

Appendix C: Summary of keywords

This Appendix is not part of the FITS standard, but is included for convenient reference.

All of the mandatory and reserved keywords that are defined in the standard, except for the reserved WCS keywords that are discussed separately in Sect. 8, are listed in Tables C.1, C.2, and C.3. An alphabetized list of these keywords and their definitions is available online: http://heasarc.gsfc.nasa.gov/docs/fcg/standard_dict.html.

Table C.1: Mandatory *FITS* keywords for the structures described in this document.

Primary HDU	Conforming extension	Image extension	ASCII table extension	Binary table extension	Compressed images ⁶	Compressed tables ⁶	Random groups records
SIMPLE	XTENSION	XTENSION ¹	XTENSION ²	XTENSION ³	ZIMAGE =T	ZTABLE =T	SIMPLE
BITPIX	BITPIX	BITPIX	BITPIX = 8	BITPIX = 8	ZBITPIX	ZNAXIS1	BITPIX
NAXIS	NAXIS	NAXIS	NAXIS = 2	NAXIS = 2	ZNAXIS	ZNAXIS2	NAXIS
NAXISn ⁴	NAXISn ⁴	NAXISn ⁴	NAXIS1	NAXIS1	ZNAXISn	ZPCOUNT	NAXIS1 = 0
END	PCOUNT	PCOUNT = 0	NAXIS2	NAXIS2	ZCMPTYPE	ZFORMn	NAXISn ⁴
	GCOUNT	GCOUNT = 1	PCOUNT = 0	PCOUNT		ZCTYPn	GROUPS = T
	END	END	GCOUNT = 1	GCOUNT = 1		ZTILELEN	PCOUNT
			TFIELDS	TFIELDS			GCOUNT
			TFORMn ⁵	TFORMn ⁵			END
			TBCOLn ⁵	END			
			END				

⁽¹⁾XTENSION=_'IMAGE_...' for the image extension. ⁽²⁾XTENSION=_'TABLE_...' for the ASCII table extension. ⁽³⁾XTENSION=_'BINTABLE' for the binary table extension. ⁽⁴⁾Runs from 1 through the value of NAXIS. ⁽⁵⁾Runs from 1 through the value of TFIELDS. ⁽⁶⁾required in addition to the mandatory keywords for binary tables.

Table C.2: Reserved *FITS* keywords for the structures described in this document.

All ¹ HDUs	Array ² HDUs	ASCII table extension	Binary table extension	Compressed images	Compressed tables	Random groups records	
DATE	EXTNAME	BSCALE	TSCALn	TSCALn	ZTILEn	FZTILELN	PTYPEn
DATE-OBS	EXTVER	BZERO	TZEROn	TZEROn	ZNAMEi	FZALGOR	PSCALn
ORIGIN	EXTLEVEL	BUNIT	TNULLn	TNULLn	ZVALi	FZALGn	PZEROn
AUTHOR	EQUINOX	BLANK	TTYPEn	TTYPEn	ZMASKCMP		
REFERENC	EPOCH ³	DATAMAX	TUNITn	TUNITn	ZQUANTIZ		
COMMENT	BLOCKED ³	DATAMIN	TDISPn	TDISPn	ZDITHER0		
HISTORY	EXTEND ⁴		TDMAXn	TDIMn	ZSIMPLE	ZTHEAP	
TELESCOP	TELESCOP		TDMINn	THEAP	ZEXTEND		
OBJECT	INSTRUME		TLMAXn	TDMAXn	ZBLOCKED		
OBSERVER			TLMINn	TDMINn	ZTENSION		
CONTINUE				TLMAXn	ZPCOUNT		
INHERIT ⁵				TLMINn	ZGCOUNT		
CHECKSUM					ZCHECKSUM	ZCHECKSUM	
DATASUM					ZDATASUM	ZDATASUM	

⁽¹⁾These keywords are further categorized in Table C.3. ⁽²⁾Primary HDU, image extension, user-defined HDUs with same array structure. ⁽³⁾Deprecated. ⁽⁴⁾Only permitted in the primary HDU. ⁽⁵⁾Only permitted in extension HDUs, immediately following the mandatory keywords.

Table C.3: General reserved *FITS* keywords described in this document.

Production	Bibliographic	Commentary	Observation
DATE	AUTHOR	COMMENT	DATE-OBS
ORIGIN	REFERENC	HISTORY	TELESCOP
BLOCKED ¹			INSTRUME
			OBSERVER
			OBJECT
			EQUINOX
			EPOCH ¹

⁽¹⁾Deprecated.

- The last paragraph of Sect. 4.1.2.3 was corrected to state that the ASCII text characters have hexadecimal values 20 through 7E, not 41 through 7E.

H.3. List of modifications to the latest FITS standard

1. The representation of time coordinates has been incorporated by reference from Rots et al. (2015) and is summarized in Sect. 9. Cross-references have been inserted in pre-existing sections of the Standard (namely in Sect. 4.2.7, 4.3, 4.4.2.1, 4.4.2.2 and 5.4, as well as in various places of Sect. 8, like 8.3 and 8.4.1). New keywords are listed in a rearranged Table 22. Contextually an erratum was applied in Sect. 8.4.1: keywords OBSGEO-[XYZ] were incorrectly marked as OBSGEO-[XYZ]*a*; the TAI-UTC difference in Table 30 was updated with respect to Rots et al. (2015) taking into account the latest leap second; the possibility of introducing more sources for the solar system ephemerides was re-worded (at the end of Sect.9.2.5 and in Table 31).
2. The continued string keywords described in Sect. 4.2.1.2 were originally introduced as a *FITS* convention since 1994, and registered in 2007. The text of the original convention is reported at http://fits.gsfc.nasa.gov/registry/continue_keyword.html. The differences with this standard concern:
 - In the convention, the LONGSTRN keyword was used to signal the possible presence of long strings in the HDU. The use of this keyword is no longer required or recommended.
 - Usage of the convention was *not recommended* for reserved or mandatory keywords. Now it is *explicitly forbidden* unless keywords are explicitly declared long-string.
 - To avoid ambiguities in the application of the previous clause, the declaration of string keywords in sections 8, 9 and 10 has been reset from the generic ‘character’ to ‘string’.
 - It is also explicitly clarified there is no limit to the number of continuation records.
 - The description of continued comment field is new.
3. The blank header space convention described in Sect. 4.4.2.4 was used since 1996, and registered in 2014. The text of the original convention is reported at <http://fits.gsfc.nasa.gov/registry/headerspace.html>. It included a *recommendation* about using the convention in a controlled environment, which does not appear in this standard.

4. The INHERIT keyword described in Sect. 4.4.2.6 was originally introduced as a *FITS* convention since 1995, and registered in 2007. The text of the original convention is reported at <http://fits.gsfc.nasa.gov/registry/inherit.html>. See also references and practical considerations therein.

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5. The table keywords described in Sect. 7.2.2 and 7.3.2 were originally introduced as a *FITS* convention since 1993, and registered in 2006. The text of the original convention is reported at <http://fits.gsfc.nasa.gov/registry/colminmax.html>. The differences with this standard concern:
 - The exclusion of undefined or IEEE special values when computing maximum and minimum is now *mandatory* while it was *optional*.
 - The original text included the possibility of using the fact TDMINn were greater than TDMAXn (or TLMINn greater than TLMAXn) as an indication the values were undefined. This clause has been removed
 - The original text contained usage examples and additional minor explanatory details.
6. The checksum keywords described in Sect. 4.4.2.7 were originally introduced as a *FITS* convention since 1994, and registered in 2007. The text of the original convention is reported at <http://fits.gsfc.nasa.gov/registry/checksum.html>. The differences with this standard concern:
 - The omission of some additional implementation guidelines.
 - The omission of a discussion on alternate algorithms and relevant additional references.
7. The conventions for compressed data described in Sect. 10. were originally introduced as a couple of *FITS* conventions registered in 2007 and 2013. The text of the original conventions is reported at <http://fits.gsfc.nasa.gov/registry/tilecompression.html> for compressed images and at <http://fits.gsfc.nasa.gov/registry/tiletablecompression.html> for compressed binary tables. The differences with this standard concern:
 - In Sect. 10.3.3 the original text for FZALGn mentioned the possibility that, ‘If the column cannot be compressed with the requested algorithm (e.g., if it has an inappropriate data type), then a default compression algorithm will be used instead.’ But there is no default algorithm. This is irrelevant for the Standard.
 - In Sect. 10.4 the alias ‘RICE_ONE’ is *not* adopted in the Standard as a synonym for ‘RICE_1’.
 - In Sect. 10.4.3 a sentence was left out about requiring additional instructions in PLIO to make it work for more than 2^{12} bits, since we aren’t allowing this possibility in the Standard.
 - In Sect. 10.4.4 the reference to a ‘smoothing flag’ was dropped.
 - Also in Sect. 10.4.4 the *scale factor* is now floating point, while it was originally integer.
 - In Table 36 (and Sect. 10.3.5) the NOCOMPRESS algorithm is explicitly mentioned.

8. The Green Bank convention mentioned in Sect. 8.2 was in use since 1989, and registered in 2010. The text of the registered convention is reported at <http://fits.gsfc.nasa.gov/registry/greenbank/greenbank.pdf>. The original text contains some additional details about the history of the convention.

Appendix I: Random Number Generator

This Appendix is not part of the FITS standard, but is included for informational purposes.

The portable random number generator algorithm below is from Park & Miller (1988). This algorithm repeatedly evaluates the function

$$seed = (a * seed) \bmod m$$

where the values of a and m are shown below, but it is implemented in a way to avoid integer overflow problems.

```
int random_generator(void) {
/* initialize an array of random numbers */

int ii;
double a = 16807.0;
double m = 2147483647.0;
double temp, seed;
float rand_value[10000];

/* initialize the random numbers */
seed = 1;
for (ii = 0; ii < N_RANDOM; ii++) {
temp = a * seed;
seed = temp - m * ((int) (temp / m) );
/* divide by m for value between 0 and 1 */
rand_value[ii] = seed / m;
}
}
```

If implemented correctly, the 10 000th value of seed will equal 1 043 618 065.

Appendix J: CHECKSUM Implementation Guidelines

This Appendix is not part of the FITS standard, but is included for informational purposes.

J.1. Recommended CHECKSUM Keyword Implementation

The *recommended* CHECKSUM keyword algorithm described here generates a 16-character ASCII string that forces the 32-bit 1's complement checksum accumulated over the entire *FITS* HDU to equal negative 0 (all 32 bits equal to 1). In addition, this string will only contain alphanumeric characters within the ranges 0–9, A–Z, and a–z to promote human readability and transcription. If the present algorithm is used, the CHECKSUM keyword value *must* be expressed in fixed format, with the starting single quote character in column 11 and the ending single quote character in column 28 of the *FITS* keyword record, because the relative placement of the value string within the keyword record affects the computed HDU checksum. The steps in the algorithm are as follows:

1. Write the CHECKSUM keyword into the HDU header with an initial value consisting of 16 ASCII zeros ('0000000000000000') where the first single quote character is in column 11 of the *FITS* keyword record. This specific initialization string is required by the encoding algorithm described in Sect. J.2 The final comment field of the keyword, if any, must also be written at this time. It is recommended

References

Note: Many of these *FITS* references are available electronically from the NASA Astrophysics Data System (ADS) and/or the *FITS* Support Office web sites at
<http://adswwww.harvard.edu> and
http://fits.gsfc.nasa.gov/fits_documentation.html.

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