.

2. File header

The file header is stored in a 4096 byte header block. However transaction log files can have a header block of 1024 bytes.

The file header is 512 bytes of size and consists of:

offset	size	value	description
0	4	“regf”	The signature
4	4		Primary sequence number Matches the secondary sequence number if the hive was properly synchronized
8	4		Secondary sequence number Matches the primary sequence number if the hive was properly synchronized
12	8		Last modification date and time in UTC Filetime
20	4		Major version
24	4		Minor version
28	4		File type 0x0000 => normal 0x0001 => transaction log
32	4		Unknown (format) 0x0001
36	4		The root key offset Primary sequence number Matches the secondary sequence number if the hive was properly synchronized
40	4		Hive bins data size
44	4		Unknown 0x0001
48	64		Unknown Sometimes contains the last part of the filename in UTF-16 LE most of the time with an end-of-string character, but not always. Unused bytes are 0.
112	396		Unknown Can contain remnant data Padding used for the checksum?

offset	size	value	description
508	4		Checksum XOR-32 of the previous 508 bytes

```

file offset = ( hive bin number x hive block size ) + header block size
             = ( hive bin number x 4096 ) + 4096
             = ( hive bin number + 1 ) x 4096

```

Version (Major.Minor)	Description
1.3	used in NTUSER.DAT, SAM
1.5	used in .sav REGF, SYSTEM

Note: if sequence numbers don't match the hive has partial data, apply .LOG on top of PRIMARY

2.1. Dirty vector

For a transaction log the first block contains the dirty vector. The dirty vector is variable of size and consists of:

offset	size	value	description
512	4		In transaction log: the dirty vector signature "DIRT"
516	...		In transaction log: bitmap of dirty hive bin pages 1 => indicates a dirty hive bin page
...		Padding to 4096

3. Hive bin

The hive bin consists of:

- the hive bin header
- the hive bin cells

3.1. Hive bin header

The hive bin header is 32 bytes of size and consists of:

offset	size	value	description
0	4	"hbin"	The signature
4	4		The offset of the hive bin Value in bytes and relative from the start of the hive bin data
8	4		Size of the hive bin Value in bytes

offset	size	value	description
12	4		Reserved 0 most of the time, can contain remnant data
16	4		Reserved 0 most of the time, can contain remnant data
20	8		Timestamp 0 most of the time, can contain remnant data Only the root (first) hive bin seems to contain a valid filetime
28	4		Spare Value similar to the size Number of bytes

3.2. Hive bin cell

The hive bin cell is variable of size and consists of:

offset	size	value	description
0	4		Cell size The value contains the 4 bytes of the size itself. The value is negative if the cell is allocated or positive if the cell is unallocated. The size is 8 byte aligned
4	...		Cell data

If a hive bin cell becomes unallocated and is adjacent to another unallocated cell, they are merged by having the first cell's size extended.

4. Hive bin cell values

A hive bin cell values contain different types of data. Some of the types of data are identifier by a 2 byte signature value.

Value	Description
“lf” “lh” “li” “ri”	Sub keys list
“nk”	Named key
“sk”	Security key
“vk”	Value key
“db”	Data block key

4.1. Named key

The named key is variable of size and consists of:

offset	size	value	description
0	2	“nk”	Signature
2	2		Flags See section: 4.1.1 Flags
4	8		Last (key) written date and time Filetime
12	4		Unknown Empty value
16	4		Parent key offset The offset value is in bytes and relative from the start of the hive bin data
20	4		number of sub keys
24	4		number of volatile sub keys
28	4		Sub keys list offset The offset value is in bytes and relative from the start of the hive bin data Refers to a sub keys list or contains -1 (0xffffffff) if empty. See section: 4.3 Sub key list
32	4		Volatile sub keys list offset The offset value is in bytes and relative from the start of the hive bin data Refers to a sub keys list or contains -1 (0xffffffff) if empty. See section: 4.3 Sub key list
36	4		number of values
40	4		Values list offset The offset value is in bytes and relative from the start of the hive bin data Refers to a values list or -1 (0xffffffff) if empty. See section: 4.5 Values list
44	4		Security key offset The offset value is in bytes and relative from the start of the hive bin data Refers to a security key or -1 (0xffffffff) if empty. See section: 4.2 Security key
48	4		Class name offset The offset value is in bytes and relative from the start of the hive bin data

offset	size	value	description
			Refers to a class name or -1 (0xffffffff) if empty.
52	4		Largest sub key name size
56	4		Largest sub key class name size
60	4		Largest value name size
64	4		Largest value data size
68	4		Unknown Some run-time caching index or hash?
72	2		Key name size
74	2		Class name size
76	...		Key name string ASCII or Unicode string not terminated by an end-of-string character Maximum of 255 characters
...	...		Padding due to 8 byte alignment of cell size Sometimes contains remnant data

4.1.1. Flags

Value	Identifier	Description
0x0001		Is volatile key
0x0002		Is mount point (of another registry hive)
0x0004		Is root key (of current registry hive)
0x0008		Cannot be deleted
0x0010		Is symbolic link key
0x0020		Name is an ASCII string Otherwise the name is an Unicode (UTF-16 little-endian) string
0x0040		Is predefined handle
0x0080		Unknown
0x1000		Unknown
0x4000		Unknown

TODO

Value	Meaning
REG_STANDARD_FORMAT	
1	

The key or hive is saved in standard format. The standard format is the only format supported by Windows 2000.

REG_LATEST_FORMAT
2

The key or hive is saved in the latest format. The latest format is supported starting with Windows XP. After the key or hive is saved in this format, it cannot be loaded on an earlier system.

REG_NO_COMPRESSION
4

The key or hive is saved with no compression. This option accommodates faster save operations.

4.2. Security key

The security key is variable of size and consists of:

offset	size	value	description
0	2	“sk”	Signature
2	2		Unknown
4	4		Previous security key offset The offset value is in bytes and relative from the start of the hive bin data
8	4		Next security key offset The offset value is in bytes and relative from the start of the hive bin data
12	4		Reference count
16	...		NT security descriptor

4.3. Sub key list

The sub key list is variable of size and consists of:

offset	size	value	description
0	2	“lf”, “lh”, “li”, “ri”	Signature
2	2		Number of elements
4	...		Sub key list elements
			Padding due to 8 byte alignment of cell size Sometimes contains remnant data

4.3.1. “lf” and “lh” sub key element

For “lf” and “lh” sub key lists the sub key list element is 8 bytes of size and consists of:

offset	size	value	description
0	4		Named key offset The offset value is in bytes and relative from the start of the hive bin data What about data offset 0 and 0xffffffff?
4	4		Hash value A different hash function is used for different sub key list types

LF => Leaf ?

LH => Hashed leaf ?

4.3.2. “li” sub key element

For “li” sub key lists the sub key list element is 4 bytes of size and consists of:

offset	size	value	description
0	4		Named key offset The offset value is in bytes and relative from the start of the hive bin data. What about data offset 0 and 0xffffffff?

LI => Leaf item ?

4.3.3. “ri” sub key element

For “ri” sub key lists the sub key list element is 4 bytes of size and consists of:

offset	size	value	description
0	4		Sub key list offset The offset value is in bytes and relative from the start of the hive bin data What about data offset 0 and 0xffffffff?

RI => Reference item ?

4.4. Value key

The value key is variable of size and consists of:

offset	size	value	description
0	2	“vk”	Signature
2	2		Value name size If the value name size is 0 the value name is “(default)”

offset	size	value	description
4	4		Data size See note below
8	4		Data offset The offset value is in bytes and relative from the start of the hive bin data. What about data offset 0 and 0xffffffff?
12	4		Data type See section: 4.4.1 Data types
16	2		Flags See section: 4.4.2 Flags
18	2		Unknown (padding) Can contain remnant data
20	...		Value name ASCII or Unicode string not terminated by an end-of-string character Maximum of 260 ASCII characters or 16383 Unicode characters
...	...		Padding due to 8 byte alignment of cell size Sometimes contains remnant data

A data size of 0 represents that the value is not set (or NULL).

If the MSB 0x80000000 of the data size is set the data offset actually contains the data value.

- A data size of 4 uses all 4 bytes of the data offset
- A data size of 2 uses the last 2 bytes of the data offset (on a little-endian system)
- A data size of 1 uses the last byte (on a little-endian system)
- A data size of 0 represents that the value is not set (or NULL).

The behavior on a big-endian system is unknown.

4.4.1. Data types

Value	Identifier	Description
0x00000000	REG_NONE	Undefined type
0x00000001	REG_SZ	String [MSDN] states that this is either in ASCII or Unicode with an end-of-string character Although the string seems to be always stored as UTF-16 little-endian and sometimes the end-of-string character is not included. Also see: 6 Corruption scenarios
0x00000002	REG_EXPAND_SZ	String that contains expandable (environment) variables like %PATH% Either in ASCII or Unicode with an end-of-string character
0x00000003	REG_BINARY	Binary data

Value	Identifier	Description
0x00000004	REG_DWORD REG_DWORD _LITTLE_ENDIAN	32-bit integer (double word) little-endian
0x00000005	REG_DWORD _BIG_ENDIAN	Integer 32-bit signed little-endian (double word)
0x00000006	REG_LINK	String that contains a symbolic link Either in ASCII or Unicode with an end-of-string character
0x00000007	REG_MULTI_SZ	Array of strings Either in ASCII or Unicode with an end-of-string character
0x00000008	REG_RESOURCE_LIST	Resource list
0x00000009	REG_FULL_RESOURCE_DESCRIPTOR	Full resource descriptor
0x0000000a	REG_RESOURCE_REQUIREMENTS_LIST	Resource requirements list
0x0000000b	REG_QWORD REG_QWORD _LITTLE_ENDIAN	Integer 64-bit signed little-endian (quad word)

4.4.2. Flags

Value	Identifier	Description
0x0001		Name is an ASCII string Otherwise the name is an Unicode (UTF-16 little-endian) string

4.5. Values list

The value list is variable of size and consists of:

offset	size	value	description
0	...		Value key list entries
...	...		Padding due to 8 byte alignment of cell size Sometimes contains remnant data

A value list entry is 4 bytes of size and consists of:

offset	size	value	description
0	4		Value key offset The offset value is in bytes and relative from the start of the hive bin data.

offset	size	value	description
			What about data offset 0 and 0xffffffff?

4.6. Value data

The value data is stored directly in a hive bin cell.

According to [MSDN] the value data has a maximum size of the available memory in the latest format (1.5) and 1 MiB in the standard format (1.3). In the latest format (1.5) values larger than 16344 bytes are stored in multiple segments. Data about these segments is stored in the data block key. These large values are also referred to as long values.

[MSDN] Long values (more than 2,048 bytes) should be stored as files with the file names stored in the registry. This helps the registry perform efficiently.

4.6.1. Data block key

The data block key is 12 bytes of size and consists of:

offset	size	value	description
0	2	“db”	Signature
2	2		number of segments
4	4		Data block (segment) list offset The offset value is in bytes and relative from the start of the hive bin data. What about data offset 0 and 0xffffffff?
8	4		Padding due to 8 byte alignment of cell size Sometimes contains remnant data

4.6.2. Data block segment list

The data block segment list is variable of size and consists of:

offset	size	value	description
0	...		Data block segment list entries
...	...		Padding due to 8 byte alignment of cell size Sometimes contains remnant data

A data block list entry is 4 bytes of size and consists of:

offset	size	value	description
0	4		Data block segment data offset The offset value is in bytes and relative from the start of the hive bin data. What about data offset 0 and 0xffffffff?

4.6.3. Data block segment data

The data block segment data is stored directly in a hive bin cell.

5. Hash algorithms

5.1. LH sub key hash algorithm

Note that the hash operations are modulus 32-bit and the string is traversed per character. E.g. for an UTF-16 little-endian string the character is 2 bytes of size.

```
uint32_t hash_value = 0;

for( string_index = 0;
    string_index < string_length;
    string_index++ )
{
    hash_value *= 37;
    hash_value += uppercase( string[ string_index ] );
}
```

Note that uppercase must be able to handle Unicode.

It's unknown how extended UTF-16 (4-byte) characters are handled.

6. Corruption scenarios

6.1. Value data size exceeds hive bin cell value size

In this scenario the value data size exceeds the hive bin cell value size it currently is assumed that the cell value size is the one to be used. Seeing it operates on a lower level then the value data size.

Is the next hive bin cell value unallocated?

6.2. Value key size too small

In this scenario the values list references the offset of a value key of which the actual hive bin cell value size is too small to be the size of the value key. Also the data in the bin cell value does not match a value key. Was the hive bin cell value unallocated?

6.3. Integer value data too large

In this scenario the value is e.g. of type REG_DWORD_LITTLE_ENDIAN and the value data consist of more than 4 bytes. It is assumed the same applies to REG_DWORD_BIG_ENDIAN and REG_QWORD_LITTLE_ENDIAN.

```
Value key data:
00000000: 76 6b 06 00 08 00 00 00 50 54 cf 01 04 00 00 00 vk..... PT.....
00000010: 01 00 6f 00 6c 50 61 72 61 6d 00 00 ..o.lPar am..

signature                : vk
value name size          : 6
data size                 : 0x00000008 (8)
```

```

data offset          : 0x01cf5450
data type           : 4 (REG_DWORD_LITTLE_ENDIAN) Integer 32-bit
signed little-endian
flags               : 0x0001
                    Value name is an ASCII string

unknown1            : 0x006f (111)
value name           : lParam
value name hash      : 0x4343bfdd
padding:
00000000: 00 00                                ..

value data:
00000000: 00 00 00 00 00 00 00 00 30 00 00 00  ..... 0...

value data padding:
00000000: 30 00 00 00                                0...

```

The Windows Registry-editor indicates this as an invalid value and presents it as binary data.

6.4. String value data too small

In this scenario the value is of type REG-SZ. The value data contains an UTF-16 little-endian string but the value data size is 1 too small. The size of the hive bin cell value is larger than the value data.

In this scenario the additional byte was a 0-byte and can be safely ignored.

Note that this can also apply to values stored in the data offset.

```

signature           : vk
value name size      : 11
data size           : 0x80000003 (3)
data offset        : 0x00000031
data type           : 1 (REG_SZ) String
flags               : 0x0001
                    Value name is an ASCII string

unknown1            : 0x0000 (0)
value name           : bEnableFlag
value name hash      : 0x6f09ddef
padding:
00000000: 00 00 00 00 00 00  .....

```

6.5. String value data too large

In this scenario the value is e.g. of type REG_SZ and the value data consist of more bytes than the size of the string. It is assumed the same applies to REG_EXPAND_SZ.

```

Value key data:
00000000: 76 6b 0b 00 0b 02 00 00 b8 7b 35 00 01 00 00 00 vk..... {5.....
00000010: 01 00 00 00 57 50 50 46 69 6c 65 4e 61 6d 65 00 ....WPPF fileName.
00000020: 00 00 00 00                                ....

signature           : vk
value name size      : 11

```

```

data size           : 0x0000020b (523)
data offset         : 0x00357bb8
data type           : 1 (REG_SZ) String
flags               : 0x0001
                   Value name is an ASCII string

unknown1            : 0x0000 (0)
value name          : WPPFileName
value name hash     : 0x4588b1a4
padding:
00000000: 00 00 00 00 00                      .....

value data:
00000000: 4d 00 65 00 64 00 69 00 61 00 53 00 74 00 61 00  M.e.d.i. a.S.t.a.
00000010: 63 00 6b 00 00 00 00 00 d0 3e 9f 01 30 46 9f 01  c.k..... .>..0F..
00000020: f0 f4 06 00 ff ff ff ff c8 f7 06 00 20 e9 90 7c  .... ..|
...

```

The Windows Registry-editor indicates this as a valid value and presents the string “MediaStack”.

7. Notes

```

SPARE value in XP SYSTEM regf
unknown spare           : 0x00000000 (0)
unknown spare           : 0x00002000 (8192)
unknown spare           : 0x0011a000 (1155072)
unknown spare           : 0x0011c000 (1163264)
unknown spare           : 0x00120000 (1179648)
unknown spare           : 0x00122000 (1187840)
unknown spare           : 0x00123000 (1191936)
unknown spare           : 0x00125000 (1200128)
unknown spare           : 0x00126000 (1204224)
unknown spare           : 0x00127000 (1208320)
unknown spare           : 0x0012a000 (1220608)
unknown spare           : 0x0012d000 (1232896)
unknown spare           : 0x0012e000 (1236992)
unknown spare           : 0x00131000 (1249280)
unknown spare           : 0x00143000 (1323008)
unknown spare           : 0x00145000 (1331200)
unknown spare           : 0x00148000 (1343488)
unknown spare           : 0x00152000 (1384448)
unknown spare           : 0x00184000 (1589248)
unknown spare           : 0x00185000 (1593344)
unknown spare           : 0x00186000 (1597440)
unknown spare           : 0x00187000 (1601536)
unknown spare           : 0x00188000 (1605632)
unknown spare           : 0x00189000 (1609728)
unknown spare           : 0x0018a000 (1613824)
unknown spare           : 0x001bf000 (1830912)
unknown spare           : 0x001c7000 (1863680)
unknown spare           : 0x00218000 (2195456)
unknown spare           : 0x00224000 (2244608)

```

7.1. Transaction log

Hive bins size is set but the file has not sufficient size to store the hive bins.

Appendix A. References

[PROBERT03]

Title: Windows Kernel Internals - NT Registry Implementation
Author(s): David B. Probert
Date: August 29, 2003
URL: <http://www.i.u-tokyo.ac.jp/edu/training/ss/lecture/new-documents/Lectures/09-Registry/Registry.pdf>

[NORRIS09]

Title: The Internal Structure of the Windows Registry
Author(s): Peter Norris
Date: February 2009
UTL: <http://amnesia.gtisc.gatech.edu/~moyix/suzibandit.ltd.uk/MSc/>

[MORGAN09]

Title: The Windows NT* Registry File Format
Version: 0.4
Author(s): Timothy D. Morgan
Date: June 9, 2009
URL: <http://www.sentinelchicken.com/data/TheWindowsNTRegistryFileFormat.pdf>

[WINREG]

Title: WinReg.txt
Author(s): B.D.

[MSDN]

Title: Registry
URL: <http://msdn.microsoft.com>
URL: [http://msdn.microsoft.com/en-us/library/windows/desktop/ms724872\(v=vs.85\).aspx](http://msdn.microsoft.com/en-us/library/windows/desktop/ms724872(v=vs.85).aspx)

Appendix B. GNU Free Documentation License

Version 1.3, 3 November 2008

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