

Return of the Codes: SAS®®, Windows®®, and Your's

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ABSTRACT

Robust applications participate in the give-and-take discussion between commands and return codes. This presentation encourages applications developers to implement comprehensive return code processing. Three distinct categories are considered in this presentation. First, we consider return codes from SAS®. Second, we consider return codes from Windows® (as an example of operating system return codes). Third, we discuss development principles for writing your own return messages. The examples draw from SAS/AF®, but the three return code categories and authoring principles affect all SAS applications development (including robust SAS Macro development).

INTRODUCTION

One way to view applications development is like an ongoing conversation. In the generic case, the application allows multiple users to retrieve and update information asynchronously from other users and a data warehouse. The phrase *return code* categorizes most of these messages, since the message is often a number which can be looked up on a table or documentation. It is possible for the return message to be a phrase or sentence, but even then, the meanings of the words might be specific to an application and therefore still require knowledge beyond basic English.

Application developers should use all available return codes, and continue to study new software releases to make sure that newly available information is incorporated into the program. Microsoft Corporation (2006a) states the goal succinctly:

Well-written applications include error-handling code that allows them to recover gracefully from unexpected errors. When an error occurs, the application may need to request user intervention, or it may be able to recover on its own. In extreme cases, the application may log the user off or shut down the system.

Robust applications not only predict and prevent errors, but they also respond and react, and when necessary, terminate as gracefully as possible. An application can receive return messages from the programming language, the operating system, and from itself:

- Return messages from the programming language (such as SCL) include whether a command successfully completed, and sometimes how well it completed or failed.
- Return messages from the operating system can result from issuing an operating system command.
- Return messages from an application are explicitly programmed to result from running a function, method, or command within the operating environment.

The purpose of this paper is to describe how these three return code categories support robust applications development. This paper will not discuss all aspects or combinations of the rich conversation an application has with its environment, but will specifically focus on error messages and recovering gracefully from unexpected or unintentional results. Potential errors fall into one of two categories: 1) an unexpected result from a single command (a *hard* error); or 2) an expected result from a command which signals an unexpected result within a larger application context (a *soft* error).

RETURN CODES FROM SAS

SAS 9.1.3 provides return codes in different feature categories. This section will summarize handling return messages using six feature categories:

1. System Options
2. Automatic Macro Variables
3. ARM (Application Response Measurement) Macros
4. Functions
5. Call MODULE Routine
6. PUT Statement

SYSTEM OPTIONS

SAS Institute (2006t) defines *system option*:

System options are instructions that affect your SAS session. They control the way that SAS performs operations such as SAS System initialization, hardware and software interfacing, and the input, processing, and output of jobs and SAS files.

The SAS session includes return codes and messages that developers can use in applications. The SAS documentation provides specific instruction on how to obtain system option information and how to use them (SAS Institute, 2006u). Though the entire list is of general interest and potential importance to a generic application, this paper highlights some specific examples useful for error handling.

Table 1.
SAS System Options Important for Return Code Processing

Category	SAS System Options	Description
Environment control: Error handling	BYERR System Option	Controls whether SAS generates an error message and sets the error flag when a <code>_NULL_</code> data set is used in the SORT procedure
	CLEANUP System Option	Specifies how to handle an out-of-resource condition
	DMSSYNCHK System Option	Enables syntax check mode for multiple steps in the SAS windowing environment
	DSNFERR System Option	Controls how SAS responds when a SAS data set is not found
	ERRORABEND System Option	Specifies how SAS responds to errors
	ERRORBYABEND System Option	Specifies how SAS responds to BY-group error conditions
	ERRORCHECK= System Option	Controls error handling
	ERRORS= System Option	Controls the maximum number of observations for which complete error messages are printed
	FMTERR System Option	Determines whether SAS generates an error message when a format of a variable cannot be found
	QUOTELENMAX System Option	Specifies that SAS write to the SAS log a warning about the maximum length for strings in quotation marks
Files: SAS Files	SYNTAXCHECK System Option	Enables syntax check mode for multiple steps in non-interactive or batch SAS sessions
	VNFERR System Option	Controls how SAS responds when a <code>_NULL_</code> data set is used
	NEWS= System Option	Specifies a file that contains messages to be written to the SAS log
	DATASTMTCHK= System Option	Prevents certain errors by controlling the SAS keywords that are allowed in the DATA statement
	DKRICOND= System Option	Controls the level of error detection for input data sets during processing of DROP=, KEEP=, and RENAME= data set options
	DKROCOND= System Option	Controls the level of error detection for output data sets during the processing of DROP=, KEEP=, and RENAME= data set options and the corresponding DATA step statements
	DLDMGACTION= System Option	Specifies what type of action to take when a SAS catalog or a SAS data set in a SAS data library is detected as damaged
	MERGENOBY System Option	Controls whether a message is issued when MERGE processing occurs without an associated BY statement
	INVALIDDATA= System Option	Specifies the value SAS is to assign to a variable when invalid numeric data are encountered
Input control: Data Processing		

Log and procedure output control: SAS log	ECHOAUTO System Option	Controls whether autoexec code in an input file is echoed to the log
	LOGPARM= System Option	Controls when SAS log files are opened, closed, and, in conjunction with the LOG= system option, how they are named
	MSGLEVEL= System Option	Controls the level of detail in messages that are written to the SAS log
	NOTES System Option	Writes notes to the SAS log
	OVP System Option	Overprints output lines
	PRINTMSGLIST System Option	Controls the printing of extended lists of messages to the SAS log
	SOURCE System Option	Controls whether SAS writes source statements to the SAS log
	SOURCE2 System Option	Controls whether SAS writes secondary source statements from included files to the SAS log
Macro: SAS macro	MACRO System Option	Specifies whether the SAS macro language is available
	MCOMPILENOTE= System Option	Issues a NOTE to the log upon successful compilation of a macro
	MERROR System Option	Controls whether SAS issues a warning message when a macro-like name does not match a macro keyword
	MFILE System Option	Specifies whether MPRINT output is directed to an external file
	MLOGIC System Option	Controls whether SAS traces execution of the macro language processor
	MLOGICNEST System Option	Displays macro nesting information in the MLOGIC output in the SAS log
	MPRINT System Option	Displays SAS statements that are generated by macro execution
	MPRINTNEST System Option	Displays macro nesting information in the MPRINT output in the SAS log
	SERROR System Option	Controls whether SAS issues a warning message when a defined macro variable reference does not match a macro variable
	SYMBOLGEN System Option	Controls whether the results of resolving macro variable references are written to the SAS log
System administration: Performance	ARMSUBSYS= System Option	Enables and disables the ARM subsystems that determine the internal SAS processing transactions to be logged
	CMPOPT= System Option	Specifies the type of code generation optimizations to use in the SAS language compiler

System options intentionally provide features which remain active over several tasks or even an entire SAS session. Sometimes, applications may need to set or reset certain options during processing. This paper recommends studying the documentation for system options which may be of use, and those in the above table. Querying system options is available through read-only dictionary tables:

A DICTONARY table is a read-only SAS data view that contains information about SAS data libraries, SAS data sets, SAS macros, and external files that are in use or available in the current SAS session. A DICTONARY table also contains the settings for SAS system options that are in effect. When you access a DICTONARY table, SAS determines the current state of the SAS session and returns the desired information accordingly. This process is performed each time a DICTONARY table is accessed, so you always have current information.

DICTONARY tables can be accessed by a SAS program by using either of these methods:

- run a PROC SQL query against the table, using the DICTONARY libref

- use any SAS procedure or the DATA step, referring to the PROC SQL view of the table in the SASHELP library.

(SAS Institute, 2006a)

The SAS documentation considers DICTIONARY tables as part of the SQL procedure (SAS Institute, 2006x), though they can be read as dictionary views outside the SQL procedure. The SAS documentation provides a good overview on how system options are stored in these special SAS datasets (SAS Institute, 2006k). Dictionary tables are in vogue for SAS applications development papers, and many recent papers provide excellent instruction on how to use this important tool for applications development (Davis, 2001; Dilorio and Abolafia, 2004; Eberhardt and Brill, 2006; Lafler, 2005).

Because dictionary tables are read-only, the feature cannot be used to set options. System options could be set with an OPTIONS statement. However, this paper recommends using the SCL commands OPTGETC, OPTGETN, OPTSETC and OPTSETN, which each have return codes for successful completion.

AUTOMATIC MACRO VARIABLES

SAS Institute (2006i) provides a good introduction to macro variables. Later, the documentation describes the role and scope of *automatic macro variables* (SAS Institute, 2006j):

When you invoke SAS, the macro processor creates *automatic macro variables* that supply information related to the SAS session. Automatic variables are global except SYSPBUFF, which is local. Automatic macro variables are often useful in conditional logic such as a %IF statement with actions determined by the value that is returned. %IF is described in Macro Language Dictionary... You can assign values to automatic macro variables that have read and write status. However, you cannot assign a value to an automatic macro variable that has read-only status... Use %PUT _AUTOMATIC_ to view all available automatic macro variables. There are also system-specific macro variables that are created only on a particular platform.

Automatic macro variables act as complement to the system options. While system options set the state of the SAS session, the automatic macro variables allow the SAS session to report its state. The writeable automatic macro variables allow the developer to store state information. Though all automatic macro variables help build a robust application, the following table includes those of particular interest to generic return code processing.

Table 2.
Automatic Macro Variables Important for Return Code Processing

Status	Variable	Contains
Read and Write	SYSRC	various system-related return codes
read-only	SYSPROCESSID	the process id of the current SAS process
	SYSPROCESSNAME	the process name of the current SAS process

ARM (APPLICATION RESPONSE MEASUREMENT) MACROS

SAS Institute (2006m) defines the term *ARM macros*:

The ARM [Application Response Measurement] macros provide a way to measure the performance of applications as they are executing. The macros write transaction records to the ARM log. The ARM log is an external output text file that contains the logged ARM transaction records. You insert the ARM macros into your SAS program at strategic points in order to generate calls to the ARM API [Application Programming Interface] function calls. The ARM API function calls typically log the time of the call and other related data to the log file. Measuring the time between these function calls yields an approximate response-time measurement. An ARM macro is self-contained and does not affect any code surrounding it, provided that the variable name passed as an option to the ARM macro is unique. The ARM macros are used in open code (code that is not in PROC or DATA steps) and in DATA step or SCL environments... The ARM macros are not part of SAS Macro Facility. They are part of the SAS ARM interface.

The SAS documentation provides instruction on monitoring performance using ARM macros, including what it is and how it works (SAS Institute, 2006r). SAS describes ARM macros in version 9 as a manageability feature to check the availability and transaction rates of SAS applications (SAS Institute, 2006y, p. 7). The topic deserves its own paper and tutorial. The ARM macros are activated with a SAS system option, and the information is accessed through macros run between data steps or procedures. These functions could be coded through other means, specifically by using the SAS macro facility. However, the ARM macros have been optimized to run quickly alongside an application, therefore providing minimum performance burden on the process. The information is stored in global

macro variables, but ARM functions allow for transferring the data from ARM macro variables to application variables or macro variables. Transferring the information becomes important when using nested macros, SCL methods, and SAS/AF objects. The current ARM framework makes them best suited for monitoring data step and SAS procedure submissions. Application developers should be aware of any enhancements SAS makes to the ARM macros.

FUNCTIONS

SAS Institute (2006d) defines the term *function*:

A SAS *function* performs a computation or system manipulation on arguments and returns a value. Most functions use arguments supplied by the user, but a few obtain their arguments from the operating environment. In Base SAS software, you can use SAS functions in DATA step programming statements, in a WHERE expression, in macro language statements, in PROC REPORT, and in Structured Query Language (SQL). Some statistical procedures also use SAS functions. In addition, some other SAS software products offer functions that you can use in the DATA step. Refer to the documentation that pertains to the specific SAS software product for additional information about these functions.

The SAS documentation provides instruction on how to use functions (SAS Institute, 2006f). Some SAS functions moderate how an application can use return messages.

Table 3.
SAS Functions Important for Return Code Processing

Category	Functions	Description
External Files	SYMSG Function	Returns the text of error messages or warning messages from the last data set or external file function execution
	SYSRC Function	Returns a system error number
Macro	SYMEXIST Function	Returns an indication of the existence of a macro variable
Special	GETOPTION Function	Returns the value of a SAS system or graphics option
	SYSGET Function	Returns the value of the specified operating environment variable
	SYSPROCESSID Function	Returns the process id of the current process
	SYSPROCESSNAME Function	Returns the process name associated with a given process id or the name of the current process
	SYSPROD Function	Determines if a product is licensed
	SYSTEM Function	Issues an operating environment command during a SAS session and returns the system return code

Application developers can use these functions within data steps or in SAS/AF code to provide applications with information on system processing. Besides the listed functions, many SCL functions also have return codes useful in robust applications development.

CALL MODULE ROUTINE

SAS Institute (2006d) defines the term *CALL routines*:

A *CALL routine* alters variable values or performs other system functions. CALL routines are similar to functions, but differ from functions in that you cannot use them in assignment statements. All SAS CALL routines are invoked with CALL statements; that is, the name of the routine must appear after the keyword CALL on the CALL statement.

The SAS documentation provides instruction on the syntax for CALL routines, one of which is CALL module (SAS Institute, 2006c). The documentation for the CALL module routine says it "calls the external routine without any return code" (SAS Institute, 2006c). The text is almost correct because a CALL module routine may have any number of input, updated, or return fields among its arguments. The text would better read that a CALL module "calls the external routine without an explicit SAS return code". Logically, SAS cannot return a code since it is unaware of what to expect from the CALL module routine. The SAS session might know the types of variables passed (such as character or numeric) but will not be able to categorize a CALL as being successful or not.

Using the CALL module is important because for SAS 9.1.3 running on Windows, it allows a user to call the Windows API, and generically any DLL (dynamic linked library) programmed in Windows (SAS Institute, 2006n). In like manner,

SAS running on Unix allows the CALL module access to shared executable libraries (SAS Institute, 2006q). In each case, these modules can provide return messages which may help build a more robust application.

PUT STATEMENT

The PUT statement is one of the most versatile tools for reporting on return codes. Used in a SAS session, the statement can allow for reporting values from inside a data step. Also, the statement can output either SAS-defined or user-defined macro variables. The output destination can be the log or any other ODS (output delivery system) location. The PUT statement can apply a SAS format to the output. SAS Institute (2006w) provides extended information on this versatile reporting tool. Also, the SAS documentation instructs on how to use statements (SAS Institute, 2006v). PUT statements are not the only way to report errors, and instead (or in addition) a developer might choose to write information to a SAS dataset.

SUMMARY

The following table summarizes what SAS provides natively across platforms for return code messages, and for catching errors:

Table 4. Summary of SAS Features Important for Return Code Processing		
Category	Description	URL Reference (Retrieved June 1, 2006)
System Options	Sets choices for the SAS session state	http://support.sas.com/onlinedoc/913/getDoc/en/lrdict.hlp/a000309878.htm (SAS Institute, 2006s)
Automatic Macro Variables	Provides information on the system state	http://support.sas.com/onlinedoc/913/getDoc/en/mcrolref.hlp/a002047074.htm (SAS Institute, 2006h)
ARM Macros	Provides a lightweight structure for measuring and monitoring application performance	http://support.sas.com/onlinedoc/913/getDoc/en/lrdict.hlp/a002295646.htm (SAS Institute, 2006l)
Functions	Provides interactive information on current processing	http://support.sas.com/onlinedoc/913/getDoc/en/lrdict.hlp/a000245852.htm (SAS Institute, 2006b)
CALL Module Routine	Allows for accessing modules though Windows and Unix	http://support.sas.com/onlinedoc/913/getDoc/en/lrdict.hlp/a000471253.htm (SAS Institute, 2006c)
PUT Statement	General reporting tool	http://support.sas.com/onlinedoc/913/getDoc/en/lrdict.hlp/a000161869.htm (SAS Institute, 2006w)

Robust applications probably will use features in these categories beyond those listed, but the focus of this paper are the essential return code features for a SAS session. The next section covers Windows specifically, and shows how SAS works with Windows to provide return messages important for handling errors.

RETURN CODES FROM WINDOWS

Assuming SAS 9.1.3 running on the Windows platform, the applications developer has the choice of return messages in these categories:

1. SAS System Options for Windows
2. SAS Automatic Macro Variables for Windows
3. SAS Functions and CALL Routines for Windows
4. Windows System Error Codes

The first three categories are extensions to those mentioned in the first section of this paper. The SAS documentation includes a separate platform-specific area of documentation which includes commands not in the general lists. The next table provides the URL (uniform resource locator) for these additional system options, automatic macro variables, functions, and CALL routines for Windows:

Table 5.
SAS Documentation on Windows-Specific Features Important for Return Code Processing

Category	Description	URL Reference (Retrieved June 1, 2006)
System Options for Windows	Sets choices for the SAS session state	http://support.sas.com/onlinedoc/913/getDoc/en/hostwin.hlp/sysopts.htm (SAS Institute, 2006p)
Automatic Macro Variables for Windows	Provides information on the system state	http://support.sas.com/onlinedoc/913/getDoc/en/hostwin.hlp/automacrovar.htm (SAS Institute, 2006g)
Functions and CALL Routines for Windows	Provides interactive information on current processing	http://support.sas.com/onlinedoc/913/getDoc/en/hostwin.hlp/function.htm (SAS Institute, 2006o)

The fourth category is *Windows System Error Codes* and refers to what the SAS session can obtain from the Windows API through a CALL module command. Using this CALL routine, a SAS application can set, update, or retrieve information from the Windows session. As mentioned, earlier, the SAS documentation provides instruction on how to call Windows DLLs from a SAS application (SAS Institute, 2006n). Also, several SAS users have published papers on the topic, including my colleague David Johnson (Johnson 2001, 2003, 2005; Woo, 2006).

When SAS runs in Windows (or any operating system) there are only a subset of commands available for return code processing, and as much as possible, processing is encapsulated within the SAS session. Even many database and disk functions available by calling a Windows operating system DLL are best called through SAS functions because SAS is aware of what to expect and can provide an appropriate return code. However, the papers cited give examples of calling the Windows API, in situations when there is a need to use a function (either defined by Windows or programmed by the user in a DLL) not available in SAS. After calling these functions, it might be important to interpret what Windows calls system error codes. Unlike the comparatively parsimonious tables of SAS return codes, the Microsoft documentation lists thousands of these codes in a single table (Microsoft Corporation, 2006c). These codes can be retrieved from inside SAS using the *GetLastError* function (Microsoft Corporation, 2006b).

In a large SAS/AF application I support, I use Windows error return codes during several places when I access the Windows API. Microsoft has also implemented another feature which developers may want to emulate, an event log and event viewer. The log is merely a list of certain return codes by category, typically errors. In my SAS/AF processing, I have chosen to not log and track errors (though I could) and rather use logging to track successful application runs (to provide a record of work accomplished and also allow for overall performance monitoring).

Thus, when considering how to build a robust application, it's also important to consider the SAS document specific to that operating environment. Additional features, such as functions, automatic macro variables, and system options may allow for additional tools for error checking and handling. The Windows operating system documentation provides many error checking tools and features available to SAS applications.

YOUR RETURN CODES

This paper assumes that an *application* includes subroutines, implemented as methods or script modules. The methods might be written in SAS/AF or a .NET language or Java. The script module might be a SAS macro or Javascript. Complex applications might use object-oriented and scripting languages to achieve the task. The whole scope of this complexity is bundled into what this paper calls an *application*, whether it is one single code structure or a federation of communicating code structures.

In any application conversation, there are three mutually distinct outcomes after issuing a command:

1. Receive no response
2. Receive a response sometimes
3. Always receive a response

The third case is best, when the language or operating system or application always returns an adequately thorough explanation. In case number one, it is not possible to tell whether a command issued was successful. No response is an indication of a poor language (command), or operating system, or application. The second case might involve a

complex response, where the code is more than just a binary successful or not, but might include flavors of success. In a typical programming environment, all three cases are present. By providing your own customized return codes, messages, and framework, you can supplement what is available and improve your application.

The previous sections showed what SAS can provide, and what SAS and Windows can provide together. This last category expands the idea to the generic case where any number of applications and languages are communicating. Because the developer chooses to put these pieces together, it is possible and recommended to not only organize these interfaces logically, but also provide intelligent return messages which reflect successful completion of these complex tasks. Based on concepts and categories in previous sections, the following table provides ideas about how to develop your own return codes.

Table 6. Customized Extensions for Return Code Processing	
Category	Description
Application Options	Similar to SAS system options, application options are variables declared either globally or locally for an application, and allow for return code processing to be controlled from a higher level. The variables could be stored in application datasets, similar to the read-only dictionary tables.
Application Macro Variables	Similar to SAS automatic macro variables, the application macro variables (global or local) provide the ability to keep the state at a specific point. Information stored could be character or text (though macro variables always store information as text).
Application Macros	Similar to SAS ARM Macros, the application can have its own macros to monitor and measure performance. These customized macros could extend the capabilities of ARM macros, providing the application with robust reporting on performance. Developing these macros separately from other macros allows them to be used in future applications.
Functions	Similar to SAS functions, applications can define methods in SCL. These methods can provide a return code, and could extend or incorporate what SAS natively provides for return code processing. Encapsulating these methods individually, or as a group (creating a class or classes using SAS/AF) would allow these methods or classes to be copied into future applications.
CALL Module Routine	Similar to calling Windows DLLs, SAS applications running in Windows could call programmed .NET DLLs. These modules could have return codes and messages helping the application to become more robust. Generically developed DLLs have the advantage of being used across many custom applications.
Reporting Datasets and Forms	Instead of simply using the PUT statement to send variable values to the log or ODS destination, an application could send the information into a dataset, which could include the computer name and time and date of logging. Also, the application could have customized forms for reporting errors, including the option to send those reports as an attachment or the body of an e-mail.

The above table provides categorized ideas for actively creating and developing a robust return code processing system alongside a current application. Applications should interpret and respond to passive return codes from SAS and the operating system (such as Windows). However, robust applications participate also in the active and dynamic process of preparing and delivering customized return code messages. These extensions might be best implemented as binary return codes, but they also could be as complex as fully formatted e-mails that include explanatory text and graphics.

When developing a library of return code features and mechanisms, a generically developed return messaging framework could be used across future customized programs. Common features of SAS and Windows return codes provide insight into best practices for generic return code development. For example, by keeping the commands simple and the messages general, these same tools can be used across many applications. Specific or complex reports might make sense for specific applications, but will not have generalized use across a library of future customized code. In object-oriented terms, it is best to allow base features to remain in parent classes, and have specific return code features implemented through overloading methods, overwriting methods, or inheritance.

Based on the SAS and Windows development structure, the following bullet points provide advice for reusable customized return messaging development:

- Use binary codes for success or failure
- When more than binary codes are returned, consider using globally enumerated macro variables, global SCL variables, global SCL lists, or SAS read-only datasets to allow for named references to return code conditions
- Use simple, reusable names for macros, functions, and classes

- Code for the complete set of possible conditions, not only the ones proven through experience

CONCLUSION

This paper outlined three major categories of return code processing in SAS application. The first category included what SAS provides directly. The second category included what SAS provides with Microsoft Windows. The last category covered what the applications developer can provide when linking multiple languages and applications. Robust applications not only predict and prevent errors, but they also respond and react, and when necessary, terminate as gracefully as possible. Developer who incorporate newly available return codes as well as code better return messages improve their own understanding of not only what is available in programming languages, but also provides insight into how to improve both languages and applications.

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