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CANopen object dictionary of an injector

This article describes the functionality and the possible relationships of the CANopen objects specified for injectors in CiA 425-2.

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The object dictionary (OD) implemented on a CANopen-connected injector is a list of objects existing at run-time and accessible by a scanner via the CANopen network. Each object serves a specific purpose. The OD as a whole defines the injector's application functionality. It determines the injector's operation aspects e.g., features, capabilities, communication parameters, injection protocol parameters, and expected behaviors in case of communication loss. The scanner, which controls the injector, learns those aspects by reading the objects from the injector's OD. The scanner can also influence the injector's behavior by writing new values to the objects, if allowed by the injector. An object can provide a "read-only" (ro), "write-only" (wo), or "read- and-write" (rw) access. An injector may restrict the object's access permission based on its own control measures or safety requirements.

An object in the OD can be one of the two object types: simple and complex. A simple object (variable), contains a single data piece with the data-type (Boolean, Unsigned8, etc.) as specified in CiA 301. A complex object (array or record) contains multiple pieces of data. These pieces may have the same data type (array) or different data-types (record). Each object in the OD is addressed with a 16-bit index and an 8-bit sub-index (00_h for variables; 00_h to FE_h for arrays or records). Each object can be accessed by a scanner using the SDO (service data object) service.

As mentioned above, the OD exists only at the run- time. Once the injector starts up, its OD, with all objects populated with default values, becomes accessible to the scanner. As some of the objects (e.g. 1016_h, 6070_h) have invalid default values, the scanner has to configure them via SDO.

When the injector shuts down, all object values (including the configured) are lost, as object 1010_h (store parameters) may not be supported by the injector. Every time the injector starts up (or resets), the scanner must re-configure certain objects. An electronic data sheet (EDS) is a file that lists all the objects (and their default values) supported by an injector. Using the injector's EDS file, the scanner knows which objects the injector supports, and which objects have to be configured.

The OD is divided into communication profile area (objects 1000_h to $1FFF_h$, e.g. heartbeat), manufacturer- specific profile area (2000_h to $5FFF_h$, not specified objects), and standardized profile area (6000_h to $67FF_h$). The standardized profile area objects in CiA 425-2 specify the com- mon application functionality of an injector (see table 1). The objects of the category "conditional" may have to be implemented depending on the injector compliance class.

Index	Object Name	Object/Data Type	Category*
Device Identity and Profile Version Objects			
6070_h	Scanner identity	RECORD	M
6073_h	Profile Version	UNSIGNED32	M
Injector FSA-related Objects			
6000_h	Control word	UNSIGNED32	M
6001_h	Status word	UNSIGNED32	M
6006_h	Communication lost	UNSIGNED8	M
Injector Function Objects			
6007_h	Functions supported	UNSIGNED32	M
6008_h	Global attributes support	ARRAY	M
Injector Capability Objects			
6002_h	Injection mode	UNSIGNED8	M
$600D_h$	Maximum configurable volume	ARRAY	O
$601A_h$	Maximum configurable pressure	UNSIGNED16	O
6028_h	Maximum configurable total flow rate	ARRAY	O
6050_h	Configured piston content	ARRAY	C
6051_h	Injector capabilities	ARRAY	C
Injection Protocol Objects			
6005_h	Examination delay	ARRAY	C
6019_h	Configured pressure limit	UNSIGNED16	C
6020_h	Configured phase type	ARRAY	C
6024_h	Configured total flow rate	ARRAY	C
6025_h	Configured total volume	ARRAY	C
6027_h	Configured delay duration	ARRAY	O
$6031_h - 6038_h$	Configured piston ratio 1 – Configured piston ratio 8	ARRAY	C
$603E_h$	Configuration check command	UNSIGNED8	reserved
$603F_h$	Configuration error list	ARRAY	C
Dynamic Injection Objects			
6009_h	Current injected total volume	UNSIGNED16	C
$600A_h$	Current pressure	UNSIGNED16	C
$600B_h$	Current total flow rate	UNSIGNED16	C
$600C_h$	Current volume remaining	ARRAY	C
Achieved Injection Objects			
6021_h	Achieved average total flow rate	ARRAY	reserved
6022_h	Achieved total volume	ARRAY	C
6023_h	Achieved duration	ARRAY	C
6029_h	Achieved peak flow rate	ARRAY	C
6039_h	Start phase timestamp	ARRAY	O
$603A_h$	End phase timestamp	ARRAY	C
Unit and Increment Definition Objects			
6041_h	Time unit	UNSIGNED32	C
6042_h	Flow rate unit	RECORD	C
6043_h	Pressure limit unit	RECORD	C
6044_h	Volume unit	RECORD	C
6045_h	Piston ratio unit	ARRAY	O
$604A_h$	Display increment unit	ARRAY	O

* M – mandatory; O – optional; C – conditional

Standardized profile area objects for injectors (Source: CiA 425-2)

	Bit	Description
0	rearm	Whether remote arming (from scanner) is supported
1	*reserved*	
2	ecg	Whether ECG (electrocardiogram) is supported
3	*reserved*	
4	skip	Whether "skip forward to phase" command is supported
5	hc	Whether injector state of hold configuration is supported
6	rc	Whether injector state of ready configuration is supported
7	drb[1]	How a delay phase should be handled after hold state
8	mix[2]	Whether mixed flow is supported
9-31	*reserved*	

Bit field specification of 6007_h (Source: CiA 425-2)

whether it should provide its own identity to the injector.

Device identity and profile version

The scanner identity object (6070_h) includes the scanner's CANopen vendor-ID, product code, revision number, and serial number. After the injector starts up or resets, the scanner has to identify itself to the injector by providing this object with appropriate data. Otherwise, the injector will not communicate with the scanner for security reasons. The injector's identity (same object type as 6070_h) is specified in object 1018_h. Upon the injector's startup, the scanner can read this object to determine

Object 6073_h specifies the CiA 425-1 and CiA 425-2 versions supported by the injector. A scanner reads this object during configuration to interpret the injector objects correctly, as their definitions could have been changed between versions (e.g. 6028_h).

Injector FSA-related objects

Object 6000ₕ contains the scanner command, which the injector receives via RPDO 1 (receive process data object). Among others, it causes a transition from the current injector FSA (finite state automaton) state to a new state. On a successful state transition, the injector stores a status word (with the new state) in object 6001ₕ and transmits the object value to the scanner via TPDO 1 (transmit PDO). If the injector fails to execute the state transition, it sends an emergency message. Then, it sends a copy of the status word still containing the current state. Object 6006ₕ specifies whether (and which) state transition an injector will perform in case of communication loss during an injection. The scanner reads this object during configuration, so it knows what to expect when communication loss occurs.

Injector function objects

Object 6007$_h$ provides the functions supported by an injector. This 32-bit object currently defines 7 bit (see table 2).

Note:

1. Bit 7 indicates how an injector handles a remaining delay phase after being put on hold. Assuming that the injector is currently executing a delay phase with a duration of 15 s. When the duration counts down to 5 s, the operator decides to push the hold button (state transition from procedure executing to hold). After a while (not defined how long), the operator ends the hold by pushing the hold-resume button (state transition from hold to procedure executing). What should happen to the remaining 5 s of the delay phase? If bit 7 is set to 0, the injector will terminate the delay phase immediately, and move on to the next phase (if any). If bit 7 is 1, the injector will resume counting down the remaining 5 s.
2. Dual-flow is a special and the most common case of the mixed flow, where two syringes are active in an injection phase.

Some injector functions (global attributes) can be controlled remotely by the scanner via the "set global attributes" command (see 6000$_h$). Object 6008$_h$ is an array with two 16-bit sub-indices (see table 3). Sub-index 1 indicates which global attributes the injector has implemented (bit = 0), meaning that they can be controlled locally by the injector. Since these are the injector's implementation details, sub-index 1 has "ro" as access. Sub-index 2 indicates which global attributes (from those implemented by the injector) are further granted permission to be also controlled remotely by the scanner (bit = 1). However, there exist disagreement among the SIG (special interest group) contrast media injector members about which device should grant the permission for the remote control. If it is the injector, sub-index 2 should have the "ro" access type. But if it is the scanner, sub-index 2 should be "rw". In the current version of CiA 425-2, sub-index 2 is "rw". The author thinks that sub-index 2 should be "ro". In other words, the injector should decide which global attributes can be remotely controlled. For example, an injector may support an XDS (extravasation detection system) as an accessory (sub-index 1: bit 3 = 0 i.e. implemented), but it may not allow the scanner to remotely activate it due to the injector's own safety requirements (sub-index 2: bit 3 = 0 i.e. not supported). In such cases, the injector will not delegate the permission to the scanner.

Injector capability objects

Object 6002$_h$ indicates what kind of injection an injector can perform, such as CT, CV, or MR injection. In addition, bit 0 indicates whether remote arming is allowed, which requires that the injector supports remote arming (6007$_h$: bit 0 = 1, see table 2). Interestingly, this object has the "rw" access permission in the idle state and in any of the configuration states. This implies that a scanner is potentially able to configure this object so that, for example, a CT injector can be turned into an MR injector. This is unlikely to happen. So, this object is usually implemented as "ro" in all injector states.

Bit		6000ₕ Global Attribute Bit
0-2		*reserved*
3	11	Activate/stop XDS
4	12	Start/stop KVO (keep veins open)
5	13	Lock/unlock local Arm button
6	14	Lock/unlock local Start button
7	15	Lock/unlock local Hold-Resume button
8	16	Lock/unlock local configuration
9	17	Transition 8* automatic/commanded
10	18	Provide phase number/type
11	22	Provide examination delay status
12	23	Provide injector reconfiguration status
13	19	Provide configuration check status
14-15		*reserved*

* Injection completed to procedure completed

Bit field specification of 6008 $_h$ sub-indices (Source: CiA 425-2)

Object 600D$_h$ indicates the maximum configurable volume of an injection protocol to use for each fluid type (see 6050$_h$ below). This is the total capacity of all syringes filled with the same fluid type. Each sub-index of this array represents one syringe (or piston) type. Object 601A$_h$ indicates the maximum allowed pressure for the syringes installed on the injector. It applies to all injection phases. Originally, object 6028$_h$ indicated the maximum configurable total flow rate for each injection protocol phase. For a dual-flow phase, it was the total of the two involved flow rates. Since CiA 425 version 2.2.0 the meaning of this object has changed. Now it means the maximum flow rate for each syringe (or piston). Therefore, the word "total" in the object's name is no longer appropriate.

Object 6050$_h$ indicates the fluid type (e.g. contrast media, saline) in each syringe (represented by a sub-index). The highest bit of each sub-index value also indicates whether that syringe is in service. Object 6051$_h$ (array) indicates the maximum number of possible phases (sub-index 1), the maximum number of injection phases (sub-index 2) and the maximum number of delay phases (sub-index 3, see also 6020$_h$).

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