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SuperCharge & TurboCharge Decompiler Technical Notes

This document contains notes for my use on the Super/TurboCharge decompiler. But it may be of help for anyone trying to understand how the decompiler programs work.

First a few notes on the internal make up of a compiled executable.

The compiled program can be split into four main parts.

The first is the initialization of the compiled program, error handling, and some common utility routines.

The second part is a group of routines that are called from the encoded version of the original SuperBASIC program. These routines preform many of the SuperBASIC commands and functions. Which of these routines that are included, and the order that they appear in, is dependent upon the original SuperBASIC program when it was compiled. The Discharge_bas program will attempt to identify these routines, and assign them to codes, in the _codes file, that are used by the main decompilers.

The third part is the encoded version of the original SuperBASIC program.
This part is also subdivided into a program/variables initialization area, and the program itself.
In Turbo compiled programs the initialization area may appear both before, and after the program area.

The fourth part is a list of SuperBASIC commands and functions that are not handled by the compiled program, but are called from the operating system. These are commands like WINDOW, PAPER, BEEP, SIN(), etc.
This list may also contain externally loaded commands and functions like DEVICE_STATUS.
SuperCharge has a default set of these command whether used or not, however Turbo only includes commands that are actually used by the compiled program.

Register usage in Turbo (taken from Turbo source code)

Reg	Description	Name
A1	Maths stack pointer	maths
A4	Heap pointer	data
A5	Pseudo program pointer	thread
A6	Task base pointer	base
D0	QDOS Request code register	request
D5	Turbo error number	error
D6	(low word) BASIC line number	lineno

Checksums in Library files

In the library files, there is a checksum to uniquely identify the code routines from the second part of the compiled program. The checksum is comprised of 40 bits. Split into two parts.
A 16 bit byte count of the routine. And a 24 bit checksum of the bytes of the routine. And is shown as a 10 character hexadecimal number.

The checksum is not a simple sum of the bytes in the routine, but a sum of the sum of the bytes in the routine. The double checksum is to get around the problem I encountered on more than one occasion, where two different routines happened to produce the same simple checksum.

example -

00100033C7

This routine contains 16 bytes ($0010), and the 16 bytes make a checksum of ($00033C7)

Procedures and Functions

While Procedures and Functions with the same names appear in all the decompilers. They may differ in their coding to allow for differences in the decompilers.

PROCedure SaveMe
Saves a copy of the program

FuNction GetString$(ptr)
Returns a string of a standard QDOS string (word length then bytes of string) stored in memory at ptr

FuNction GetInt(ptr)
Returns a signed integer stored in memory at ptr

FuNction GetWord(address)
Returns an unsigned integer stored in memory at address

FuNction FLT(string$)
Converts a 12 character (six byte) hex string into a floating point number

FuNction FLT$(n)
Convert a Floating point number into a 12 character (six byte) hex string
by PJW & Steven Pool V0.02 03/12/17

FuNction NameListLen(start)
Returns the number of the highest name list entry in the keywords section at the end of the compiled program
start is the address in memory of the keyword table

PROCedure EmptyPipe (channel)
Makes sure the pipe is empty. If it is not empty, it is reported to channel, the pipe is emptied displaying the contents of the pipe.

FuNction GetTOS$
Remove and return the item at the rear end of the pipe.

PROCedure FlagLine (num$)
If the line number, num$ does not already exist in the Proc/Fun list, it is added.

FuNction CheckProcFun(num$)
Checks to see if the line number, num$ is in the Proc/Fun list. If it is, then create a DEFine PROCedure/FuNction line.
Also checks for unresolved SELect's and IF's.
Returns when line numbers are present

0 If the line number is not in the Proc/Fun list.
1 If its a multiline DEFine PROCedure/FuNction.
2 If its a single line DEFine PROCedure/FuNction.

and when line numbers are suppressed

0 If the line number is not in the Proc/Fun list.
1 If PROCedure/FuNction definitions are in freeform mode.
2 If PROCedure/FuNction definitions are in structured mode.

PROCedure AssignArray(varNum,noElements)
Adds an array entry into the arrayElements array

FuNction GetElements(varNum)
Returns the number of elements for an array. varNum is the SuperCharge reference for the array.

PROCedure ListProcs
List the Procedure/Function line numbers to the log file

PROCedure ReadCodeArray (file$)
Read in the code array from file$. The Format is index number,hex word index value
E.g. 23,90FA - codeArray(23)=$90FA

PROCedure DoDataLines
Create DATA statements. DATAarray(0) holds the number of RESTORE commands.
Other indexes are addresses of data starts.

PROCedure CheckELSE (ptr,type)
Check to see if an ELSE is needed. Ptr is the current program position.
Type, is the size of the GO TO used for the ELSE. 0 = word sized. 1 = long sized.

FuNction CheckENDIF
Check for pending END IF

PROCedure StripIFStack
Strips the top item off the IFStack and ELSEStack string

PROCedure LoadFile (file$)
Load the file (file$) and set base addresses initialBase, base, and filelength.

PROCedure CheckValues
Check values in file, and set various pointers.

PROCedure GetVersion
Get program version information and set marker variables.

PROCedure FindArrayElements (sc)
Scan variable initialization area looking for arrays, and filling in arrayElements.

PROCedure StartNewLine (linenumber)
Start a new listing line starting with the supplied line number.

PROCedure InitNewLine
Initialize line decompose variables.

PROCedure InitMain
Set up variables for decompiling.

PROCedure StatementSeperator
If line numbers are suppressed, start a new line. Otherwise output a colon (:) separator.

PROCedure CheckSELects (nl)
Checks for any outstanding SELect processing to deal with. If nl is 1, then we are at the start of a new line

PROCedure CheckLastSELect
Checks to see if this is the last selection. If so output SELect ON instruction.
Otherwise add to current SELection and continue.

PROCedure ScanProcFun (keycode,progstart,progEnd)
Scans the program for Procedure and Function calls, and adds them to a list.

FuNction CountParameters (ptr)
Try to count the number of parameters in a Proc/Fun definition.

PROCedure ExternalGlobal (ptr)
Deal with EXTERNAL/GLOBAL constructs. Ptr, points at the start of the definitions.

Global variables

(sc) SuperDisCharge
(tc) TurboDisCharge

If one of these two are shown, it means that this variable is specific to one of the decompilers.

filelength	Length of executable file.
initalBase	Loaded base address, may be different to ‘base’ if Qemulator header found.
base	Start of the executable.
finish	End of the executable.
progOffset	Offset from start of executable to start of BASIC program area.
prog	Running pointer for the BASIC program.
basicProgStart	Start of BASIC program area.
varInitOffset	Offset from start of executable to start of variable init area.
varInitStart	Start of variable init area.
keywords	Start of keyword table.
progEnd	End of BASIC program area.
TCver$	Library file version from executable.
TCtitle$	TurboCharge copyright message.
jobName$	Executables job name.
DATAendMarker	Word that marks the end of any DATA in the initialization area.
DATAexist	Flag to indicate if any DATA statements need to processed 0 if no READ instructions encountered 1 if READ instructions encountered
lineStart	Word that marks ‘move.w (a5)+,d6’, the start of a BASIC program line.
progStartAdj (tc)	An adjustment for the start of the BASIC program in compiler versions that have a RETRY_HERE inserted before the start of the BASIC program
A6	Address in loaded executable that represents the A6 register.
keywordOffset	Address that is a base for accessing Keywords. Not a pointer to the keyword list itself.
lineNoExist	1 if compiled program has embedded line numbers 0 if compiled program does not have line numbers.
freeform (tc)	1 if the FREEFORM option was used during compiling. 0 if the STRUCTURED option was used during compiling. The decompiler will assume FREEFORM until it encounters a STRUCTURED style Procedure of Function definition.
lineStartPrefix	Prefix code for BASIC program line start, or -1 if no embedded line numbers.
lineCount	Number of program lines decompiled.
lineNo	Line number of line currently de compiling.
pseudoLine (tc)	Address of a reference point when line numbers are suppressed
ch	Channel to send decompiled output to.
er (sc) errCh (tc)	Channel to send Errors & log to.
proc$	Line numbers of Procedures and Functions, separated by *****

pcount		Number of items in the pipe.
InIF		Number of levels of nested IF's.
IFStack$		List of 8 character HEX destination addresses of END IF's or ELSE's.
ELSEStack$		
FORselect$	(tc)	Used to hold the selection for FOR statement e.g. "1 TO 5,8,10 TO 12"
FORstep$	(tc)	Used to hold the STEP value
FORvar$	(tc)	Used to hold the FOR variable reference
newLine		0 = Not at the start of a new line.
InPrint		0 = Not in a PRINT/INPUT.
SELselect$	(tc)	Used to hold the selection for SELect statement e.g. "1 TO 5,8,10 TO 12"
InProcFun		0 = Not in a Procedure or Function
InSel		Number of levels of nested SELect's
Indef		0 = Not in any DEFine's. Once in a DEFinition, it points to just past the end of the definition block. Unless the STRUCTED option was used during compiling, Then Indef is set to -1.
channelOpenCheck		0 = No pending channel operations.
currentChannel$		Current channel number, or channel variable/expression.
key		Holds the current operation prefix code.

Arrays

nameList()	Array of offsets for keywords at end of code.
arrayElements(100,1)	Holds the number of elements in arrays, 101 entries of 2
DATAarray(100)	DATA statement RESTORE points
codeArray(249)	The code array, 250 entries
selStack(20,2)	Holds information on nested SELect's
	Second index - 0 Pointer to possible END SELect
	1 Pointer to next test/REMAINDER/END SELect
	2 Select variable

Turbo Toolkit commands handled in the Keywords section

ALLOCATION, DEALLOCATE, SEARCH_MEMORY, PEEK_F, BASIC_F, FREE_MEMORY, BASIC_B%, BASIC_W%, BASIC_L, BASIC_POINTER, BASIC_NAME$, BASIC_TYPE%, BASIC _INDEX%, TYPE_IN, SET_PRIORITY, COMMAND_LINE, END_CMD, CONNECT, CHANNEL_ID, SET _CHANNEL, EXECUTE, EXECUTE_W, EXECUTE _A, DEFAULT _DEVICE, LIST_TASKS, REMOVE_TASK, SUSPEND_TASK, RELEASE_TASK, DATASPACE, CURSOR_ON, CURSOR_OFF, EDIT$, EDITF, EDIT%, SET_FONT, POSITION, SET_POSITION, INTEGER$, FLOAT$, STRING$, STRING%, STRINGF, GET%, GETF, GET$, INPUT$, DEVICE_STATUS, DEVICE_SPACE

Turbo toolkit commands handled by the compiler internally

PEEK$, POKE$, COMPILED, OPTION_CMD$, DATA_AREA (makes an empty line), RETRY_HERE, MOVE_MEMORY, SNOOZE, LEN(variable), ERLIN%, ERNUM%

Known SuperCharge versions

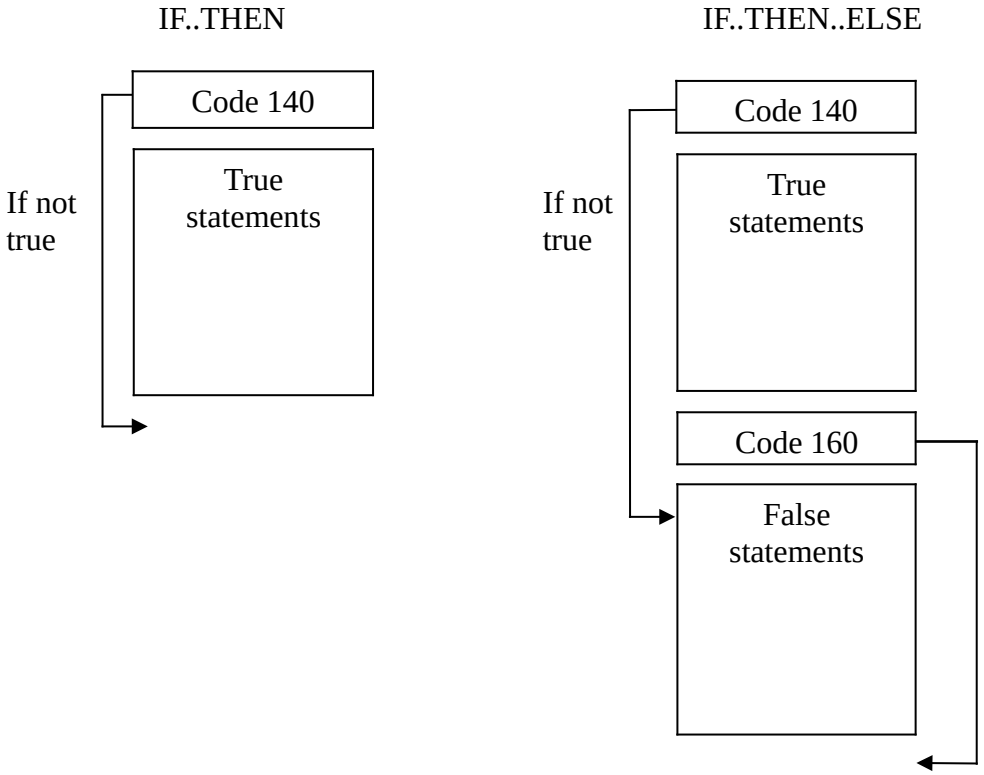
Version	Copyright message	Known by DisCharge
0.14	1985 Simon N Goodwin	yes
1.09		no
1.11	1985 Simon N Goodwin	yes
1.15	1985 Simon N Goodwin	yes
1.17	1985 Simon N Goodwin	yes
1.18		yes
1.19	1985 Simon N Goodwin	yes
2.00	SuperCharge Digital Precision	yes

Known TurboCharge versions

Version	Parser?	Codegen	Copyright message	Known by DisCharge
		5.00	1986 Simon N Goodwin	yes
		5.05	1986 Simon N Goodwin	yes
		5.09	1987 The Turbo Team	yes
		5.10	1987 The Turbo Team (like 5.09)	yes
3.24	2.00/2.04	5.10	1987 The Turbo Team	yes
	3.24	5.35	2000 The Turbo Team	yes
5.09	3.44	5.37	2000 The Turbo Team	yes

Format of program storage in the compiled program

Where there are differences between SuperCharge and TurboCharge, and the different versions. It will be maked, as so - (TC 5.10) meaning the format for Turbo with a code generator of Version 5.10 is different.



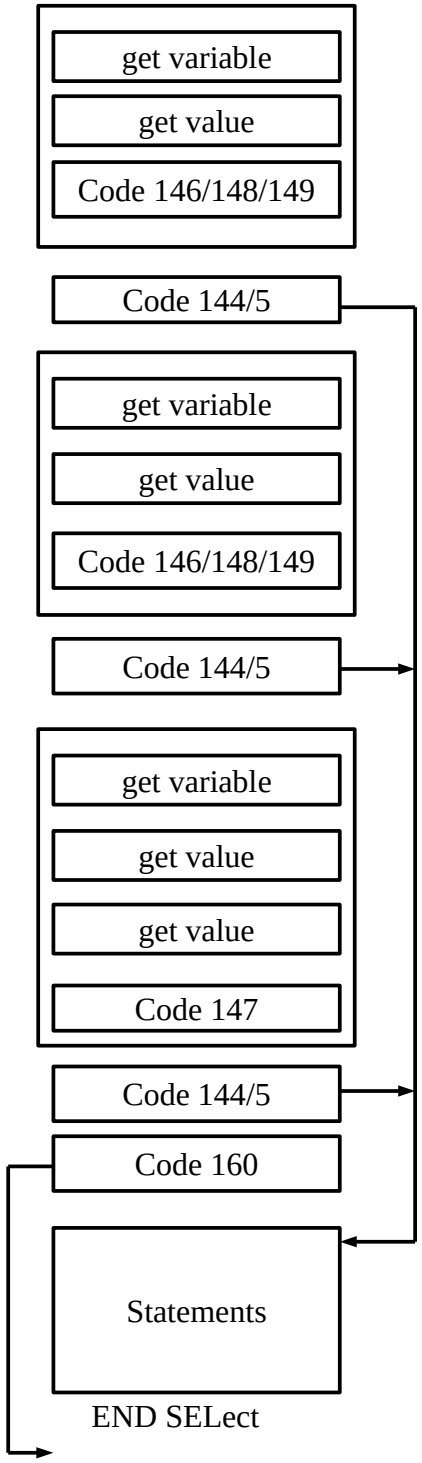
Note - In Turbo, the code 160 (word sized GO TO) may be a code 240 (long sized GO TO) in large programs.

REPeat loops in SuperCharge V2.00

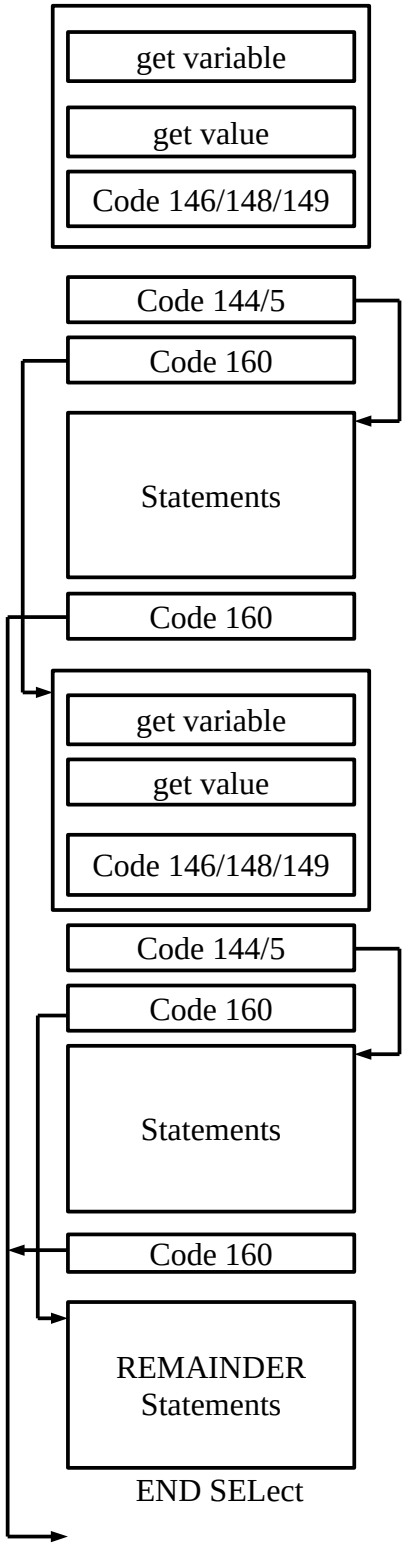
Code 135 (NEXT/ END FOR) is also used in REPeat loops for NEXT

Usual SELects

Select ON x 1,7,14.2 TO 10



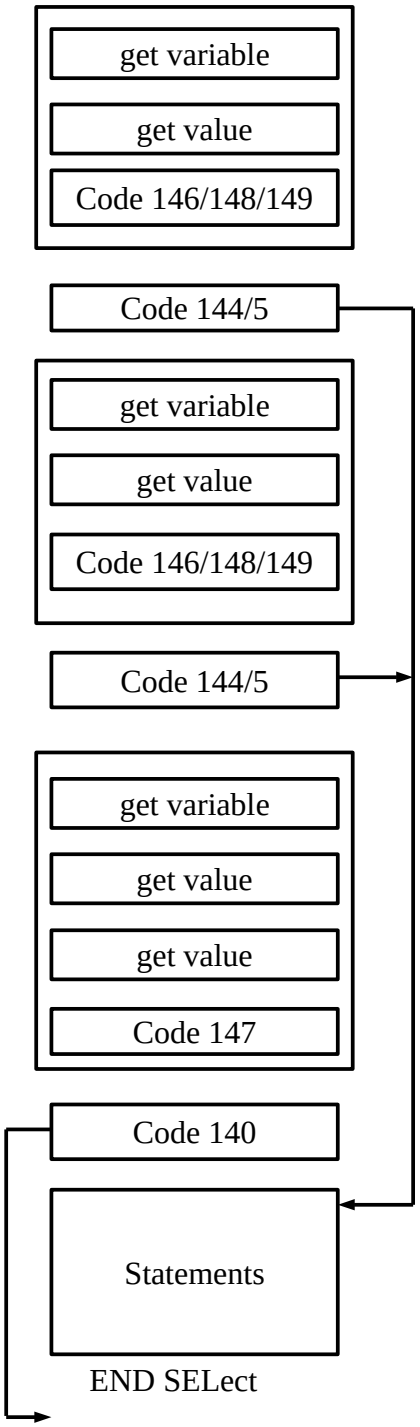
SELect ON x
ON x=..
ON x=..
ON x=REMAINDER..



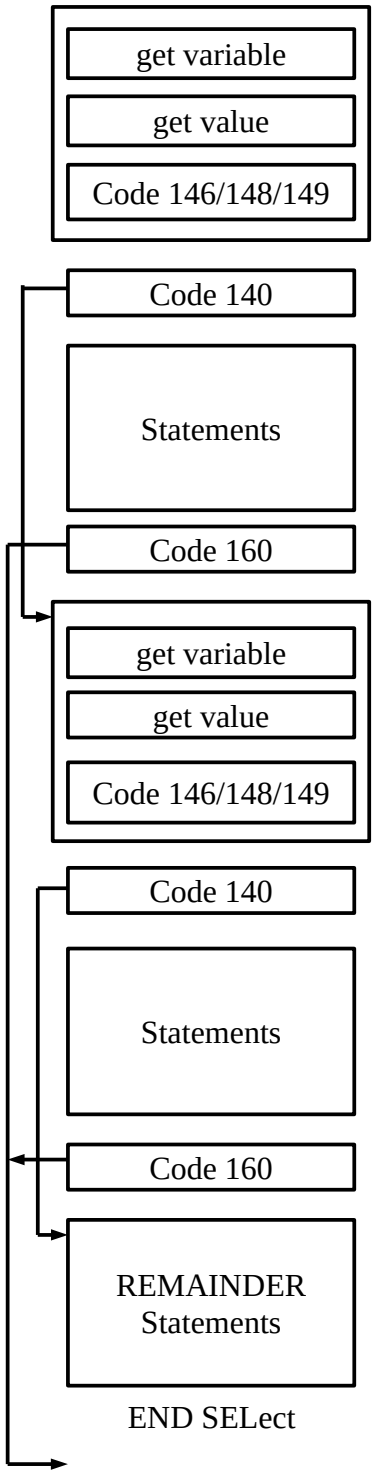
Note - In Turbo, the code 160 (word sized GO TO) may be a code 240 (long sized GO TO) in large programs. The 145 codes may be 144 in TurboCharge

SELect with Turbo versions 5.00 to 5.10

Select ON x 1,7,14.2 TO 10



SELect ON x
ON x=..
ON x=..
ON x=REMAINDER..



Note - In Turbo, the code 160 (word sized GO TO) may be a code 240 (long sized GO TO) in large programs. The 145 codes may be 144 in TurboCharge. Code 140 is equal to IF..THEN

Procedure and Function definitions

SuperCharge

Start	2 words	Go To (160),	A6 offset

Followed by the parameters, if any. Note that the parameters are in reverse order

Integer	4 Words	Code 101,	variable reference,
		Code 62,	variable reference
Float	4 words	Code 102,	variable reference,
		Code 63,	variable reference
String	6 words	Code 85	
		Code 103,	variable reference
		Code 190?	
		Code 64	variable reference

Turbo is as above except for

Start	2 words	Go To (160),	A6 offset, or may be -
Start	3 words	Go To (240),	A6 offset, in long programs.
String	2 Words	Code 103 or 107	variable reference
Float Array	2 words	Code 125	variable reference

If the Structured option was used in compilation, then there is no GOTO (code 160/240) and offset at the start of the Procedure/Function definition. Except for the first definition, which has a STOP (code 161).

Local variables

SuperCharge

Integer	2 words	Code 101,	LOCal variable reference
Float	2 words	Code 102,	LOCal variable reference
String	4 words	Code 55,	256 (max string length?)
		Code 103,	LOCal variable reference
Integer array	2 words	Code 260,	LOCal array reference
Float array	2 words	Code 261,	LOCal array reference
String array	4 words	Code 262,	LOCal 256 (max string length?)
		Code 263,	LOCal array reference

Turbo

Integer	2 words	Code 101 or 126,	LOCal variable reference
Float	2 words	Code 102,	LOCal variable reference
String	4 words	Code 55,	100 (max string length?)
		Code 103 or 107	LOCal variable reference
Integer array	2 words	Code 260,	LOCal array reference
Float array	2 words	Code 261,,125?	LOCal array reference
String array	4 words	Code 262,	LOCal 256 (max string length?)
		Code 263,	LOCal array reference

Calling Procedures and Functions

After the parameters (if any) have been placed on the stack.

SuperCharge	2 Words	Code 100,	A6 offset
Turbo	3 Words	Code 99,	Long A6 offset (don't know what's different to 100)
Turbo	3 Words	Code 100,	Long A6 offset

In-bedded DATA statements

The contents of DATA lines are not in-bedded in the codec BASIC program where they belong, But inserted in the initialization area before the main part of the BASIC program.

The end of the DATA being marked with a $8300 for SuperCharge, and $8001 for TurboCharge.

Decoding the DATA is as follows -

SuperCharge
If the first word is less then $7FFF, Then it's a string in the normal QDOS fashion of a length word followed by the characters of the string.

If the first word is exactly $7FFF, Then it's an integer in the next word.

If the first word is $8000 and above, Then its a float.
Do a 2's complement (invert all bits and add 1) to the word.
This is the first two bytes of the float. And the next two words are the rest of the float.

TurboCharge
If the first word is less then $7FFF, Then it's a string in the normal QDOS fashion of a length word followed by the characters of the string

If the first word is $8000 and above, Then its a number.
Do a 2's complement (invert all bits and add 1) to the word
If the result is less than, or equal to $FFF, Then it's a float. In which case, subtract $1BB8 from this result. And this is the first two bytes of the float. And the next two words are the rest of the float.
If the result is greater than $FFF, Then it's an integer.

If the first word is exactly $7FFF, Then it's part of a T_CONFIG. In which case, read the next word, which is a normal integer.

GLOBAL and EXTERNAL variables

Global variable and procedures are defined in the variables initialization as normal.

External variables do not appear in the variable initialization (but function parameters do).

EXTERNAL/GLOBAL definition block in a compiled program

Start	2 words	Go To(160),	A6 offset to just past end of definition block
	1 word	code 191	Marks start of individual entries
For each Global or External definition			
	1 word	The definition number. Followed by either a word of zero, or a byte giving the length of a definition name, followed by the bytes of the name padded out to a word boundary.	
Then for each entry in the definition			
	2 words	1st word is a type code, 2nd word is a variable/proc reference	
	repeats....		
	1 word	A zero marks the end of the definition	
At the end of all the definitions			
	4 words	$FFFF, $0000, $4EAE, $8218 This marks the end of the definitions	

Decoding the type word
The type word defines the type of the entry in the definition

Bits 0 to 4	Entry type	1 = string 2 = float 4 = integer 8 = Procedure 16 = Function
Bit 5	Set for an array	
Bit 6	Set for a parameter to a proc/fun	
Bits 9 to 11	Number of array dimensions	

Example -	$0422 (%0000 0100 0010 0010)	This is a float array with 2 dimensions y(0,0)
	$0014(%0000 0000 0001 0100)	This is an integer function
	$0261(%0000 0010 0110 0001)	and this is a string parameter for the function note, it is defined as a single dimension array which is a normal string in a compiled program

Threaded and Inline code
Compiled programs are usually generated in Threaded code. However sections of the code can be generated in Inline mode, where instead of having the usual coded version of the original SuperBASIC program stored, you have machine code routines buried inside the coded version of the original SuperBASIC program.

The original SuperBASIC has these lines surrounded by a **REMark +**, and a **REMark -**

At the time of writing this, I have only come across one SuperCharged program that uses Inline code. And at this time I have not thought of a method of automatically decoding this Inline code back into SuperBASIC.

I have added to DisCharge, limited support for Inline code. When you decompile a program using Inline code, it will generate code something like.

```
44 REMark +
45 REMark ** Inline code line **
46 REMark ** Inline code line **
47 REMark ** Inline code line **
48 REMark ** Inline code line **
49 REMark ** Inline code line **
50 REMark ** Inline code line **
51 REMark -
```

Where **** Inline code line ****** means that the decompiler found a program line of Inline code.

This code is made from joining up the code routines that are normally called separately. However there is nothing separating the code segments, so the decompiler does not know how to identify, and separate the routines.

Hence this code will need to be decompiled by hand.

Format of the Inline code.
I only have the one program that uses Inline code, and this is how it's laid out in this compiled program, which has line numbers.

The **REMark +** line start with a normal code 0 word, followed by a line number word, then an A6 offset word pointing to the start of the inline machine code.

Each program line of the 'inline' code starts with the word $3C3C, followed by a line number word, then the machine code of the program line.

This continues until the **REMark -** line is reached, which starts with the word $3C3C, followed by a line number word, then a long word 'jump to subroutine relative to A6' starting $4EAExxxx. The second word may vary between different versions of the original compiler.

You then revert back to the normal compiled code 0 word, followed by a line number word.

The code routines that are joined together may not be exactly as as they appear in the library routines, but close enough to be able to identify them.

Variable references and data that were in the coded version of the SuperBASIC program are handled slightly differently.

Variable references are handled by setting a pointer to the variable, then moving the value either onto, or off of, the stack pointed to by A1.

```
246E88BC    movea.l   -$7744(a6),a2        point at ‘var88BC’
```

Note that the SuperBASIC variable reference is the second word of the ‘movea.l’ instruction. In this case the ‘88BC’

```
3392E800    move.w    (a2),$00(a1,a6.l)    get value onto the stack

34B1E800    move.w    $00(a1,a6.l),(a2)    set variable from the stack
```

Note that the format of the instruction may change between different versions of the compiler used, but it always involves moving between the A1 stack, and A2.