Supplement to operating instruction

- DEUTSCH
- ENGLISH

HART interface

SU_HART_x23xV1-6LX

FLUXUS *72*

FLUXUS *831

PIOX *72*

PIOX S831

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Supplement to operating instruction for
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1 Einführung

Hinweis!

Diese Ergänzung gilt zusammen mit der Betriebsanleitung des Ultraschall-Durchflussmessgeräts FLUXUS oder PIOX. Sie sollten die Ergänzung, die Betriebsanleitung und die Sicherheitshinweise vollständig gelesen und verstanden haben, bevor Sie den Messumformer einsetzen.

HART (Highway Addressable Remote Transducer) ist ein Master-Slave-Protokoll für die digitale Feldkommunikation. Es ermöglicht die Kommunikation zwischen Feldgeräten und einem Prozessleitsystem. Die Datenübertragung erfolgt nach dem Bell-202-Standard.

HART ist als Option für die Messumformer FLUXUS *72*, FLUXUS *831, PIOX *72* und PIOX S831 erhältlich.
FLUXUS *72* und PIOX *72* sind für HART-Protokoll-Revision 7 ausgelegt.
FLUXUS *831 und PIOX S831 sind für HART-Protokoll-Revision 8 ausgelegt.

Im vorliegenden Dokument werden alle gerätespezifischen Funktionen und die Implementierung des HART-Protokolls erläutert. Darüber hinaus wird die Funktionsweise des Messumformers hinreichend beschrieben, um sicherzustellen, dass er im Prozess korrekt verwendet und in HART-fähigen Host-Anwendungen vollständig unterstützt wird.

Wenn der Messumformer über eine HART-Schnittstelle verfügt, können keine anderen Feldbusschnittstellen verwendet werden.

Begriffe und Abkürzungen

Abkürzung	Erläuterung
DD	Device Description (Gerätebeschreibung)
DTM	Device Type Manager (Gerätetypmanager)
FDT	Field Device Tool (Feldgerätetool)
FSK	Frequency Shift Keying (Frequenzumtastung)
HCF	HART Communication Foundation
LSB	Least Significant Bit (niedrigstwertiges Bit)
MSB	Most Significant Bit (höchstwertiges Bit)
PDU	Protocol Data Unit (Protokolldateneinheit)
PLC	Programmable Logic Controller (speicherprogrammierbare Steuerung)
PV	Primary Variable (Primärvariable)
QV	Quaternary Variable (Quartärvariable)
SV	Secondary Variable (Sekundärvariable)
TV	Tertiary Variable (Tertiärvariable)

2 Grundlagen

HART-Protokoll

Das HART-Protokoll folgt dem ISO/OSI-Referenzmodell.

Wie bei den meisten Feldkommunikationssystemen nutzt HART lediglich Schicht 1, 2 und 7.

OSI-Schicht		Funktion	HART
7	Anwendung (Application)	Bereitstellung netzwerkfähiger Anwendungen	kommandoorientierte, vordefinierte Datentypen und Anwendungsprozesse
6	Darstellung (Presentation)	Konvertierung der Anwendungsdaten in die Formate von Netzwerk und lokalem Computer	
5	Sitzung (Session)	Verbindungsmanagementdienste für Anwendungen	
4	Transport	Konvertierung der Anwendungsdaten in die Formate von Netzwerk und lokalem Computer	
3	Vermittlung (Network)	Ende-zu-Ende-Routing von Paketen, Auflösung von Netzwerkadressen	
2	Sicherung (Data Link)	Erstellung der Datenpaketstruktur, Aufteilung des Bitdatenstroms in Blöcke (Frames), Fehlererkennung	binäres, byteorientiertes Master-Slave-Protokoll mit Token-Passing
1	Bitübertragung (Physical)	mechanische/elektrische Verbindung, Übertragung des Rohbitstroms	gleichzeitiges analoges und digitales Signal, handelsübliche Kupferkabel (4...20 mA)

HART-Frame

Ein HART-Frame besteht aus folgenden 9 Feldern:

Feld	Erläuterung
Präambel	besteht aus mindestens drei 0x-FF-Bytes und wird für die Synchronisation von Master und Slave benötigt
Delimiter	gibt an, wer sendet (Master, Slave, Slave im Burst-Modus) und ob eine kurze oder lange Protokolldateneinheit (PDU) verwendet wird
Adresse	Beim kurzen Format besteht die Adresse aus 1 Byte. Das erste Bit dient zur Unterscheidung zwischen Primär- und Sekundärmaster. Das zweite Bit kennzeichnet Burst-Telegramme. Bis Revision 6 erfolgt die Adressierung der Feldgeräte über 4 Bits (Adresse 0 bis 15), ab Revision 7 über 6 Bits (Adresse 0 bis 63). Bei der langen Adressierung werden 5 Bytes verwendet.
Erweiterungsbytes (Option)	Definition von der HART Communication Foundation kontrolliert
Kommando	Byte für HART-Kommando
Bytezähler	Länge des Datenfelds (Status- und Datenbytes)
Status	je 1 Byte für Kommunikationsfehlercode/Antwortcode und Gerätestatus
Daten (Option)	zur Übertragung von Informationen zwischen Host-Anwendung und Feldgerät
Prüfsumme	XOR-Prüfsumme aller Bytes eines Telegramms ab dem Delimiter

HART-Kommunikation

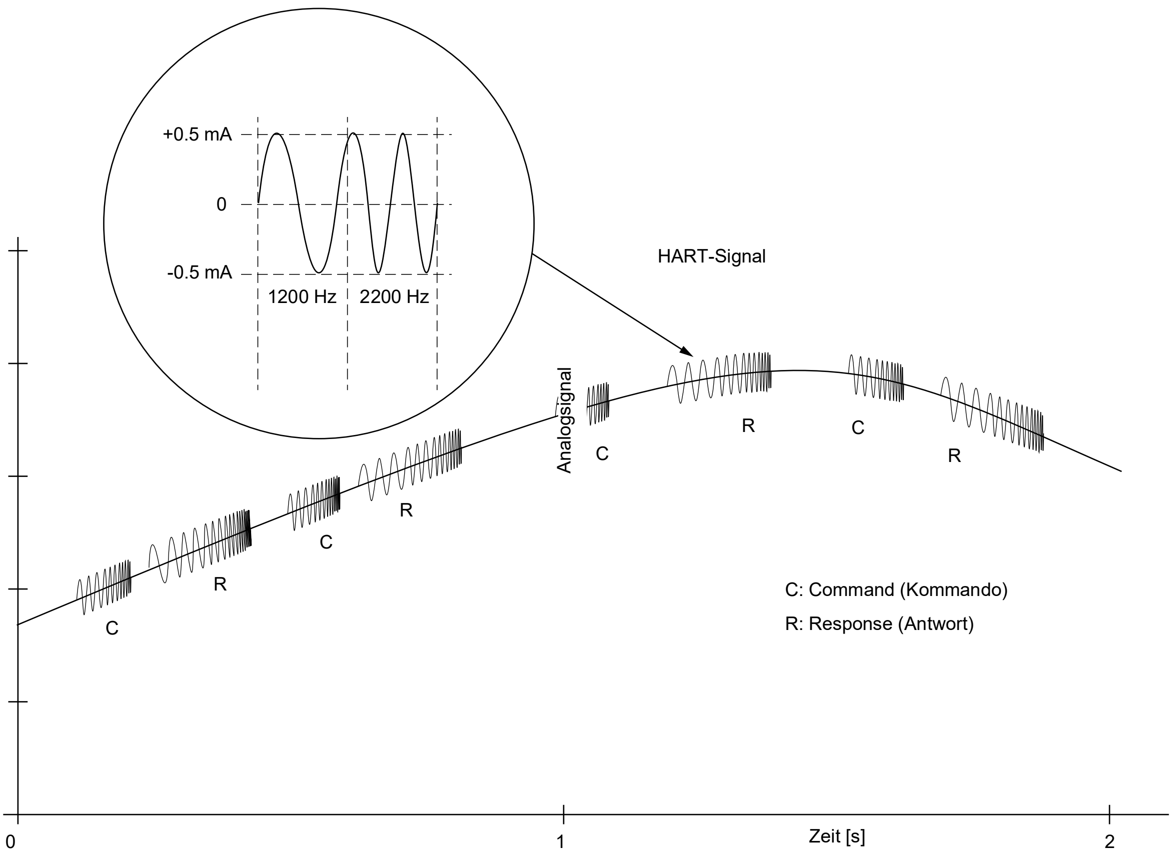
HART ist ein weit verbreiteter Branchenstandard zur digital erweiterten Kommunikation (4...20 mA) mit intelligenten, mikroprozessorgestützten Feldgeräten. Dabei handelt es sich um ein digitales Master-Slave-Protokoll, d. h. ein Slave sendet nur Informationen, wenn er hierzu von einem Master aufgefordert wird.

Das digitale Signal wird auf die analoge Stromschleife aufmoduliert, ohne diese zu beeinflussen. Die Stromschleife (4...20 mA) überträgt nur eine Prozessvariable, aber mit der höchsten Übertragungsrate. Der digitale Datenkanal dient zur Gerätekonfiguration und ermöglicht den Zugriff auf verschiedene Prozessvariablen.

Die Überlagerung des digitalen Signals mit der Stromschleife erfolgt per Frequenzumtastung (FSK) nach dem Bell-202-Kommunikationsstandard. Eine binäre 1 wird mit einer Frequenz von 1200 Hz dargestellt, eine 0 mit 2200 Hz. Damit ist die HART-Kommunikation auf 1200 Baud begrenzt.

HART stellt für jede Stromschleife zwei Master bereit: einen Primär- und einen Sekundärmaster. Typische Primärmaster sind speicherprogrammierbare oder computerbasierte Steuerungen sowie Überwachungssysteme. Zu den Sekundärmastern zählen z .B. Hand-Kommunikationsgeräte. Beide Master können mit ein und derselben Stromschleife verbunden werden, ohne dass die Kommunikation gestört wird.

Abb. 2.1: HART-Signal bei 4...20 mA



HART-Netzwerkkonfiguration

HART-Geräte können in folgenden zwei Netzwerkkonfigurationen betrieben werden:

- Punkt-zu-Punkt-Netzwerk
- Multidrop-Netzwerk

Bei einer Punkt-zu-Punkt-Verbindung wird über das Signal von 4...20 mA eine Prozessvariable kommuniziert. Die Übertragung der anderen Prozessvariablen und der Konfigurationsdaten erfolgt digital (siehe Abb. 2.2).

Das HART-Protokoll bietet zudem die Möglichkeit, in einer Multidrop-Netzwerkkonfiguration mehrere Feldgeräte mit passiven Stromausgängen an ein und dieselbe Stromschleife anzuschließen. In diesem Fall ist die Kommunikation ausschließlich digital. Der Strom jedes Feldgeräts ist auf 4 mA festgelegt und das Analogsignal enthält keinerlei Informationen über eine Prozessvariable (siehe Abb. 2.3).

Abb. 2.2: Punkt-zu-Punkt-Netzwerk

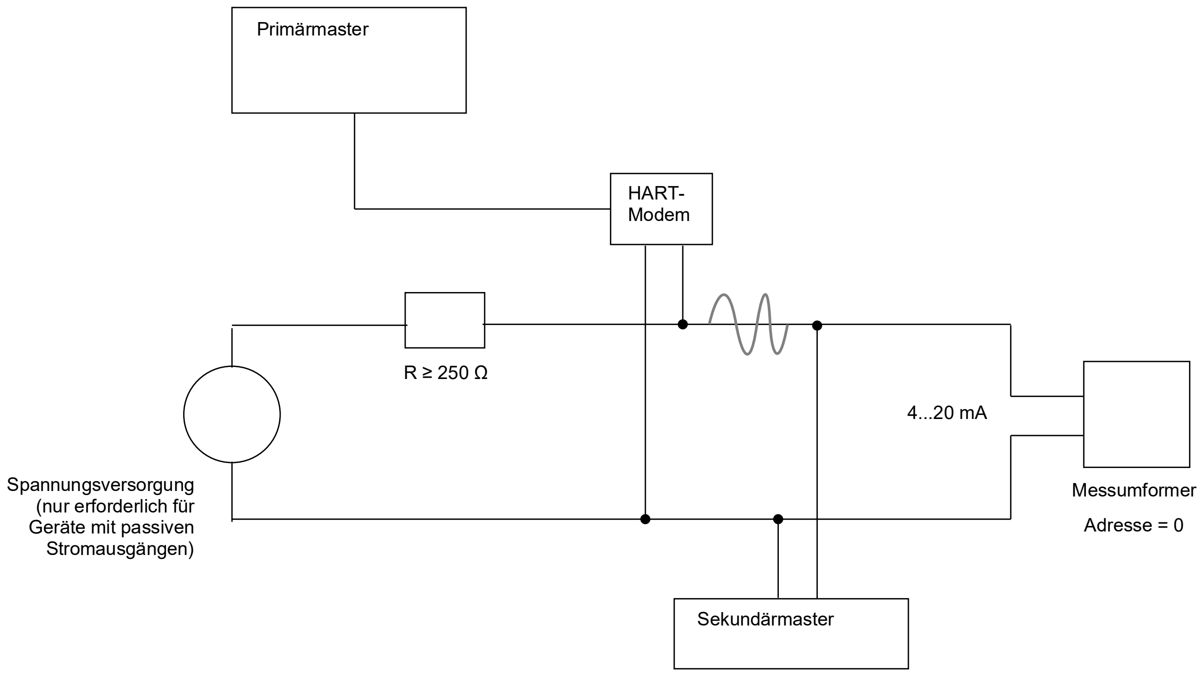
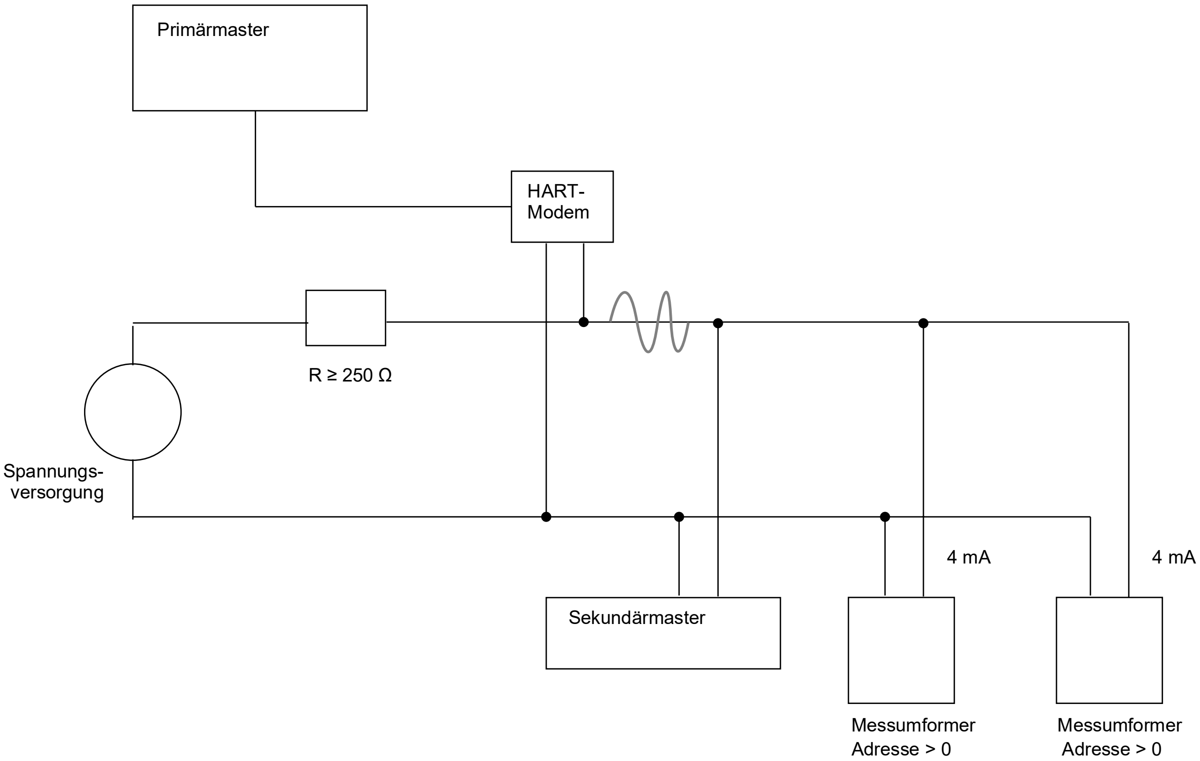
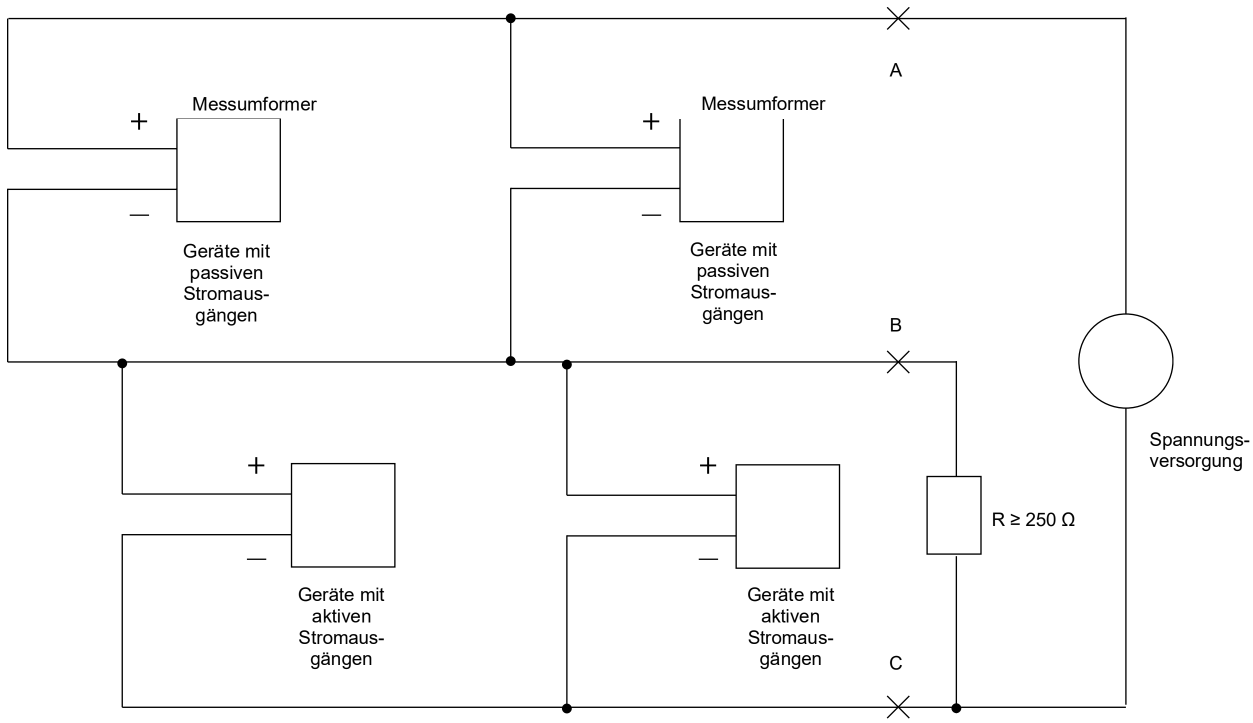


Abb. 2.3: Multidrop-Netzwerk



Zudem ist es möglich, in einem Multidrop-Netzwerk Geräte mit passiven und aktiven Stromausgängen miteinander zu kombinieren. Ein HART-Master kann über A und B, B und C oder über ein Feldgerät mit jedem beliebigen Feldgerät kommunizieren (siehe Abb. 2.4).

Abb. 2.4: Multidrop-Netzwerk mit Geräten mit passiven und aktiven Stromausgängen



3 Installation

3.1 Einstellungen am Messumformer

• Wählen Sie den Programmzweig `Sonderfunktionen\Kommunikation\HART`.
• Drücken Sie ENTER.

```
Sonderfunktionen\Kommunikation\HART\HART aktivieren
```

• Wählen Sie in der Auswahlliste den Listeneintrag `Bus`, um die HART-Schnittstelle zu aktivieren.
• Drücken Sie ENTER.

```
Sonderfunktionen\Kommunikation\HART\...\Bus\HART:PV
```

Informationen zum HART-Wert PV werden angezeigt.
FLUXUS *72*, PIOX *72*:
• Drücken Sie Taste 2 oder 8, um die Maßeinheit anzuzeigen.
• Drücken Sie ENTER.
FLUXUS *831, PIOX S831:
• Drücken Sie Taste ↓, um die Maßeinheit anzuzeigen.
• Drücken Sie ENTER.
Der HART-Wert PV kann im Menüpunkt `Optionen\...\Ausgänge\Strom I1(A:HART)` eingegeben oder geändert werden.

```
Sonderfunktionen\Kommunikation\HART\...\Bus\SV
```

Die Einstellungen für die HART-Werte SV, TV, QV können geändert werden.
• Wählen Sie den Kanal, die Quellgröße und die Maßeinheit für den HART-Wert SV.
• Drücken Sie nach jeder Eingabe ENTER.
• Wiederholen Sie die Eingabe für die HART-Werte TV und QV.

Hinweis!

Die HART-Werte können sowohl im Messumformer als auch über die HART-Schnittstelle mit Hilfe des DTM/DD parametriert werden.

Die in den Messumformer eingegebenen HART-Werte werden erst beim Einschalten des Messumformers oder beim Starten der Messung an der HART-Schnittstelle gültig. Eingaben über den DTM werden während der Messung abgewiesen (HART-Schnittstelle ist schreibgeschützt).

```
Sonderfunktionen\Kommunikation\HART\Schreibgeschützt
```

• Wählen Sie `Ja`, um den Schreibschutz zu aktivieren, oder `Nein`, um ihn zu deaktivieren.
• Drücken Sie ENTER.
Diese Anzeige erscheint nur, wenn `Bus` ausgewählt wurde.

```
Sonderfunktionen\Kommunikation\HART\Eingänge via Bus
```

• Wählen Sie `Ja`, wenn Eingangswerte über den Bus eingelesen werden sollen.
• Drücken Sie ENTER.

```
Sonderfunktionen\Kommunikation\HART\Info HART
```

Die Klemmen für den Anschluss der HART-Schnittstelle werden angezeigt.
FLUXUS *72*, PIOX *72*:
Durch Drücken der Taste 2 oder 8 werden weitere Informationen angezeigt.
• Drücken Sie ENTER.
FLUXUS *831, PIOX S831:
Durch Drücken der Taste ↓ werden weitere Informationen angezeigt.
• Drücken Sie ENTER.

3.2 Anschluss des Messumformers

Gefahr!

Gefahr einer Explosion beim Einsatz des Messgeräts in explosionsgefährdeten Bereichen

Es kann zu Personen- oder Sachschäden sowie gefährlichen Situationen kommen.

→ Beachten Sie die "Sicherheitshinweise für den Einsatz in explosionsgefährdeten Bereichen" (siehe Dokument SIFLUXUS).

HART-Geräte werden in klassischer Stromschleifenanordnung angeschlossen. Schließen Sie das Buskabel an den Messumformer an. Es wird empfohlen, ein geschirmtes Kabel zu verwenden.

- Entfernen Sie den Blindstopfen für den Anschluss des Kabels am Messumformer (falls vorhanden).
- Öffnen Sie die Kabelverschraubung des Verlängerungskabels. Der Einsatz bleibt im Überwurf.
- Schieben Sie das Kabel durch Überwurf und Einsatz (siehe Abb. 3.1).
- Kürzen Sie den äußeren Schirm und kämmen Sie ihn über den Einsatz zurück.
- Drehen Sie die Dichtringseite des Körpers fest in das Gehäuse des Messumformers.
- Führen Sie das Kabel in das Gehäuse des Messumformers ein.

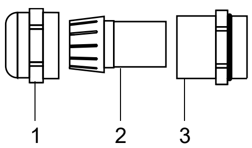
Wichtig!

Um eine gute Hochfrequenzabschirmung zu gewährleisten, ist es wichtig, einen guten elektrischen Kontakt des äußeren Schirms zum Überwurf (und damit zum Gehäuse) herzustellen.

- Fixieren Sie die Kabelverschraubung, indem Sie den Überwurf auf den Körper drehen.
- Schließen Sie das Kabel an die Klemmen des Messumformers an (siehe Tab. 3.1).

Für die Anschlüsse und Klemmen des Messumformers siehe Betriebsanleitung FLUXUS oder PIOX.

Abb. 3.1: Kabelverschraubung



1 – Überwurf
2 – Einsatz
3 – Körper

Tab. 3.1: Klemmenbelegung

Ausgang	Anschluss
HART FLUXUS *72*, PIOX *72*	P1+, P1- oder P3+, P3- Zur Anzeige der Klemmen drücken Sie ENTER, bis der Menüpunkt `Info Ausgang` im Programmzweig `Optionen\Ausgänge\I1(HART)` angezeigt wird.
HART FLUXUS *831, PIOX S831	11+, 12- Zur Anzeige der Klemmen drücken Sie ENTER, bis der Menüpunkt `Info Ausgang` im Programmzweig `Optionen\Ausgänge\I1(HART)` angezeigt wird.

4 Einlesen der Messwerte

Die HART-Schnittstelle verfügt über 4 konfigurierbare Eingänge. Die Konfiguration der Eingänge erfolgt ausschließlich über die HART-Schnittstelle (siehe Anhang A, Tab. A.100…Tab. A.104).

Über die Eingänge werden die Messgrößen digital eingelesen (siehe Tab. 4.1). Die Messgrößen stehen anschließend dem Messumformer zur weiteren Verwendung zur Verfügung.

Es kann geprüft werden, ob die eingelesenen Messgrößen in die aktuelle Messung einfließen:

• Starten Sie eine Messung.

FLUXUS *72*, PIOX *72*:

• Drücken Sie Taste 3, um den Messwert für die eingelesene Messgröße in der Messwert-Anzeige anzuzeigen.

FLUXUS *831, PIOX S831:

• Drücken Sie Taste ↓, um den Messwert für die eingelesene Messgröße in der Messwert-Anzeige anzuzeigen.

Tab. 4.1: Messgrößen und Maßeinheiten

Nr	**Kanal**	**Messgrößen** [(2)]	**Maßeinheit**	**Voreinstellung**
1	A, B, AB [(1)]	Fluidtemperatur T_{fluid}	**°C** °F	
2		Fluidtemperatur T_{aux}		
3		Fluiddruck P_{fluid}	**bar** psi	
4		Fluiddruck P_{aux}		
5		Dichte	**g/cm³** kg/m³ lb/ft³ lb/in³	
6		kin. Viskosität	**mm²/s** cSt	
7		dyn. Viskosität	**mPa*s** cP	
8		Kompressibilitätszahl des Gases	-	

(1) AB: Messgröße gilt für Kanal A und B (z.B. wenn die Eingangsgröße für beide Messkanäle verwendet werden soll)
(2) Die voreingestellten Maßeinheiten sind fett dargestellt.

5 Allgemeine Informationen zum Feldgerät

Der Messumformer hat einen Stromausgang von 4...20 mA und ist HART-fähig. Je nach Gerätekonfiguration kann der Stromausgang aktiv oder passiv betrieben werden.

Der Messumformer kommuniziert ausschließlich als Slave im Non-Burst-Modus und muss in ein System mit einem HART-Primär- oder -Sekundärmaster eingebunden werden.

Die vom Benutzer vordefinierten Parameter PV, SV, TV und QV können mit Kommando 3 ausgelesen (siehe Anhang A, Tab. A.6) und mit Kommando 51 geändert werden (siehe Anhang A, Tab. A.32).

Mit Kommando 9 (siehe Anhang B, Tab. B.1) können bis zu 8 beliebige Messwerte (siehe Anhang A, Tab. A.10) ausgelesen werden

Tab. 5.1: Identifikationsdaten des Feldgeräts

Herstellername	FLEXIM	
Hersteller-ID	6021 (Hex)	
Modellbezeichnung	FLUXUS	FLUXUS Series 8XX [A]
erweiterter Gerätetypcode	E0BD (Hex)	E52F (Hex)
Geräterevision	7	8
HART-Protokoll-Revision	7.2	7.x
Unterstützte Bitübertragungsschichten (Physical Layers)	Bell 202 FSK	
Kategorie des physischen Geräts	Ultraschall-Durchflussmessgerät	

5.1 HART-spezifische Voreinstellungen

Tab. 5.2: HART-spezifische Voreinstellungen

HART-Parameter	Voreinstellung
Slave-Adresse	0
Anzahl Antwort-Präambeln	5
Tag	*-FLX-*
Deskriptor	*-*FLUXUS*-*
Nachricht	F-L-X-F-L-X-F-L-X-F-L-X-F-L-X-
Lang-Tag	FLX - LONG TAG
Endmontagenummer	0
Tag/Monat/Jahr	28/01/1980
unterer Bereichswert der PV	0
oberer Bereichswert der PV	30
dynamische PV	7 (Volumenstrom)
dynamische SV	8 (Volumenstrom, Mengenzähler für die positive Flussrichtung)
dynamische TV	5 (Schallgeschwindigkeit)
dynamische QV	6 (Strömungsgeschwindigkeit)
PV-Einheit	19 (m^3/h)
SV-Einheit	43 (m^3)
TV-Einheit	21 (m/s)
QV-Einheit	21 (m/s)
Konfigurationsänderung durch Primärmaster	false

Tab. 5.2: HART-spezifische Voreinstellungen

HART-Parameter	Voreinstellung
Konfigurationsänderung durch Sekundärmaster	false
Konfigurationsänderungszähler	0
Anzahl empfangener STX-Telegramme	0
Anzahl gesendeter ACK-Telegramme	0
Anzahl gesendeter BACK-Telegramme	0
Fehlerwert am Stromschleifenausgang	21 (mA)

Gerätebeschreibung (DD)

Die im Feldgerät verfügbaren Informationen und Daten werden mit der Gerätebeschreibungssprache EDDL (Electronic Device Description Language) in eine textbasierte Datei geschrieben.

Diese Gerätebeschreibung (DD) kann von verschiedenen Programmen interpretiert werden und ist für die erweiterte Konfiguration des Messumformers per HART-Protokoll, einschließlich gerätespezifischer Kommandos, erforderlich.

Gerätetypmanager (DTM)

Der DTM ist ein nichteigenständig laufendes Windows-PC-Programm, das in einer Rahmenanwendung – der sogenannten FDT Frame Application (z.B. PACTware oder fdtContainer) – installiert und ausgeführt werden muss.

Der FLUXUS-DTM wird gemäß FDT-Spezifikation 1.2 programmiert und enthält die gerätespezifischen Informationen, die für die Kommunikation und Konfiguration von HART-fähigen Messumformern erforderlich sind.

5.2 Eigenschaften des Analogausgangs

Der passive Zweidraht-Stromausgang (4...20 mA) des Messumformers wird als HART-Schnittstelle verwendet. Diesem Ausgang ist der PV zugewiesen. Der Prozesswert wird gemäß Konfiguration des Messumformers linearisiert und skaliert ausgegeben.

Im `OnlyLoop`-Modus dauert die Aktualisierung der Stromschleife 100 ms.

Wenn `HART` aktiviert ist, werden die Stromschleife und die Parameter PV, SV, TV und QV innerhalb von 300 ms aktualisiert.

Für den Anschluss und die Konfiguration des Analogausgangs siehe Betriebsanleitung FLUXUS oder PIOX.

Tab. 5.3: Eigenschaften des Analogausgangs

		Werte
linearer Bereich	unterer Grenzwert	4.0 mA (0 %)
	oberer Grenzwert	20.0 mA (+100 %)
Strom	min.	3.5 mA (-3.125 %)
	max.	22 mA (+112.5 %)
Stromaufnahme im Multidrop-Netzwerk		4 mA (0 %)
externe Mindestspannung		$U_{ext} \geq R_{ext}$ * 22 mA + 7 V U_{ext} = 7 V für R_{ext} = 0 Ω U_{ext} = 12.5 V für R_{ext} = 250 Ω

Linearer Bereich

Der Prozesswert der PV wird entsprechend dem Stromausgang linear skaliert.

Fehlerwert am Stromschleifenausgang

Wenn ein Fehler auftritt (z. B. Messung nicht gestartet oder Fehlerverzögerung überschritten), wird ein Fehlerwert ausgegeben. Der Fehlerwert wird mit HART-Kommando 191 festgelegt (Bereich: 3.5...22 mA, Voreinstellung: 21 mA).

Minimaler/maximaler Stromwert

Bezeichnet den kleinsten und größten Stromwert, der konfiguriert werden kann, z. B. mit Kommando 40 (festen Strommodus aufrufen/beenden).

Stromaufnahme im Multidrop-Netzwerk

Im Mehrpunktmodus (parallel geschaltete Geräte) wird statt des Prozesswerts ein fester Stromwert von 4 mA ausgegeben.

externe Mindestspannung

Damit der Stromausgang korrekt funktioniert, muss eine Mindestspannung angelegt werden (siehe Tab. 5.3).

6 Statusinformationen

HART-spezifischer Gerätestatus

Die ersten beiden Bytes jedes Slave-Antworttelegramms enthalten Informationen zum Feldgerätestatus. Das erste Byte ist gemultiplext und enthält entweder den Kommunikationsstatus (MSB gesetzt) oder den Antwortcode (MSB nicht gesetzt) für ein bearbeitetes Kommando eines Masters. Das zweite Byte enthält Informationen zum Feldgerätestatus.

- Bei einem Kommunikationsfehler sendet das Feldgerät das Kommunikationsstatusbyte (bitorientiert) wieder zurück.
- Wenn kein Kommunikationsfehler auftritt, sendet das Feldgerät einen kommandoabhängigen Antwortcode zurück.
- Bei einem Kommunikationsfehler werden alle Bits des zweiten Bytes auf Null gesetzt. Ansonsten enthält dieses Byte den Gerätestatus, also den aktuellen Status des Slaves.

Tab. 6.1: Kommunikationsfehler

Bitmaske	Definition
0x80	Kommunikationsfehler - Wenn auf 1 gesetzt, signalisiert dieses Bit einen der folgenden Kommunikationsfehler.
0x40	Vertikaler Paritätsfehler (Vertical Parity Error) – Die Parität von mindestens einem empfangenen Byte war nicht korrekt.
0x20	Überlauffehler (Overrun Error) – Mindestens ein Byte im Empfangspuffer des UART (Universal Asynchronous Receiver Transmitter) wurde überschrieben, bevor es gelesen wurde.
0x10	Rahmenfehler (Framing Error) – Das Stoppbit von mindestens einem Byte wurde nicht vom Gerät erkannt.
0x08	Längenparitätsfehler (Longitudinal Parity Error) – Die vom Gerät berechnete Prüfsumme stimmte nicht mit dem Prüfsummenbyte am Ende des empfangenen Telegramms überein.
0x04	reserviert (auf 0 gesetzt)
0x02	Überlauf des Pufferspeichers (Buffer Overflow) – Das Telegramm war zu lang für den Empfangspuffer des Geräts.
0x01	reserviert (auf 0 gesetzt)

Bei Meldungen an den Host gibt es drei verschiedene Antwortcode-Klassen: Benachrichtigungen, Warnungen und Fehler.

Tab. 6.2: Antwortcode-Klassifizierung

Antwortcode-Klasse	Definition
Benachrichtigung	Das Kommando wurde erfolgreich ausgeführt (Antwortcode 0).
Warnung	Das Kommando wurde mit einer im Antwortcode angegebenen Abweichung ausgeführt (z. B. ein Wert wurde auf den nächstgültigen Wert gesetzt).
Fehler	Das Kommando wurde aus dem im Antwortcode angegebenen Grund nicht erfolgreich ausgeführt (z. B. Gerät schreibgeschützt).

Die nachfolgende Tabelle enthält Informationen zum Gerätestatusbyte.

Tab. 6.3: Gerätestatus

Bitmaske	Definition
0x80	Gerätefehlfunktion – Das Gerät hat einen schweren Fehler oder Ausfall festgestellt.
0x40	Konfiguration geändert – Die Gerätekonfiguration wurde durch ein Schreib- oder Einstellungskommando geändert.
0x20	Kaltstart – Es gab einen Spannungsausfall oder das Gerät wurde zurückgesetzt. Das erste Kommando erkennt das Statusbit und lässt es vom Gerät zurücksetzen.
0x10	Weitere Statusinformationen verfügbar – Über das Kommando 48 sind weitere Statusinformationen verfügbar.
0x08	Fester Schleifenstrom – Der Schleifenstrom wird auf einem festen Wert gehalten und spricht nicht auf die PV an.
0x04	Schleifenstrom gesättigt – Der Schleifenstrom hat seinen oberen oder unteren Grenzwert überschritten.
0x02	Nicht-Primärvariable außerhalb Betriebsgrenzen – Eine andere Gerätevariable als die PV hat die Betriebsgrenzen erreicht.
0x01	Primärvariable außerhalb Betriebsgrenzen – Die PV befindet sich außerhalb der Betriebsgrenzen.

Zusätzliche Informationen zum Gerätestatus

Das Feldgerät unterstützt keine zusätzlichen Informationen zum Gerätestatus.

Status der Gerätevariablen

Der Status jeder Gerätevariable kann mit dem HART-Kommando 9 gelesen werden.

Tab. 6.1: Status der Gerätevariablen

Status	
gut	Messwert ok – keine Fehler
ungenau	Fehlerverzögerung überschritten (siehe Kommando 240 und 241)
schlecht	kein Messwert verfügbar oder gesetzt

Fehlerverzögerung

Die Fehlerverzögerung ist das Zeitintervall, nach dessen Ablauf der für die Stromschleifenausgabe festgelegte Fehlerwert zur Stromschleife übertragen wird, wenn keine gültigen Messwerte vorliegen. Sie kann mit dem Kommando 240 gelesen und mit dem Kommando 241 geschrieben werden. Der voreingestellte Wert beträgt 10 Sekunden.

7 Fehlersuche

Keine Verbindung zum Host-System

• Stellen Sie sicher, dass der HART-Modus aktiviert ist.
• Bei Verwendung einer passiven Stromschleife muss eine externe Spannungsquelle von ≥ 12 V angeschlossen werden.
• Der Mindeststrom des HART-PICMOD beträgt 2.5 mA.
• Widerstand (250...1100 Ω) und Stromschleife müssen in Reihe geschaltet werden.
• Leuchten die LEDs auf dem HART-PICMOD bei Inbetriebnahme und Messung?

Verwendung des HART Service Adapter

• Mit dem HART Service Adapter lassen sich viele Fehlerquellen vermeiden.
• Zur Kommunikation mit dem FLUXUS binden Sie das HART-Modem in die Stromschleife ein.

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1 Introduction

Notice!

This supplement has to be used together with the operating instruction of the FLUXUS or PIOX ultrasonic flowmeter. Make sure you have fully read and understood this supplement, the operating instruction and the safety instructions before using the transmitter.

HART (Highway Addressable Remote Transducer) is a master/slave protocol for digital field communication. The protocol enables the communication between field devices and the monitoring system. The data is transfered using the Bell 202 standard.

HART is an option for the transmitters FLUXUS *72*, FLUXUS *831, PIOX *72* and PIOX S831.
FLUXUS *72* and PIOX *72* complies with HART protocol revision 7.
FLUXUS *831 and PIOX S831 complies with HART protocol revision 8.

This document specifies all the device specific features and documents HART protocol implementation. The functionality of the transmitter is sufficiently described to allow its proper application in a process and its complete support in HART capable host applications.

If the transmitter is equipped with a HART interface, no further fieldbus interfaces can be used.

Terms and abbreviations

abbreviation	explanation
DD	Device Description
DTM	Device Type Manager
FDT	Field Device Tool
FSK	Frequency Shift Keying
HCF	HART Communication Foundation
LSB	Least Significant Bit
MSB	Most Significant Bit
PDU	Protocol Data Unit
PLC	Programmable Logic Controller
PV	Primary Variable
QV	Quaternary Variable
SV	Secondary Variable
TV	Tertiary Variable

2 General principles

HART protocol

The HART protocol follows the ISO/OSI reference model.
As in most field communication systems, HART uses only layer 1, 2 and 7.

OSI layer		function	HART
7	application	provides the user with network capable applications	command oriented, predefined data types and application procedures
6	presentation	converts application data between network and local machine formats	
5	session	connection management services for applications	
4	transport	converts application data between network and local machine formats	
3	network	end to end routing of packets, resolving network addresses	
2	data link	establishes data packet structure, framing, error detection	a binary, byte oriented, token passing, master/slave protocol
1	physical	mechanical/electrical connection, transmits raw bit stream	simultaneous analog and digital signal, normal 4...20 mA copper wiring

HART frame

A HART frame consists of the following 9 fields:

field	explanation
preamble	consist of at least three 0xFF bytes, needed for synchronization of master and slave
delimiter	The start byte/delimiter indicates which device (master, slave, slave in burst mode) is sending and whether short or long PDU (Protocol Data Unit) is used.
address	If short addressing is used, the address consist of 1 byte. The first bit is used to differentiate between primary and secondary master. The second bit is used to identify a burst message. The addressing of a field device is provided by 4 bits (address 0...15) ≤ Rev 6 or by 6 bits (address 0...63) > Rev 6. The address for long addressing consists of 5 bytes.
[expansion bytes]	option, definition controlled by the HART Communication Foundation
command	byte for HART command
byte count	length of the data field (status and data bytes)
status	1 byte each for communication error/response code and device status
[data]	option, for information transferred between the host application and the field device
check byte	XOR checksum of all message bytes starting with the delimiter

HART Communication

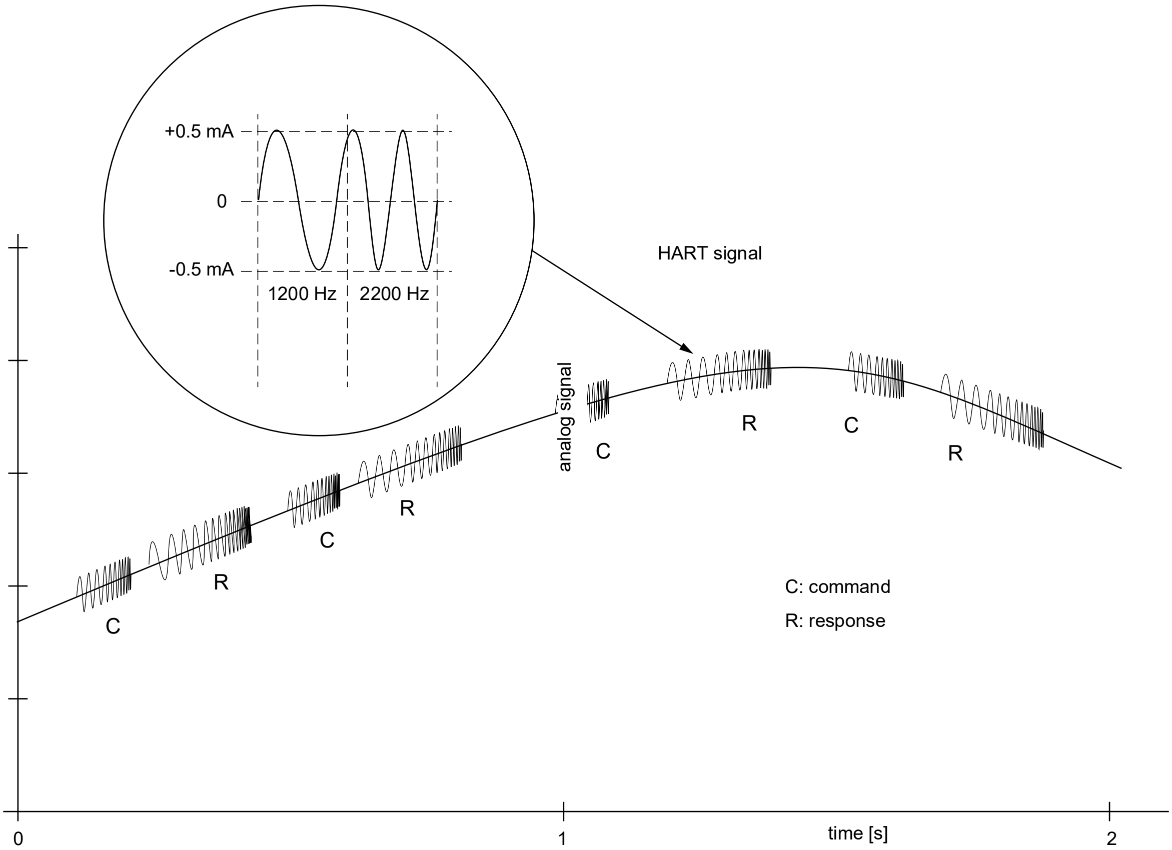
In industry, HART is widely accepted as a standard for digitally enhanced 4...20 mA communication with smart and microprocessor based field devices. It is a digital master/slave protocol which means a slave only sends information if it is requested to do so by a master.

The digital signal is modulated on the analog current loop without affecting it. The 4...20 mA current loop transmits only one process variable but at the fastest possible rate. The digital data channel is used to configure the device and allows the access to multiple process variables.

To superimpose the digital signal with the current loop, a Frequency Shift Keying (FSK) technique, based on the Bell 202 communication standard is used. Two frequencies, 1200 Hz and 2200 Hz are used to represent binary 1 and 0. Thus, HART communication is limited to 1200 Baud.

HART provides two different masters (primary and secondary) to each loop. Primary masters are typically PLCs, computer based controllers or monitoring systems. Secondary masters are for example handheld communicators. Both masters can be connected to one current loop without disturbing the communication.

Fig. 2.1: HART signal imposed on 4...20 mA



HART Network Configuration

HART devices can operate in one of two network configurations:

• point-to-point network

• multidrop network

In case of a point-to-point connection, the 4...20 mA signal is used to communicate one process variable, while other process variables or configuration data are transferred digitally (see Fig. 2.2).

The HART protocol also provides the possibility to connect several passive current output field devices on the same loop in a multidrop network configuration. In this case, communication is limited to digital communication only. The current of each field device is fixed to 4 mA, the analog signal does not carry any information about a process variable (see Fig. 2.3).

Fig. 2.2: Point-to-point network

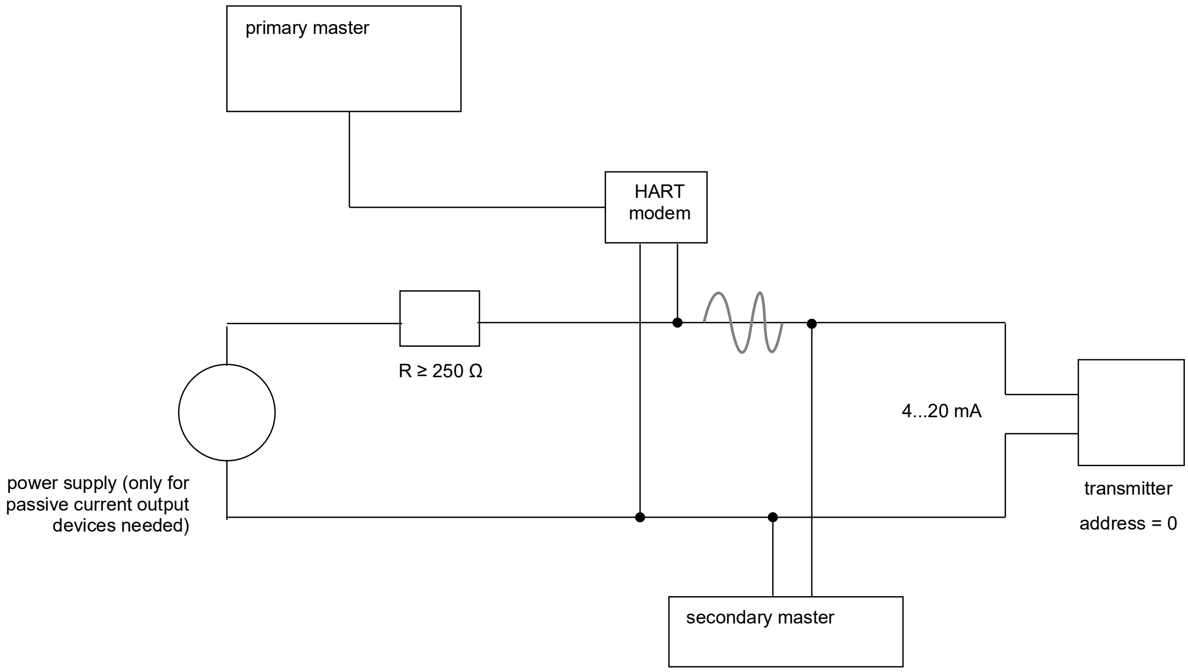
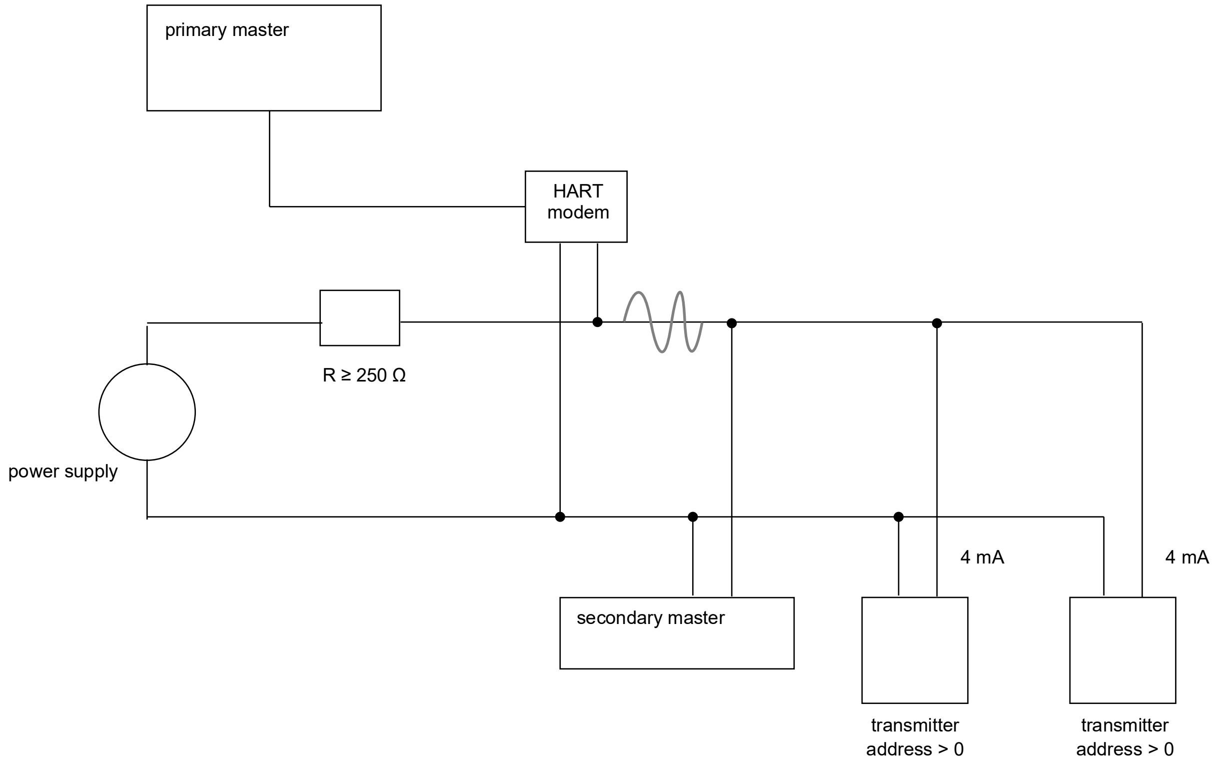
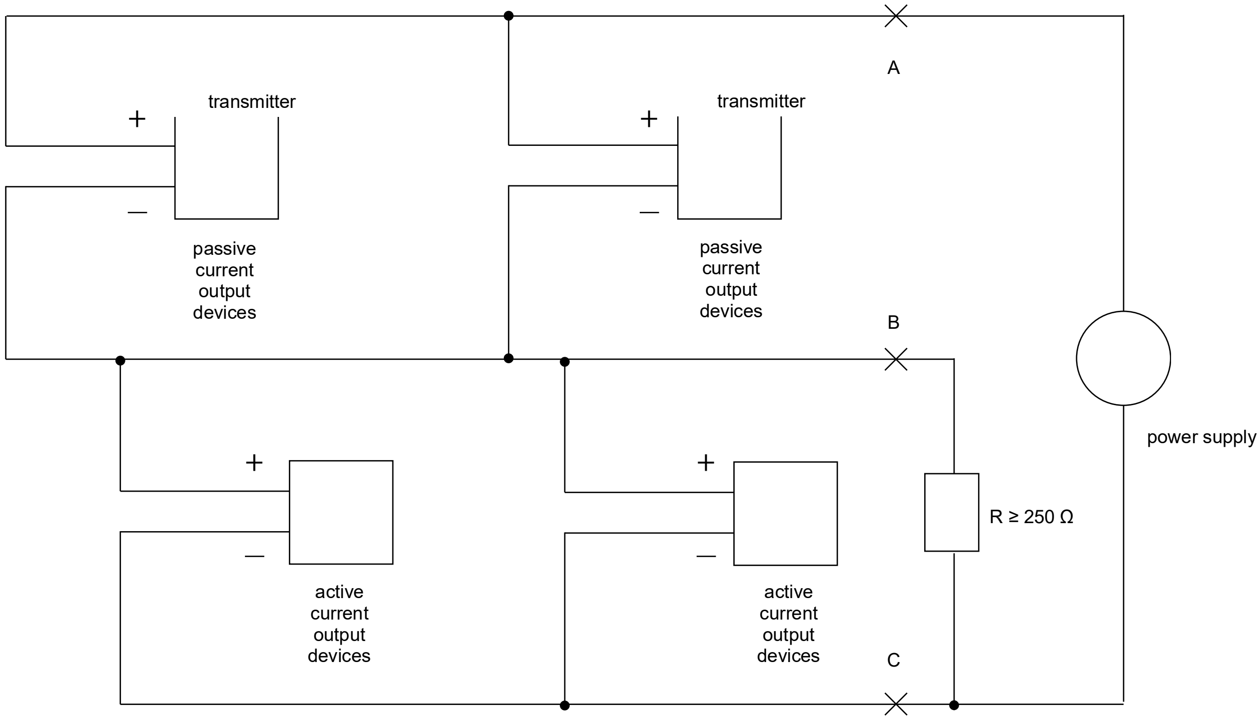


Fig. 2.3: Multidrop network



It is also possible to combine passive and active current output devices in one multidrop network. A HART master can be connected via A and B, via B and C or via a field device to communicate with any field device (see Fig. 2.4).

Fig. 2.4: Multidrop network with passive and active current output devices



3 Installation

3.1 Settings in the Transmitter

- Select the program branch `Special functions\Communication\HART`
- Press ENTER.

```
Special functions\Communication\HART\Activate HART
```

- Select the list item `Bus` in the scroll list to activate the HART interface.
- Press ENTER.

```
Special functions\Communication\HART\...\Bus\HART:PV
```

Information concerning the HART value PV is displayed.

FLUXUS *72*, PIOX *72*:

- Press 2 or 8 to display the unit of measurement.
- Press ENTER.

FLUXUS *831, PIOX S831:

- Press ↓ to display the unit of measurement.
- Press ENTER.

The HART value PV can be entered or changed in the menu item `Options\...\Outputs\Current I1(A:HART)`.

```
Special functions\Communication\HART\...\Bus\SV
```

The settings for the HART values SV, TV, QV can be changed.

- Select the channel, source item and the unit of measurement for the HART value SV.
- Press ENTER after each input.
- Repeat the input for the HART values TV and QV.

Notice!
The HART values can be parameterized in the transmitter and via the HART interface by means of the DTM/DD. The introduced HART values become valid at the HART interface after switching on the transmitter or starting a measurement. Inputs made via the DTM are rejected during the measurement (HART interface is read-only).

```
Special functions\Communication\HART\Write protected
```

- Select `Yes` to activate the write protection, `No` to deactivate it.
- Press ENTER.

This display will only be indicated if `Bus` is selected.

```
Special functions\Communication\HART\Inputs via bus
```

- Select `Yes` if input values are to be fed in via the bus.
- Press ENTER.

```
Special functions\Communication\HART\Info HART
```

The terminals for the connection of the HART interface are displayed.

FLUXUS *72*, PIOX *72*:

Further information is displayed by pressing 2 or 8.

- Press ENTER.

FLUXUS *831, PIOX S831:

Further information is displayed by pressing ↓.

- Press ENTER.

3.2 Connection of the Transmitter

Danger!

Risk of explosion when using the measuring instrument in explosive atmospheres

This may result in personal or material damage or dangerous situations.

→ Observe the "Safety instructions for the use in explosive atmospheres" (see document SIFLUXUS).

HART devices are connected in a conventional current loop arrangement. Connect the bus cable to the transmitter. It is recommended to use a shielded cable.

- Remove the blind plug from the transmitter to connect the cable (if present).
- Open the cable gland of the extension cable. The compression part remains in the cap nut.
- Push the cable through the cap nut and the compression part (see Fig. 3.1).
- Shorten the external shield and brush it back over the compression part.
- Screw the gasket ring side of the basic part tightly into the housing of the transmitter.
- Insert the cable into the housing of the transmitter.

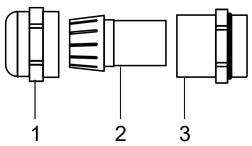
Important!

For good high frequency shielding, it is important to ensure good electrical contact between the external shield and the cap nut (and thus to the housing).

- Fix the cable gland by screwing the cap nut onto the basic part.
- Connect the cable to the terminals of the transmitter (see Tab. 3.1).

For the transmitter connections and terminals see FLUXUS or PIOX operating instruction.

Fig. 3.1: Cable gland



1 – cap nut
2 – compression part
3 – basic part

Tab. 3.1: Terminal assignment

output	connection
HART FLUXUS *72*, PIOX *72*	P1+, P1- or P3+, P3- For the display of the terminals press ENTER until the menu item `Output info` in the program branch `Options\Outputs\I1(HART)` is displayed.
HART FLUXUS *831, PIOX S831	11+, 12- For the display of the terminals press ENTER until the menu item `Output info` in the program branch `Options\Outputs\I1(HART)` is displayed.

4 Reading of measured values

The HART interface has 4 configurable inputs. The configuration of the inputs is exclusively effected via the HART interface (see annex A, Tab. A.100…Tab. A.104).

The physical quantities are digitally read via the inputs (see Tab. 4.1) and are available in the transmitter for further use.

It is possible to check whether the fed-in physical quantities are incorporated into the current measurement:

• Start a measurement.

FLUXUS *72*, PIOX *72*:

• Press 3 to display the measured value for the read physical quantity.

FLUXUS *831, PIOX S831:

• Press ↓ to display the measured value for the read physical quantity.

Tab. 4.1: Physical quantities and units of measurement

no.	channel	physical quantities [2]	unit of measurement	default value
1	A, B, AB [1]	fluid temperature T_{fluid}	**°C** °F	
2		fluid temperature T_{aux}		
3		fluid pressure P_{fluid}	**bar** psi	
4		fluid pressure P_{aux}		
5		density	**g/cm³** kg/m³ lb/ft³ lb/in³	
6		kin. viscosity	**mm²/s** cSt	
7		dyn. viscosity	**mPa*s** cP	
8		gas compressibility coefficient	-	

[1] AB: Physical quantity is valid for channel A and B (e.g. if the input quantity has to be used for both measuring channels)
[2] The default units of measurement are printed in bold.

5 General field device information

The transmitter has a 4...20 mA current output and HART capability. Depending on the device configuration, the current output can be operated in active or passive mode.

The transmitter communicates only as non-bursting slave and has to be used in a system with a HART primary or secondary master.

The parameter, predefined by the user, PV, SV, TV and QV can be read with the command 3 (see annex A, Tab. A.6) and changed with the command 51 (see annex A, Tab. A.32).

Up to 8 arbitrary measured values (see annex B, Tab. B.1) can be read with the command 9 (see annex A, Tab. A.10).

Tab. 5.1: Field device identification summary

manufacturer name	FLEXIM	
manufacturer ID	6021 (Hex)	
model name	FLUXUS	FLUXUS Series 8XX [A]
expanded device type code	E0BD (Hex)	E52F (Hex)
device revision	7	8
HART protocol revision	7.2	7.x
physical layers supported	Bell 202 FSK	
physical device category	ultrasonic flowmeter	

5.1 HART specific default settings

Tab. 5.2: HART specific default settings

HART parameter	
slave address	0
number of response preambles	5
tag	*-FLX-*
descriptor	*-*FLUXUS*-*
message	F-L-X-F-L-X-F-L-X-F-L-X-F-L-X-
long tag	FLX - LONG TAG
final assembly number	0
day/month/year	28/01/1980
PV lower range value	0
PV upper range value	30
dynamic PV	7 (volumetric flow rate)
dynamic SV	8 (volumetric flow rate, positive totalizer)
dynamic TV	5 (sound speed)
dynamic QV	6 (flow velocity)
PV unit	19 (m^3/h)
SV unit	43 (m^3)
TV unit	21 (m/s)
QV unit	21 (m/s)
configuration change by primary master	false

Tab. 5.2: HART specific default settings

HART parameter	
configuration change by secondary master	false
configuration change counter	0
count of STX messages received	0
count of ACK messages sent	0
count of BACK messages sent	0
current loop output error value	21 (mA)

Device description (DD)

The electronic device description language (EDDL) is used to describe information and data which are accessible in the field device. The result is a text-based file, the DD.

This DD can be interpreted by several programs and has to be used for enhanced configuration of the transmitter by HART protocol, including device specific commands.

Device type manager (DTM)

The DTM is a non-standalone windows PC program. It has to be installed and has to be executed in a frame application called field device tool (FDT) container (e.g. PACTware or fdtCONTAINER).

The FLUXUS DTM is programmed according to FDT specification 1.2 and includes the device specific information to communicate with and configure HART capable transmitters.

5.2 Analog output characteristics

The 2-wire 4...20 mA passive current output of the transmitter is used as the HART interface. This output corresponds to the PV. The process value will be output linearized and scaled as configured on the transmitter.

The update time of the current loop in mode `OnlyLoop` is 100 ms.

If `HART` is activated, the update time of the current loop and the parameters PV, SV, TV and QV is 300 ms.

For connection and configuration of the analog output see the FLUXUS or PIOX operating instruction.

Tab. 5.3: Analog output characteristics

		values
linear range	lower limit	4.0 mA (0 %)
	upper limit	20.0 mA (+100 %)
current	min.	3.5 mA (-3.125 %)
	max.	22 mA (+112.5 %)
multidrop current draw		4 mA (0 %)
lift-off voltage		$U_{ext} \geq R_{ext}$ * 22 mA + 7 V U_{ext} = 7 V for R_{ext} = 0 Ω U_{ext} = 12.5 V for R_{ext} = 250 Ω

Linear range

The PV process value is scaled linearly on the current output.

Current loop output error value

In case of an error (e.g. measurement is not started and the error value delay is expired), an error value is output. The error value will be set by HART command 191. Range: 3.5...22 mA, default: 21 mA.

Current minimum/maximum

The min. and max. configurable current, e.g. by command 40 (Enter/Exit Fixed Current Mode).

Multidrop current draw

To enable multidrop mode (parallel connected devices), the process value will not be output. A fixed current value of 4 mA will be output instead.

Lift-off voltage

The connection of a voltage source of a minimum voltage is required for the correct operation of the current output (see Tab. 5.3).

6 Status information

HART Specific device status

The first two bytes of every slave response message contain field device status information. The first byte is multiplexed and contains either the communication status (MSB set) or the response code (MSB not set) for a handled command from a master. The second byte contains field device status information.

- Field device returns communication status byte (bit-mapped) if a communication error is detected.
- If no communication errors occur, the field device returns a command dependent response code.
- If a communication error occurs, all bits of the second byte are zero. If not, it contains the device status which represents the current state of the slave.

Tab. 6.1: Communication errors

bit mask	definition
0x80	communication error – This bit indicates one of the following detected communication errors if it is set to 1.
0x40	vertical parity error – The parity of at least one received byte was incorrect.
0x20	overrun error – At least one byte in the receive buffer of the UART was overwritten before it was read.
0x10	framing error – The stop bit of at least one byte was not detected by the device.
0x08	longitudinal parity error – The checksum calculated by the device did not match the checksum byte at the end of the received message.
0x04	reserved (set to 0)
0x02	buffer overflow – The received message was too long for the receive buffer of the device.
0x01	reserved (set to 0)

The response codes indicate three classes of indications to the host. These are notifications, warnings and errors.

Tab. 6.2: Response code classification

response code class	definition
notification	successful command execution – The response code is 0.
warning	command was executed with a deviation as described with the response code (e.g., a value was set to its nearest legal value).
error	command was not executed successfully – The response code indicates the reason (e.g., the device is in write protect mode).

The following table shows information about the device status byte.

Tab. 6.3: Device status

bit mask	definition
0x80	device malfunction – The device detected an error or failure.
0x40	configuration changed – A write or set command which changed the device configuration was executed.
0x20	cold start – power has been removed or a device reset occurred. The first executed command recognizes this status bit and it disposes the device to reset the status bit.
0x10	more status available – More status information is available which can be read via command 48.
0x08	loop current fixed – The loop current is being held at a fixed value and is not responding the PV.
0x04	loop current saturated – The loop current is beyond its upper or lower limit.
0x02	non-primary variable out of limits – A device variable other than the PV has reached operating limits.
0x01	primary variable out of limits – The PV is beyond the operating limit.

Additional Device Status

The field device does not support an additional device status.

Device variable status

Every device variable has a status which can be read with HART command 9.

Tab. 6.1:Device variable status

status	
good	measuring value OK – no errors
poor accuracy	measuring value is older than “error value delay” (see command 240 and 241)
bad	measuring value is unavailable or never set

Error delay

The error value delay is the time interval after which the current loop output error value will be transmitted to the current loop in case no valid measured values are available. This delay can be read by command 240 and written by command 241. The default value is 10 seconds.

7 Troubleshooting

No connection to the host system

• Make sure that the HART mode is activated.

• If a passive current loop is used an external power supply of ≥12 V is required for the connection.

• The min. current value of the HART-PICMOD is 2.5 mA.

• The resistor (250 Ω to 1100 Ω) has to be installed in series with the current loop.

• Do the LEDs flash on the Modbus module during the start-up and the measurement?

Using the current loop black box

• To avoid many sources of error use the current loop black box.

• Connect the current loop and HART modem to communicate with the FLUXUS.

Annex

A Supported HART Commands

A.1 Universal Commands

All devices using the HART protocol have to recognize and support the universal commands.
The transmitter supports all 22 specified universal HART commands:

Tab. A.1: Supported universal commands

command	name
0	read unique identifier
1	read primary variable
2	read loop current and percent of range
3	read dynamic variables and loop current
6	write polling address
7	read loop configuration
8	read dynamic variable classifications
9	read device variables with status
11	read unique identifier associated with tag
12	read message
13	read tag, descriptor, date
14	read primary variable transducer information
15	read device information
16	read final assembly number
17	write message
18	write tag, descriptor, date
19	write final assembly number
20	read long tag
21	read unique identifier associated with long tag
22	write long tag
38	reset configuration changed flag
48	read additional device status

The data types used in the following tables are indicated as follows:

Tab. A.2: Data types

A	ASCII string (packed 4 characters per 3 bytes)
B	bit mapped flags
D	date (3 bytes: day, month, year 1900)
E	enum
F	floating point (4 bytes IEEE 754)
I	integer
P	packed ASCII

Tab. A.3: **Command 0**: Read unique identifier (returns identity information about the field device)

	byte no.	description	value	data type
request data bytes	none			
response data bytes	0	"254" (expansion)	- 254	I
	1...2	expanded device type (MSB...LSB)	- 0xE0BD	E
	3	number of request preambles	- 5	I
	4	HART protocol major revision	- 7	I
	5	device revision level	- X	I
	6	software revision	- X	I
	7	hardware revision(MS5B)/ physical signaling code (LS3B)	- XXXXX000	I E
	8	flags	- 1	B
	9...11	device ID number (MSB...LSB)	- X	I
	12	minimum number of response preambles	- 5	I
	13	maximum number of device variables	- 181	I
	14...15	configuration change counter (MSB...LSB)	- X	I
	16	extended field device status	- X	B
	17...18	manufacturer identification code	- 0x6021	E
	19...20	private label distributor code	- 0x6021	E
	21	device profile	- 1	E
response codes	0	no command specific errors		

X - device specific

Tab. A.4: Command 1: Read primary variable (reads the primary variable with its unit code)

	byte no.	description	data type
request data bytes	none		
response data bytes	0 1...4	primary variable unit code primary variable (F)	E F
response codes	0 8	no command specific errors update failure (if variable is simulated)	

Tab. A.5: Command 2: Read loop current and percent of range (reads the loop current and its associated percent of range)

	byte no.	description	data type
request data bytes	none		
response data bytes	0...3 4...7	primary variable loop current in mA (F) primary variable percent of range (F)	F F
response codes	0	no command specific errors	

Tab. A.6: Command 3: Read dynamic variables and loop current (reads the loop current and max. 4 predefined dynamic variables)

	byte no.	description	data type
request data bytes	none		
response data bytes	0...3	primary variable loop current in mA (F)	F
	4	primary variable unit code	E
	5...8	primary variable (F)	F
	9	secondary variable unit code	E
	10...13	secondary variable (F)	F
	14	tertiary variable unit code	E
	15...18	tertiary variable (F)	F
	19	quaternary variable unit code	E
	20...23	quaternary variable (F)	F
response codes	0	no command specific errors	
	8	update failure (if variable is simulated)	

Tab. A.7: Command 6: Writing polling address (writes the polling address and the loop current mode to the field device)

	byte no.	description	data type
request data bytes	0	polling address of device	I
	1	loop current mode	E
response data bytes	0	polling address of device	I
	1	loop current mode	E
response codes	0	no command specific errors	
	2	invalid poll address selection	
	5	too few data bytes received	
	12	invalid mode selection	

Tab. A.8: Command 7: Read loop configuration (reads polling address and the loop current mode)

	byte no.	description	data type
request data bytes	none		
response data bytes	0	polling address of device	I
	1	loop current mode	E
response codes	0	no command specific errors	

Tab. A.9: Command 8: Read dynamic variable classifications (reads the classification associated with the dynamic variables)

	byte no.	description	data type
request data bytes	none		
response data bytes	0	primary variable classification	E
	1	secondary variable classification	E
	2	tertiary variable classification	E
	3	quaternary variable classification	E
response codes	0	no command specific errors	

Tab. A.10: Command 9: Read device variables with status (allows a master to request the value and status of max. 8 device variables)

	byte no.	description	data type
request data bytes	0...7	slot 0...slot 7: device variable code	I
response data bytes	0	extended field device status	B
	1	slot 0: device variable code	E
	2	slot 0: device variable classification	E
	3	slot 0: unit code	E
	4...7	slot 0: device variable value (F)	F
	8	slot 0: device variable status	B
	9	slot 1: device variable code	E
	10	slot 1: device variable classification	E
	11	slot 1: unit code	E
	12...15	slot 1: device variable value (F)	F
	16	slot 1: device variable status	B
	17	slot 2: device variable code	E
	18	slot 2: device variable classification	E
	19	slot 2: unit code	E
	20...23	slot 2: device variable value (F)	F
	24	slot 2: device variable status	B
	25	slot 3: device variable code	E
	26	slot 3: device variable classification	E
	27	slot 3: unit code	E
	28...31	slot 3: device variable value	F
	32	slot 3: device variable status	B
	33	slot 4: device variable code	E
	34	slot 4: device variable classification	E
	35	slot 4: unit code	E
	36...39	slot 4: device variable value (F)	F
	40	slot 4: device variable status	B
	41	slot 5: device variable code	E
	42	slot 5: device variable classification	E
	43	slot 5: unit code	E
	44...47	slot 5: device variable value (F)	F
	48	slot 5: device variable status	B
	49	slot 6: device variable code	E
	50	slot 6: device variable classification	E
	51	slot 6: unit code	E
	52...55	slot 6: device variable value (F)	F
	56	slot 6: device variable status	B
	57	slot 7: device variable code	E
	58	slot 7: device variable classification	E
	59	slot 7: unit code	E

Tab. A.10: Command 9: Read device variables with status (allows a master to request the value and status of max. 8 device variables)

	byte no.	description	data type
response data bytes	60...63	slot 7: device variable value (F)	F
	64	slot 7: device variable status	B
response codes	0	no command specific errors	
	8	update failure (if variable is simulated)	

Tab. A.11: Command 11: Read unique identifier associated with tag (This command may be issued using either the device's long frame address or the broadcast address. No response is made unless the tag matches that of the device. The command returns the same identity information as command 0.)

	byte no.	description	data type
	byte no.	description	data type
request data bytes	0...5	tag - 8 chars	P
response data bytes	0...21	same as command 0: read unique identifier	
response codes	0	no command specific errors	

Tab. A.12: Command 12: Read message
(reads the message contained within the device)

	byte no.	description	data type
request data bytes	none		
response data bytes	0...23	message	P
response codes	0	no command specific errors	

Tab. A.13: Command 13: Read tag, descriptor, date (reads the tag, descriptor and date contained within the device)

	byte no.	description	data type
request data bytes	none		
response data bytes	0...5	tag - 8 chars	P
	6...17	descriptor - 16 chars	P
	18...20	date	D
response codes	0	no command specific errors	

Tab. A.14: Command 14: Read primary variable transducer information (reads the transducer serial number, limits/minimum span unit code, upper transducer limit, lower transducer limit and minimum span for the primary variable transducer)

	byte no.	description	data type
request data bytes	none		
response data bytes	0...2	transducer serial number (24 bit)	I
	3	transducer limits and min. span unit code	E
	4...7	upper transducer limit	F
	8...11	lower transducer limit	F
	12...15	min. span (F)	F
response codes	0	no command specific errors	

Tab. A.15: Command 15: Read device information (reads the alarm selection code, transfer function code, range values unit code, PV upper range value, PV lower range value, damping value and write protection code)

	byte no.	description	data type
request data bytes	none		
response data bytes	0	PV alarm selection code	E
	1	PV transfer function code	E
	2	PV upper and lower range values unit code	E
	3...6	PV upper range value (F)	F
	7...10	PV lower range value (F)	F
	11...14	PV damping value (units of seconds) (F)	F
	15	write protect code	E
	16	reserved by HCF, has to be set to 250, not used	E
	17	PV analog channel flags	B
response codes	0	no command specific errors	

Tab. A.16: Command 16: Read final assembly number (reads the final assembly number associated with the device)

	byte no.	description	data type
request data bytes	none		
response data bytes	0...2	final assembly number	I
response codes	0	no command specific errors	

Tab. A.17: Command 17: Write message (writes the message into the device)

	byte no.	description	data type
request data bytes	0...23	message	P
response data bytes	0...23	message	P
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.18: Command 18: Write tag, descriptor, date (writes the tag, descriptor, and date into the device)

	byte no.	description	data type
request data bytes	0...5	tag - 8 chars	P
	6...17	descriptor - 16 chars	P
	18...20	date	D
response data bytes	0...5	tag - 8 chars	P
	6...17	descriptor - 16 chars	P
	18...20	date	D
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.19: Command 19: Write final assembly number (writes final assembly number into the device)

	byte no.	description	data type
request data bytes	0...2	final assembly number	I
response data bytes	0...2	final assembly number	I
response codes	0 5 7	no command specific errors too few data bytes received in write protect mode	

Tab. A.20: Command 20: Read long tag (reads the (32 character full ISO Latin-1 ASCII) long tag)

	byte no.	description	data type
request data bytes	none		
response data bytes	0...31	long tag	A
response codes	0	no command specific errors	

Tab. A.21: Command 21: Read unique identifier associated with long tag (This command may be issued using the either the device's long frame address or the broadcast address.)

	byte no.	description	data type
request data bytes	0...31	long tag	A
response data bytes	0...21	same as command 0: read unique identifier	
response codes	0	no command specific errors	

Tab. A.22: Command 22: Write long tag (writes the 32-byte long tag)

	byte no.	description	data type
request data bytes	0...31	long tag	A
response data bytes	0...31	long tag	A
response codes	0 5 7	no command specific errors too few data bytes received in write protect mode	

Tab. A.23: Command 38: Reset configuration changed flag (resets the bit 6 of the device status byte)

	byte no.	description	data type
request data bytes	0...1	configuration changed counter	I
response data bytes	0...1	configuration changed counter	I
response codes	0 7 9	no command specific errors in write protect mode configuration change counter mismatch	

Tab. A.24: Command 48: Read additional device status

	byte no.	description	data type
request data bytes	none		
response data bytes	0...5	device specific status	B
	6	extended device status	B
	7	device operating mode	B
	8	standardized status 0	B
response codes	0	no command specific errors	

A.2 Common Practice Commands

The following table shows the supported common practice commands.

Tab. A.25: Supported common practice commands

command	designation
33	read device variables
35	write primary variable range values
40	enter/exit fixed current mode
44	write primary variable unit
50	read dynamic variable assignments
51	write dynamic variable assignments
53	write device variable units
59	write number of response preambles
79	write device variable
95	read device communication statistics

The data types used in the following tables are indicated as follows:

Tab. A.26: Data types

A	ASCII string (packed 4 characters per 3 bytes)
B	bit mapped flags
D	date (3 bytes: day, month, year 1900)
E	enum
F	floating point (4 bytes IEEE 754)
I	integer
P	packed ASCII

Tab. A.27: Command 33: Read device variables (allows a master to request the value of max. 4 device variables
It is not necessary to read 4 variables. 1, 2 or 3 variable codes can be transferred, too. The response contains 6, 12, 18 or 24 data bytes correspondingly.)

	byte no.	description	data type
request data bytes	0	transmitter variable code for slot 0	E
	1	transmitter variable code for slot 1	E
	2	transmitter variable code for slot 2	E
	3	transmitter variable code for slot 3	E
response data bytes	0	slot 0: device variable code	E
	1	slot 0: unit code	E
	2...5	slot 0: device variable value	F
	6	slot 1: device variable code	E
	7	slot 1: unit code	E
	8...11	slot 1: device variable value	F
	12	slot 2: device variable code	E
	13	slot 2: unit code	E
	14...17	slot 2: device variable value	F
	18	slot 3: device variable code	E
	19	slot 3: unit code	E
	20...23	slot 3: device variable value	F
response codes	0	no command specific errors	
	2	invalid selection	
	5	too few data bytes received	

Tab. A.28: Command 35: Write primary variable range values (defines the relationship between the loop current 4 and 20 mA points and the primary variable value)

	byte no.	description	data type
request data bytes	0	upper and lower range values unit code	E
	1...4	upper range value	F
	5...8	lower range value	F
response data bytes	0	upper and lower range values unit code	E
	1...4	upper range value	F
	5...8	lower range value	F
response codes	0	no command specific errors	
	2	invalid selection	
	5	too few data bytes received	
	7	in write protect mode	
	9	lower range value too high	
	10	lower range value too low	
	11	upper range value too high	
	12	upper range value too low	
	18	invalid unit code	
	29	invalid span	

Tab. A.29: Command 40: Enter/exit fixed current mode (The device is placed in fixed current mode with the loop current set to the value received. The value returned in the response data bytes reflects the rounded or truncated value actually used by the device. A level of 0 exits the fixed current mode. Fixed current mode will also be exited when power is removed from the device.)

	byte no.	description	data type
request data bytes	0...3	fixed current level in mA	F
response data bytes	0...3	fixed current level in mA	F
response codes	0	no command specific errors	
	3	passed parameter too large	
	4	passed parameter too small	
	5	too few data bytes received	
	7	in write protect mode	
	11	loop current not active (device in multidrop mode)	

Tab. A.30: Command 44: Write primary variable units (selects the units in which the primary variable and its range will be returned. This command also selects the unit for transducer limits and minimum span.)

	byte no.	description	data type
request data bytes	0	primary variable unit code	E
response data bytes	0	primary variable unit code	E
response codes	0	no command specific errors	
	2	invalid selection	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.31: Command 50: Read dynamic variable assignments (responds with the device variable numbers that are assigned to the pri mary, secondary, tertiary and quaternary variables)

	byte no.	description	data type
request data bytes	none		
response data bytes	0	device variable assigned to the primary variable	E
	1	device variable assigned to the secondary variable	E
	2	device variable assigned to the tertiary variable	E
	3	device variable assigned to the quaternary variable	E
response codes	0	no command specific errors	

Tab. A.32: Command 51: Write dynamic variable assignments (assigns device variables to the primary, secondary, tertiary and quaternary variables)

	byte no.	description	data type
request data bytes	0	device variable assigned to the primary variable	E
	1	device variable assigned to the secondary variable	E
	2	device variable assigned to the tertiary variable	E
	3	device variable assigned to the quaternary variable	E
response data bytes	0	device variable assigned to the primary variable	E
	1	device variable assigned to the secondary variable	E
	2	device variable assigned to the tertiary variable	E
	3	device variable assigned to the quaternary variable	E
response codes	0	no command specific errors	

Tab. A.33: Command 53: Write device variable units (selects the units in which the selected device variable will be returned)

	byte no.	description	data type
request data bytes	0	device variable code	E
	1	device variable unit code	E
response data bytes	0	device variable code	E
	1	device variable unit code	E
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	
	11	invalid device variable code	
	12	invalid unit code	

Tab. A.34: Command 59: Write number of response preambles (sets the number of asynchronous 0xFF preamble bytes to be sent before the start of a response message)

	byte no.	description	data type
request data bytes	0	number of response preambles	I
response data bytes	0	number of response preambles	I
response codes	0	no command specific errors	
	3	passed parameter too large	
	4	passed parameter too small	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.35: Command 79: Write device variable (a device variable is set to normal (temporarily) or a device variable is simulated)

	byte no.	description	data type
request data bytes	0	device variable code	E
	1	write device variable command code [1]	E
	2	device variable unit code	E
	3...6	device variable value	F
	7	device variable status [2]	B
response data bytes	0	number of response preambles	E
	1	write device variable command code	E
	2	device variable unit code	E
	3...6	device variable value	F
	7	device variable status	B
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	
	10	invalid write device variable code	
	12	invalid unit code	
response codes	17	invalid device variable index	

[1] a device variable is set to (normal=not simulated, fixed=simulated)

value	write device variable command code
0	normal
1	fixed value

[2] status of the simulated values

value	device variable status
0xC0	good
0x40	poor accuracy
0x80	manual/fixed
0x00	bad

Tab. A.36: Command 95: Read device communication statistics
(Reads the communication statistic of the field device. This includes the received messages from the master (STX - start of transaction) and the sent messages by the field device in burst mode (BACK - burst acknowledge) and normal mode (ACK - acknowledge))

	byte no.	description	data type
request data bytes	none		
response data bytes	0...1	count of STX messages received by the device	I
	2...3	count of ACK messages sent from the device	I
	4...5	count of BACK messages sent from the device	I
response codes	0	no command specific errors	

A.3 Device Specific Commands

The following table shows the supported device specific commands.

Tab. A.37: Supported device specific commands

command	designation
150	read parameter subset -> physical channel A pipe parameter
151	write parameter subset -> physical channel A pipe parameter
152	read parameter subset -> physical channel A fluid parameter
153	write parameter subset -> physical channel A fluid parameter
154	read parameter subset -> physical channel A transducer parameter
155	write parameter subset -> physical channel A transducer parameter
156	read parameter subset-> physical channel A measure parameter
157	write parameter subset -> physical channel A measure parameter
158	read parameter subset -> physical channel A process inputs (linkage) parameter
159	write parameter subset -> physical channel A process inputs (linkage) parameter
160	read parameter subset -> physical channel B pipe parameter
161	write parameter subset -> physical channel B pipe parameter
162	read parameter subset -> physical channel B fluid parameter
163	write parameter subset -> physical channel B fluid parameter
164	read parameter subset -> physical channel B transducer parameter
165	write parameter subset -> physical channel B transducer parameter
166	read parameter subset -> physical channel B measure parameter
167	write parameter subset -> physical channel B measure parameter
168	read parameter subset -> physical channel B process inputs (linkage) parameter
169	write parameter subset -> physical channel B process inputs (linkage) parameter
170	read parameter subset -> calculation channel Y parameter
171	write parameter subset -> calculation channel Y parameter
174	read parameter subset -> calculation channel Z parameter
175	write parameter subset -> calculation channel Z parameter
179	deactivate simulation mode of all device variables
180	read parameter subset -> process inputs parameter
181	write parameter subset -> process inputs parameter
182	read parameter subset -> process outputs parameter
183	write parameter subset -> process outputs parameter
184	read parameter subset -> global settings logger parameter
185	write parameter subset -> global settings logger parameter
186	read parameter subset -> prog protection parameter
187	write parameter subset -> prog protection parameter
188	read start & stop measurement
189	write start & stop measurement
190	read current loop output error value
191	write current loop output error value
194	read PV/current loop with sign or absolute
195	write PV/current loop with sign or absolute

Tab. A.37: Supported device specific commands

command	designation
200	read FLUXUS serial number
201	read FLUXUS firmware information
202	read HART serial number
203	read HART firmware version
222	BLOB Transfer DataIN
223	BLOB Transfer DataOUT
224	set blobIN & blobOUT to 0x00
230	clear totalizer
240	read error value delay
241	write error value delay
242	read input slot configuration
243	write input slot configuration
245	write input slot measured value
253	reset HART specific settings to factory default

The data types used in the following tables are indicated as follows:

Tab. A.38: Data types

A	ASCII string
B	bit mapped flags
D	date (3 bytes: day, month, year 1900)
E	enum
F	floating point (4 bytes IEEE 754)
I	integer
P	packed ASCII (packed 4 characters per 3 bytes)

Tab. A.39: Command 150: Read parameter subset -> physical channel A pipe parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0..3	outer diameter	F
	4	use user roughness [0=disabled, 1=enabled]	E
	5..8	roughness	F
	9	coating enabled [0=disabled, 1=enabled]	E
	10..11	coating material → values see Tab. A.73	E
	12..15	coating thickness [mm]	F
	16..19	coating sound speed	F
	20	wall enabled [0=disabled, 1=enabled]	E
	21..22	wall material → values see Tab. A.73	E
	23..26	wall thickness [mm]	F
	27..30	wall sound speed	F
	31	lining 1 enabled [0=disabled, 1=enabled]	E
	32..33	lining 1 material → values see Tab. A.73	E
	34..37	lining 1 thickness [mm]	F

Tab. A.39: Command 150: Read parameter subset -> physical channel A pipe parameter

	byte no.	description	data type
response data bytes	38..41	lining 1 sound speed	F
	42	lining 2 enabled [0=disabled, 1=enabled]	E
	43..44	lining 2 material → values see Tab. A.73	E
	45..48	lining 2 thickness [mm]	F
	49..52	lining 2 sound speed	F
response codes	0	no command specific errors	

Tab. A.40: Command 151: Write parameter subset -> physical channel A pipe parameter

	byte no.	description	data type
request data bytes	0..3	outer diameter	F
	4	use user roughness [0=disabled, 1=enabled]	E
	5..8	roughness	F
	9	coating enabled [0=disabled, 1=enabled]	E
	10..11	coating material → values see Tab. A.73	E
	12..15	coating thickness [mm]	F
	16..19	coating sound speed [if coating material = other material] [m/s]	F
	20	wall enabled [0=disabled, 1=enabled]	E
	21..22	wall material → values see Tab. A.73	E
	23..26	wall thickness [mm]	F
	27..30	wall sound speed [if wall material=other material] [m/s]	F
	31	lining 1 enabled [0=disabled, 1=enabled]	E
	32..33	lining 1 material → values see Tab. A.73	E
	34..37	lining 1 thickness [mm]	F
	38..41	lining 1 sound speed [if lining 1 material = other material] [m/s]	F
	42	lining 2 enabled [0=disabled, 1=enabled]	E
	43..44	lining 2 Material → values see Tab. A.73	E
	45..48	lining 2 thickness [mm]	F
	49..52	lining 2 sound speed [if lining 2 material = other material] [m/s]	F
response data bytes	0..3	outer diameter	F
	4	use user roughness [0=disabled, 1=enabled]	E
	5..8	roughness	F
	9	coating enabled [0=disabled, 1=enabled]	E
	10..11	coating material → values see Tab. A.73	E
	12..15	coating thickness [mm]	F
	16..19	coating sound speed	F
	20	wall enabled [0=disabled, 1=enabled]	E
	21..22	wall material → values see Tab. A.73	E
	23..26	wall thickness [mm]	F
	27..30	wall sound speed	F

Tab. A.40: Command 151: Write parameter subset -> physical channel A pipe parameter

	byte no.	description	data type
response data bytes	31	lining 1 enabled [0=disabled, 1=enabled]	E
	32..33	lining 1 material → values see Tab. A.73	E
	34..37	lining 1 thickness [mm]	F
	38..41	lining 1 sound speed	F
	42	lining 2 enabled [0=disabled, 1=enabled]	E
	43..44	lining 2 material → values see Tab. A.73	E
	45..48	lining 2 thickness [mm]	F
	49..52	lining 2 sound speed	F
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.41: Command 152: Read parameter subset -> physical channel A fluid parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0..1	fluid → values see Tab. A.74	E
	2..5	fluid sound speed fluid min. [m/s]	F
	6..9	fluid sound speed fluid max. [m/s]	F
	10..13	fluid density [g/cm^3]	F
	14..17	fluid kin. viscosity [mm^2/s]	F
	18..21	fluid gas compress factor	F
	22..25	temperature [°C]	F
	26..29	AUX temperature [°C]	F
	30..33	pressure [bar(a)]	F
	34..37	AUX pressure [bar(a)]	F
response codes	0	no command specific errors	

Tab. A.42: Command 153: Write parameter subset -> physical channel A fluid parameter

	byte no.	description	data type
request data bytes	0..1	fluid → values see Tab. A.74	E
	2..5	fluid sound speed fluid min. [if fluid = other fluid] [m/s]	F
	6..9	fluid sound speed fluid max. [if fluid = other fluid] [m/s]	F
	10..13	fluid density [if fluid = other fluid] [g/cm^3]	F
	14..17	fluid kin. viscosity [if fluid = other fluid] [mm^2/s]	F
	18..21	fluid gas compress factor [if fluid = other fluid]	F
	22..25	temperature [°C]	F
	26..29	AUX temperature [°C]	F
	30..33	pressure [bar(a)]	F
	34..37	AUX pressure [bar(a)]	F
response data bytes	0..1	fluid → values see Tab. A.74	E
	2..5	fluid sound speed fluid min. [m/s]	F
	6..9	fluid sound speed fluid max. [m/s]	F

Tab. A.42: Command 153: Write parameter subset -> physical channel A fluid parameter

	byte no.	description	data type
response data bytes	10..13	fluid density [g/cm^3]	F
	14..17	fluid kin. viscosity [mm^2/s]	F
	18..21	fluid gas compress factor	F
	22..25	temperature [°C]	F
	26..29	AUX temperature [°C]	F
	30..33	pressure [bar(a)]	F
	34..37	AUX pressure [bar(a)]	F
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.43: Command 154: Read parameter subset -> physical channel A transducer parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0	sensor to use [0=auto, 1=database, 2=other]	E
	1..7	transducer type; example → “CDM1E51” [if sensor to use=database] *	A
	8..11	transducer Piezo angle [°]	F
	12..15	transducer sound speed transducer min. [m/s]	F
	16..19	transducer sound speed transducer max. [m/s]	F
	20..23	transducer sound path length [mm]	F
	24..27	transducer edge offset [mm]	F
	28..31	transducer tolerance [ns]	I
	32..35	add cable length [m]	F
	36	sound path number	I
	37..40	transducer distance [mm]	F
response codes	0	no command specific errors	

* See FLUXUS or PIOX operating instruction → transducer

Tab. A.44: Command 155: Write parameter subset -> physical channel A transducer parameter

	byte no.	description	data type
request data bytes	0	sensor to use [0=auto, 1=database, 2=other]	E
	1..7	transducer type; example → “CDM1E51” [if sensor to use=database] *	A
	8..11	transducer piezo angle [if sensor to use=other] [°]	F
	12..15	transducer sound speed transducer min. [if sensor to use= other] [m/s]	F
	16..19	transducer sound speed transducer max. [if sensor to use= other] [m/s]	F
	20..23	transducer sound path length [if sensor to use= other] [mm]	F
	24..27	transducer edge offset [if sensor to use= other] [mm]	F
	28..31	transducer tolerance [if sensor to use= other] [ns]	I

Tab. A.44: Command 155: Write parameter subset -> physical channel A transducer parameter

	byte no.	description	data type
request data bytes	32..35	add cable length [m]	F
	36	sound path number	I
	37..40	transducer distance [mm]	F
response data bytes	0	sensor to use [0=auto, 1=database, 2=other]	E
	1..7	transducer type; example → “CDM1E51” [if sensor to use=database] *	A
	8..11	transducer piezo angle [°]	F
	12..15	transducer sound speed transducer min. [m/s]	F
	16..19	transducer sound speed transducer max. [m/s]	F
	20..23	transducer sound path length [mm]	F
	24..27	transducer edge offset [mm]	F
	28..31	transducer tolerance [ns]	I
	32..35	add cable length [m]	F
	36	sound path number	I
	37..40	transducer distance [mm]	F
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.45: Command 156: Read parameter subset -> physical channel A measure parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0	measure activate [0=disabled, 1=enabled]	E
	1	measured value → values see Tab. A.75	E
	2	unit of measurement → values see Tab. A.76...Tab. A.80	E
response data bytes	3..6	damping [s]	I
	7..10	error delay [s]	I
	11	transducer at supply [0=return, 1=supply]	E
	12	is cooling system [0=heat, 1=cool]	E
	13	keep sign [0=absolute, 1=sign]	E
	14	flow velocity low cut [0=disabled, 1=enabled]	E
	15..18	flow velocity low cut - positive values [m/s]	F
	19..22	flow velocity low cut - negative values [m/s]	F
	23	gas measure enabled [0=disabled, 1=enabled]	E
response codes	0	no command specific errors	

Tab. A.46: Command 157: Write parameter subset -> physical channel A measure parameter

	byte no.	description	data type
request data bytes	0	measure activate [0=disabled, 1=enabled]	E
	1	measured value → values see Tab. A.75	E
	2	unit of measurement → values see Tab. A.76...Tab. A.80	E
	3..6	damping [s]	I
	7..10	error delay [s]	I

Tab. A.46: Command 157: Write parameter subset -> physical channel A measure parameter

	byte no.	**description**	**data type**
request data bytes	11	transducer at supply [0=return, 1=supply]	E
	12	is cooling system [0=heat, 1=cool]	E
	13	keep sign [0=absolute, 1=sign]	E
	14	flow velocity low cut [0=disabled, 1=enabled]	E
	15..18	flow velocity low cut - positive values [m/s]	F
	19..22	flow velocity low cut - negative values [m/s]	F
	23	gas measure enabled [0=disabled, 1=enabled]	E
response data bytes	0	measure activate [0=disabled, 1=enabled]	E
	1	measured value → values see Tab. A.75	E
	2	unit of measurement → values see Tab. A.76...Tab. A.80	E
	3..6	damping [s]	I
	7..10	error delay [s]	I
	11	transducer at supply [0=return, 1=supply]	E
	12	is cooling system [0=heat, 1=cool]	E
	13	keep sign [0=absolute, 1=sign]	E
	14	flow velocity low cut [0=disabled, 1=enabled]	E
	15..18	flow velocity low cut - positive values [m/s]	F
	19..22	flow velocity low cut - negative values [m/s]	F
	23	gas measure enabled [0=disabled, 1=enabled]	E
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.47: Command 158: Read parameter subset -> physical channel A process inputs (linkage) parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0..1	link temperature →values see Tab. A.81	E
	2..3	link Aux temperature →values see Tab. A.81	E
response codes	0	no command specific errors	

Tab. A.48: Command 159: Write parameter subset -> physical channel A process inputs (linkage)

	byte no.	**description**	**data type**
request data bytes	0..1	link temperature →values see Tab. A.81	E
	2..3	link Aux temperature →values see Tab. A.81	E
response data bytes	0..1	link temperature →values see Tab. A.81	E
	2..3	link Aux temperature →values see Tab. A.81	E
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.49: Command 160: Read parameter subset -> physical channel B pipe parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0..3	outer diameter	F
	4	use user roughness [0=disabled, 1=enabled]	E
	5..8	roughness	F
	9	coating enabled [0=disabled, 1=enabled]	E
	10..11	coating material → values see Tab. A.73	E
	12..15	coating thickness [mm]	F
	16..19	coating sound speed	F
	20	wall enabled [0=disabled, 1=enabled]	E
	21..22	wall material → values see Tab. A.73	E
	23..26	wall thickness [mm]	F
	27..30	wall sound speed	F
	31	lining 1 enabled [0=disabled, 1=enabled]	E
	32..33	lining 1 material → values see Tab. A.73	E
	34..37	lining 1 thickness [mm]	F
	38..41	lining 1 sound speed	F
	42	lining 2 enabled [0=disabled, 1=enabled]	E
	43..44	lining 2 material → values see Tab. A.73	E
	45..48	lining 2 thickness [mm]	F
	49..52	lining 2 sound speed	F
response codes	0	no command specific errors	

Tab. A.50: Command 161: Write parameter subset -> physical channel B pipe parameter

	byte no.	description	data type
request data bytes	0..3	outer diameter	F
	4	use user roughness [0=disabled, 1=enabled]	E
	5..8	roughness	F
	9	coating enabled [0=disabled, 1=enabled]	E
	10..11	coating material → values see Tab. A.73	E
	12..15	coating thickness [mm]	F
	16..19	coating sound speed [if coating material = other material] [m/s]	F
	20	wall Enabled [0=disabled, 1=enabled]	E
	21..22	wall Material → Values see Tab. A.73	E
	23..26	wall thickness [mm]	F
	27..30	wall sound speed [if wall material=other material] [m/s]	F
	31	lining 1 Enabled [0=disabled, 1=enabled]	E
	32..33	lining 1 Material → values see Tab. A.73	E
	34..37	lining 1 thickness [mm]	F
	38..41	lining 1 sound speed [if lining 1 material = other material] [m/s]	F
	42	lining 2 Enabled [0=disabled, 1=enabled]	E
	43..44	lining 2 Material → values see Tab. A.73	E
	45..48	lining 2 thickness [mm]	F

Tab. A.50: Command 161: Write parameter subset -> physical channel B pipe parameter

	byte no.	description	data type
request data bytes	49..52	lining 2 sound speed [if lining 2 material = other material] [m/s]	F
response data bytes	0..3	outer diameter	F
	4	use user roughness [0=disabled, 1=enabled]	E
	5..8	roughness	F
	9	coating enabled [0=disabled, 1=enabled]	E
	10..11	coating material → values see Tab. A.73	E
	12..15	coating thickness [mm]	F
	16..19	coating sound speed	F
	20	wall Enabled [0=disabled, 1=enabled]	E
	21..22	wall Material → values see Tab. A.73	E
	23..26	wall thickness [mm]	F
	27..30	wall sound speed	F
	31	lining 1 enabled [0=disabled, 1=enabled]	E
	32..33	lining 1 material → values see Tab. A.73	E
	34..37	lining 1 thickness [mm]	F
	38..41	lining 1 sound speed	F
	42	lining 2 enabled [0=disabled, 1=enabled]	E
	43..44	lining 2 material → values see Tab. A.73	E
	45..48	lining 2 thickness [mm]	F
	49..52	lining 2 sound speed	F
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.51: Command 162: Read parameter subset -> physical channel B fluid parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0..1	fluid → values see Tab. A.74	E
	2..5	fluid sound speed fluid min. [m/s]	F
	6..9	fluid sound speed fluid max. [m/s]	F
	10..13	fluid density [g/cm^3]	F
	14..17	fluid kin. viscosity [mm^2/s]	F
	18..21	fluid gas compress factor	F
	22..25	temperature [°C]	F
	26..29	AUX temperature [°C]	F
	30..33	pressure [bar(a)]	F
	34..37	AUX pressure [bar(a)]	F
response codes	0	no command specific errors	

Tab. A.52: Command 163: Write parameter subset -> physical channel B fluid parameter

	byte no.	description	data type
request data bytes	0..1	fluid → values see Tab. A.74	E
	2..5	fluid sound speed fluid min. [if fluid = other fluid] [m/s]	F
	6..9	fluid sound speed fluid max. [if fluid = other fluid] [m/s]	F
	10..13	fluid density [if fluid = other fluid] [g/cm^3]	F
	14..17	fluid kin. viscosity [if fluid = other fluid] [mm^2/s]	F
	18..21	fluid gas compress factor [if fluid = other fluid]	F
	22..25	temperature [°C]	F
	26..29	AUX temperature [°C]	F
	30..33	pressure [bar(a)]	F
	34..37	AUX pressure [bar(a)]	F
response data bytes	0..1	fluid → values see Tab. A.74	E
	2..5	fluid sound speed fluid min. [m/s]	F
	6..9	fluid sound speed fluid max. [m/s]	F
	10..13	fluid density [g/cm^3]	F
	14..17	fluid kin. viscosity [mm^2/s]	F
	18..21	fluid gas compress factor	F
	22..25	temperature [°C]	F
	26..29	AUX temperature [°C]	F
	30..33	pressure [bar(a)]	F
	34..37	AUX pressure [bar(a)]	F
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.53: Command 164: Read parameter subset -> physical channel B transducer parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0	sensor to use [0=auto, 1=database, 2=other]	E
	1..7	transducer Type; example → “CDM1E51” [if sensor to use=database] *	A
	8..11	transducer piezo angle [°]	F
	12..15	transducer sound speed transducer min. [m/s]	F
	16..19	transducer sound speed transducer max. [m/s]	F
	20..23	transducer sound path length [mm]	F
	24..27	transducer edge offset [mm]	F
	28..31	transducer tolerance [ns]	I
	32..35	add cable length [m]	F
	36	sound path number	I
	37..40	transducer distance [mm]	F
response codes	0	no command specific errors	

* See FLUXUS or PIOX operating instruction → transducer

Tab. A.54: Command 165: Write parameter subset -> physical channel B transducer parameter

	byte no.	description	data type
request data bytes	0	sensor to use [0=auto, 1=database, 2=other]	E
	1..7	transducer type; example → “CDM1E51” [if sensor to use=database] *	A
	8..11	transducer piezo angle [if sensor to use=other] [°]	F
	12..15	transducer sound speed transducer min. [if sensor to use= other] [m/s]	F
	16..19	transducer sound speed transducer max. [if sensor to use= other] [m/s]	F
	20..23	transducer sound path length [if sensor to use= other] [mm]	F
	24..27	transducer edge offset [if sensor to use= other] [mm]	F
	28..31	transducer tolerance [if sensor to use= other] [ns]	I
	32..35	add cable length [m]	F
	36	sound path number	I
	37..40	transducer distance [mm]	F
response data bytes	0	sensor to use [0=auto, 1=database, 2=other]	E
	1..7	transducer type; example → “CDM1E51” [if sensor to use=database] *	A
	8..11	transducer piezo angle [°]	F
	12..15	transducer sound speed transducer min. [m/s]	F
	16..19	transducer sound speed transducer max. [m/s]	F
	20..23	transducer sound path length [mm]	F
	24..27	transducer edge Offset [mm]	F
	28..31	transducer tolerance [ns]	I
	32..35	add cable length [m]	F
	36	sound path number	I
	37..40	transducer distance [mm]	F
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.55: Command 166: Read parameter subset -> physical channel B measure parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0	measure activate [0=disabled, 1=enabled]	E
	1	measured value → values see Tab. A.75	E
	2	unit of measurement → values see Tab. A.76...Tab. A.80	E
	3..6	damping [s]	I
	7..10	error delay [s]	I
	11	transducer at supply [0=return, 1=supply]	E
	12	is cooling system [0=heat, 1=cool]	E
	13	keep sign [0=absolute, 1=sign]	E
	14	flow velocity low cut [0=disabled, 1=enabled]	E
	15..18	flow velocity low cut - positive values [m/s]	F

Tab. A.55: Command 166: Read parameter subset -> physical channel B measure parameter

	byte no.	description	data type
response data bytes	19..22	flow velocity low cut - negative values [m/s]	F
	23	gas measure enabled [0=disabled, 1=enabled]	E
response codes	0	no command specific errors	

Tab. A.56: Command 167: Write parameter subset -> physical channel B measure parameter

	byte no.	description	data type
request data bytes	0	measure activate [0=disabled, 1=enabled]	E
	1	measured value → values see Tab. A.75	E
	2	unit of measurement → values see Tab. A.76...Tab. A.80	E
	3..6	damping [s]	I
	7..10	error delay [s]	I
	11	transducer at supply [0=return, 1=supply]	E
	12	is cooling system [0=heat, 1=cool]	E
	13	keep sign [0=absolute, 1=sign]	E
	14	flow velocity low cut [0=disabled, 1=enabled]	E
	15..18	flow velocity low cut - positive values [m/s]	F
	19..22	flow velocity low cut - negative values [m/s]	F
	23	gas measure enabled [0=disabled, 1=enabled]	E
response data bytes	0	measure activate [0=disabled, 1=enabled]	E
	1	measured value → values see Tab. A.75	E
	2	unit of measurement → values see Tab. A.76...Tab. A.80	E
	3..6	damping [s]	I
	7..10	error delay [s]	I
	11	transducer at supply [0=return, 1=supply]	E
	12	is cooling system [0=heat, 1=cool]	E
	13	keep sign [0=absolute, 1=sign]	E
	14	flow velocity low cut [0=disabled, 1=enabled]	E
	15..18	flow velocity low cut - positive values [m/s]	F
	19..22	flow velocity low cut - negative values [m/s]	F
	23	gas measure enabled [0=disabled, 1=enabled]	E
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.57: Command 168: Read parameter subset -> physical channel B process inputs (linkage) parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0..1	link temperature →values see Tab. A.81	E
	2..3	link Aux temperature →values see Tab. A.81	E
response codes	0	no command specific errors	

Tab. A.58: Command 169: Write parameter subset -> physical channel B process inputs (linkage)

	byte no.	description	data type
request data bytes	0..1	link temperature →values see Tab. A.81	E
	2..3	link AUX temperature →values see Tab. A.81	E
response data bytes	0..1	link temperature →values see Tab. A.81	E
	2..3	link AUX temperature →values see Tab. A.81	E
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.59: Command 170: Read parameter subset -> calculation channel Y parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0	activate calculation [0=disabled, 1=enabled]	E
	1	input channel 1 → values see Tab. A.82	E
	2	input channel 2 → values see Tab. A.82	E
	3	calculation method [0=AND, 1=OR]	E
	4..7	low cut negative value →unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	8..11	low cut positive value →unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	12	measured value → values see Tab. A.75	E
	13	measuring unit →values see Tab. A.76...Tab. A.80	E
	14..17	damping [s]	I
	18..21	error delay [s]	I
response codes	0	no command specific errors	

Tab. A.60: Command 171: Write parameter subset -> calculation channel Y parameter

	byte no.	description	data type
request data bytes	0	activate calculation [0=disabled, 1=enabled]	E
	1	input channel 1 → values see Tab. A.82	E
	2	input channel 2 → values see Tab. A.82	E
	3	calculation method [0=AND, 1=OR]	E
	4..7	low cut negative value →unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	8..11	low cut positive value →unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	12	measured value → values see Tab. A.75	E
	13	measuring unit →values see Tab. A.76...Tab. A.80	E
	14..17	damping [s]	I
	18..21	error delay [s]	I
response data bytes	0	activate calculation [0=disabled, 1=enabled]	E
	1	input channel 1 → values see Tab. A.82	E
	2	input channel 2 → values see Tab. A.82	E
	3	calculation method [0=AND, 1=OR]	E

Tab. A.60: Command 171: Write parameter subset -> calculation channel Y parameter

	byte no.	description	data type
response data bytes	4..7	low cut negative value →unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	8..11	low cut positive value →unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	12	measured value → values see Tab. A.75	E
	13	measuring unit →values see Tab. A.76...Tab. A.80	E
	14..17	damping [s]	I
	18..21	error delay [s]	I
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.61: Command 174: Read parameter subset -> calculation channel Z parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0	activate calculation [0=disabled, 1=enabled]	E
	1	input channel 1 → values see Tab. A.82	E
	2	input channel 2 → values see Tab. A.82	E
	3	calculation method [0=AND, 1=OR]	E
	4..7	low cut negative value →unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	8..11	low cut positive value →unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	12	measured value → values see Tab. A.75	E
	13	measuring unit →values see Tab. A.76...Tab. A.80	E
	14..17	damping [s]	I
	18..21	error delay [s]	I
response codes	0	no command specific errors	

Tab. A.62: Command 175: Write parameter subset -> calculation channel Z parameter

	byte no.	description	data type
request data bytes	0	activate calculation [0=disabled, 1=enabled]	E
	1	input channel 1 → values see Tab. A.82	E
	2	input channel 2 → values see Tab. A.82	E
	3	calculation method [0=AND, 1=OR]	E
	4..7	low cut negative value →unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	8..11	low cut positive value →unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	12	measured value → values see Tab. A.75	E
	13	measuring unit →values see Tab. A.76...Tab. A.80	E
	14..17	damping [s]	I
	18..21	error delay [s]	I
response data bytes	0	activate calculation [0=disabled, 1=enabled]	E

Tab. A.62: Command 175: Write parameter subset -> calculation channel Z parameter

	byte no.	description	data type
response data bytes	1	input channel 1 → values see Tab. A.82	E
	2	input channel 2 → values see Tab. A.82	E
	3	calculation method [0=AND, 1=OR]	E
	4..7	low cut negative value →unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	8..11	low cut positive value →unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	12	measured value → values see Tab. A.75	E
	13	measuring unit →values see Tab. A.76...Tab. A.80	E
	14..17	damping [s]	I
	18..21	error delay [s]	I
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.63: Command 180: Read parameter subset -> process inputs parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0	activate input T1 [0=disabled, 1=enabled]	E
	1	connected sensor T1 [0=PT100, 1=PT1000]	E
	2	activate inputT2 [0=disabled, 1=enabled]	E
	3	connected sensor T2 [0=PT100, 1=PT1000]	E
response codes	0	no command specific errors	

Tab. A.64: Command 181: Write parameter subset -> process inputs parameter

	byte no.	description	data type
request data bytes	0	activate input T1 [0=disabled, 1=enabled]	E
	1	connected sensor T1 [0=PT100, 1=PT1000]	E
	2	activate inputT2 [0=disabled, 1=enabled]	E
	3	connected sensor T2 [0=PT100, 1=PT1000]	E
response data bytes	0	activate input T1 [0=disabled, 1=enabled]	E
	1	connected sensor T1 [0=PT100, 1=PT1000]	E
	2	activate inputT2 [0=disabled, 1=enabled]	E
	3	connected sensor T2 [0=PT100, 1=PT1000]	E
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.65: Command 182: Read parameter subset -> process outputs parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0	activate output I1 [0=disabled, 1=enabled]	E

Tab. A.65: Command 182: Read parameter subset -> process outputs parameter

	byte no.	description	data type
response data bytes	1	channel I1 → values see Tab. A.82	E
	2..5	measured value I1 →values see Tab. A.84	E
	6	value or status I1 [0=value, 1=status]	E
	7	source scaling - absolute of source value I1 [0=No, 1=Yes]	E
	8..11	source scaling - low scale value I1 → unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	12..15	source scaling - full scale value I1 → unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	16	source scaling - on error I1 [0=Min, 1=Hold, 2=Max, 3=Error]	E
	17..20	physical output range - min output I1 [mA]	F
	21..24	physical output range - max output I1 [mA]	F
	25..28	physical output range - error output I1 [mA]	F
	29	activate output I2 [0=disabled, 1=enabled]	E
	30	channel I2 → values see Tab. A.82	E
	31..34	measured value I2 →values see Tab. A.84	E
	35	value or status I2 [0=value, 1=status]	E
	36	source scaling - absolute of source value I2 [0=No, 1=Yes]	E
	37..40	source scaling - low scale value I2 → unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	41..44	source scaling - full scale value I2 → unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	45	source scaling - on error I2 [0=Min, 1=Hold, 2=Max, 3=Error]	E
	46..49	physical output range - min output I2 [mA]	F
	50..53	physical output range - max output I2 [mA]	F
	54..57	physical output range - error output I2 [mA]	F
response codes	0	no command specific errors	

Tab. A.66: Command 183: Write parameter subset -> process outputs parameter

	byte no.	description	data type
request data bytes	0	activate output I1 [0=disabled, 1=enabled]	E
	1	channel I1 → values see Tab. A.82	E
	2..5	measured value I1 →values see Tab. A.84	E
	6	value or status I1 [0=value, 1=status]	E
	7	source scaling - absolute of source value I1 [0=No, 1=Yes]	E
	8..11	source scaling - low scale value I1 → unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	12..15	source scaling - full scale value I1 → unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	16	source scaling - on error I1 [0=Min, 1=Hold, 2=Max, 3=Error]	E
	17..20	physical output range - min output I1 [mA]	F
	21..24	physical output range - max output I1 [mA]	F
	25..28	physical output range - error output I1 [mA]	F
	29	activate output I1 [0=disabled, 1=enabled]	E
	30	channel I2 → values see Tab. A.82	E

Tab. A.66: Command 183: Write parameter subset -> process outputs parameter

	byte no.	description	data type
request data bytes	31..34	measured value I2 →values see Tab. A.84	E
	35	value or status I2 [0=value, 1=status]	E
	36	source scaling - absolute of source value I2 [0=no, 1=yes]	E
	37..40	source scaling - low scale value I2 → unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	41..44	source scaling - full scale value I2 → unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	45	source scaling - on error I2 [0=min, 1=Hold, 2=max, 3=error]	E
	46..49	physical output range - min output I2 [mA]	F
	50..53	physical output range - max output I2 [mA]	F
	54..57	physical output range - error output I2 [mA]	F
response data bytes	0	activate output I1 [0=disabled, 1=enabled]	E
	1	channel I1 → values see Tab. A.82	E
	2..5	measured value I1 →values see Tab. A.84	E
	6	value or status I1 [0=value, 1=status]	E
	7	source scaling - absolute of source value I1 [0=no, 1=yes]	E
	8..11	source scaling - low scale value I1 → unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	12..15	source scaling - full scale value I1 → unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	16	source scaling - on error I1 [0=min, 1=hold, 2=max, 3=error]	E
	17..20	physical output range - min output I1 [mA]	F
	21..24	physical output range - max output I1 [mA]	F
	25..28	physical output range - error output I1 [mA]	F
	29	activate output I2 [0=disabled, 1=enabled]	E
	30	channel I2 → values see Tab. A.82	E
	31..34	measured value I2→values see Tab. A.84	E
	35	value or Status I2 [0=Value, 1=Status]	E
	36	source scaling - absolute of source value I2 [0=no, 1=yes]	E
	37..40	source scaling - low scale value I2 → unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	41..44	source scaling - full scale value I2 → unit of measurement see Tab. A.83 (in dependence on the selected measured value)	F
	45	source scaling - on error I2 [0=min, 1=hold, 2=max, 3=error]	E
	46..49	physical output range - min output I2 [mA]	F
	50..53	physical output range - max output I2 [mA]	F
	54..57	physical output range - error output I2 [mA]	F
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.67: Command 184: Read parameter subset -> global settings / logger parameter

	byte no.	description	data type
request data bytes	none		
response data bytes	0	channel → values see Tab. A.85	B
	1..4	rate [s]	F
	5	options → values see Tab. A.86	B
response codes	0	no command specific errors	

Tab. A.68: Command 185: Write parameter subset -> global settings / logger parameter

	byte no.	description	data type
request data bytes	0	channel → values see Tab. A.85	B
	1..4	rate [s]	F
	5	options → values see Tab. A.86	B
response data bytes	0	channel → values see Tab. A.85	B
	1..4	rate [s]	F
	5	options → values see Tab. A.86	B
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.69: Command 186: Read parameter subset -> protection code

	byte no.	description	data type
request data bytes	none		
response data bytes	0	protection activate [0=disabled, 1=enabled]	E
	1..4	protection code [0..999999]	I
response codes	0	no command specific errors	

Tab. A.70: Command 187: Write parameter subset -> protection code

	byte no.	description	data type
request data bytes	0	protection activate [0=disabled, 1=enabled]	E
	1..4	protection code [0..999999]	I
response data bytes	0	protection activate [0=disabled, 1=enabled]	E
	1..4	protection code [0..999999]	I
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.71: Command 188: Read start & stop measurement

	byte no.	description	data type
request data bytes	none		
response data bytes	0	start measuring [0=Do nothing, 1=start, 2=stop]	E
response codes	0	no command specific errors	

Tab. A.72: Command 189: Write start & stop measurement

	byte no.	description	data type
request data bytes	0	start measuring [0=do nothing,1=start, 2=stop]	E
response data bytes	0	start measuring [0=do nothing,1=start, 2=stop]	E
response codes	0	no command specific errors	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.73: Material data

material name	Enum16
other Material	00000
carbon steel	00001
stainless steel	00002
plastic	00003
glass	00004
copper	00005
aluminum	00006
brass	00007
lead	00008
ductile iron	00010
asbestos cement	00011
PVC	00012
PE	00013
PP	00014
grey cast iron	00015
bitumen	00016
rubber	00017
acrylic	00018
Teka PEEK	00019
Tekason	00020
Sintimid	00021
Cu-Ni-Fe	00022
titanium	00023
PFA	00024
PVDF	00025
GRP	00029
DUPLEX	00030
concrete	00035
PU	00036
additional device revision 8	
user material 01	09000
user material 02	09001
user material 03	09002
user material 04	09003

Tab. A.73: Material data

material name	Enum16
user material 05	09004
user material 06	09005
user material 07	09006
user material 08	09007
user material 09	09008
user material 10	09009
user material 11	09010
user material 12	09011
user material 13	09012
user material 14	09013
user material 15	09014
user material 16	09015

Tab. A.74: Fluid data

fluid name	Enum16
other fluid	10000
water	10001
gasoline	10002
methanol	10004
acetone	10005
HCl 37%	10007
Glycol	10008
BP Transcal LT	10012
BP Transcal N	10013
R22 Freon	10014
R134 Freon	10017
diesel	10019
ammonia (NH3)	10023
Shell Thermina B	10039
30% Glycol / H2O	10040
50% Glycol / H2O	10041
80% H2SO4	10042
96% H2SO4	10043
ISO VG 22	10050
ISO VG 32	10051
ISO VG 46	10052
ISO VG 68	10053
ISO VG 100	10054
ISO VG 150	10055
ISO VG 220	10056
seawater	10058
ethanol	10059

Tab. A.74: Fluid data

fluid name	Enum16
20% Glycol / H2O	10060
40% Glycol / H2O	10061
HCl 25%	10062
30% H2SO4	10063
HF acid 50%	10064
HF acid 80%	10065
caustic soda 10%	10066
caustic soda 20%	10067
crude oil high API	10070
crude oil low API	10071
mobiltherm 594	10072
mobiltherm 603	10073
methane gas	10074
paraffin 248	10075
silicon oil	10076
LD4-200bar-GST	10077
natural gas user	10078
propane-liquid	10079
propane-gas	10080
air	10081
oxygen	10082
hydrogen	10083
argon	10084
helium	10085
ethylen_sc<50bar	10087
ethylen_sc>50bar	10088
nitrogen	10089
Std natural gas	10091
R407C	10092
R410A	10093
butane	10094
lubricant	10123
petroleum	10124
glycol/H2O	10125
seawater	10126
soda lye	10127
hydrochl. acid	10128
nitric acid	10129
sulfuric acid	10130
hydrofluoric acid	10131
ammonia/H2O	10132

Tab. A.74: Fluid data

fluid name	Enum16
calcium chloride	10133
high-pressure steam	10134
propylene	10135
chlorine	10136
hydrogen chlor.	10137
natural gas (wet gas)	10138
low-pressure steam	10139
NGE natural gas H	10140
NGE natural gas L	10141
NGE natural gas F	10142
supercritical steam	10143
additional device revision 8	
user fluid 01	19000
user fluid 02	19001
user fluid 03	19002
user fluid 04	19003
user fluid 05	19004
user fluid 06	19005
user fluid 07	19006
user fluid 08	19007
user fluid 09	19008
user fluid 10	19009
user fluid 11	19010
user fluid 12	19011
user fluid 13	19012
user fluid 14	19013
user fluid 15	19014
user fluid 16	19015
user fluid 17	19016
user fluid 18	19017
user fluid 19	19018
user fluid 20	19019
user fluid 21	19020
user fluid 22	19021
user fluid 23	19022
user fluid 24	19023
user fluid 25	19024
user fluid 26	19025
user fluid 27	19026
user fluid 28	19027
user fluid 29	19028

Tab. A.74: Fluid data

fluid name	**Enum16**
user fluid 30	19029
user fluid 31	19030
user fluid 32	19031

Tab. A.75: Measured values

flow velocity	0
volumetric flow rate	1
standard volumetric flow rate	2
mass flow rate	3
heat flow	4
sound speed fluid	5
concentration	6

Tab. A.76: Unit of measurement - flow velocity

unit of measurement	**description**	**Enum**
m/s	meter per second	0
cm/s	centimeter per second	1
in/s	inch per second	2
ft/s	foot per second	3

Tab. A.77: Unit of measurement - standard volumetric flow rate

unit of measurement	**description**	**Enum**
m^3/h	cubic meter per hour	0
m^3/min	cubic meter per minute	1
m^3/s	cubic meter per second	2
l/h	liter per hour	3
l/min	liter per minute	4
l/s	liter per second	5
USgph (US-gal/h)	gallon per hour	6
USgpm (US-gal/m)	gallon per minute	7
USgps (US-gal/s)	gallon per second	8
bbl/d	barrel per day	9
bbl/h	barrel per hour	10
bbl/m	barrel per minute	11
USgpd (US-gal/d)	gallon per day	12
Ml/d (Megalit/d)	megaliter per day	13
m^3/d	cubic meter per day	14
hl/h	hectoliter per hour	15
hl/min	hectoliter per minute	16
hl/s	hectoliter per second	17
MGD (US-Mgal/d)	million gallons per day	18
CFD	cubic foot per day	19

Tab. A.77: Unit of measurement - standard volumetric flow rate

unit of measurement	description	Enum
CFH	cubic foot per hour	20
CFM	cubic foot per minute	21
CFS	cubic foot per second	22
ml/min	milliliter per minute	23
KGPM (US-Kgal/m)	kilogallon per minute	24
MMCFD	million cubic feet per day	25
MMCFH	million cubic feet per hour	26
KCFD	kilo cubic foot per day	27
KCFH	kilo cubic foot per hour	28
km^3/h	1000 cubic meters per hour	29

Tab. A.78: Unit of measurement - mass flow rate

unit of measurement	description	Enum
t/h	metric ton per hour	0
kg/h	kilogram per hour	1
kg/min	kilogram per minute	2
g/s	gram per second	3
t/d	metric ton per day	4
kg/s	kilogram per second	5
lb/d	pound per day	6
lb/h	pound per hour	7
lb/m	pound per minute	8
lb/s	pound per second	9
klb/h	kilopound per hour	10
klb/m	kilopound per minute	11

Tab. A.79: Unit of measurement - heat flow

unit of measurement	description	Enum
W	Watt	0
kW	kilowatt	1
MW	megawatt	2
GW	gigawatt	3
kBTU/minute	kBTU per minute	4
kBTU/hour	kBTU per hour	5
MBTU/hour	MBTU per hour	6
MBTU/day	MBTU per day	7
TON (TH)	TON, totals in TONhours	8
TON (TD)	TON, totals in TONdays	9
kTON (kTH)	kTON, totals in TONhours	10
kTON (kTD)	kTON, totals in TONdays	11

Tab. A.80: Unit of measurement - sound speed fluid

unit of measurement	description	Enum
m/s	meter per second	0
ft/s	foot per second	1

Tab. A.81: Linking options

no linking	0x0000
fixed value	0x4356
T1	0x5431
T2	0x5432

Tab. A.82: Channel

none	0x00
channel A	0x41
channel B	0x42
channel Y	0x59
channel Z	0x5A

Tab. A.83: Internal unit

flow velocity	m/s
volumetric flow rate	m3/s
standard volumetric flow rate	m3/s
mass flow rate	kg/s
heat flow	W
sound speed fluid	m/s
concentration	None
volume	m3
mass	kg
heat	Ws
density	Kg/m3
kinematic viscosity	mm2/s
dynamic viscosity	mPa*s
temperature	°C
pressure	bar

Tab. A.84: Physical quantity - process output

physical quantity	Enum32	Enum32 (String)
sound speed	0x43464C55	“CFLU“
flow velocity	0x46535452	“FSTR“
volumetric flow rate	0x46564F4C	“FVOL“
standard volumetric flow rate	0x464E564F	“FNVO“
mass flow rate	0x464D4153	“FMAS“
heat flow	0x46484541	“FHEA“
concentration	0x464B4E5A	“FKNZ“
volumetric flow rate, positive totalizer	0x5156505F	“QVP_“

Tab. A.84: Physical quantity - process output

physical quantity	Enum32	Enum32 (String)
volumetric flow rate, negative totalizer	0x51564E5F	“QVN_“
standard volumetric flow rate, positive totalizer	0x514E505F	“QNP_“
standard volumetric flow rate, negative totalizer	0x514E4E5F	“QNN_“
mass flow rate, positive totalizer	0x514D505F	“QMP_“
mass flow rate, negative totalizer	0x514D4E5F	“QMN_“
heat flow, positive totalizer	0x5148505F	“QHP_“
heat flow, negative totalizer	0x51484E5F	“QHN_“
temperature	0x5054465F	“PTF_“
temperature AUX	0x5054585F	“PTX_“
pressure	0x5050465F	“PPF_“
pressure AUX	0x5050585F	“PPX_“
density	0x50524F48	“PROH“
kin. viscosity	0x50564B5F	“PVK_“
dyn. viscosity	0x5056445F	“PVD_“
gas comp.factor	0x50474346	“PGCF“

Tab. A.85: Data logger channel -> Bit Enum

none	0
channel A	1
channel B	2
channel Y	16
channel Z	32

Tab. A.86: Data logger options -> Bit Enum

store diagnostic	4
store amplitude	8
store fluid sound speed	16
store totalizer	32
average storage	64
as ring Buffer	128

Tab. A.87: Command 179: Deactivate simulation mode of all device variables
(resets all device variables to normal if one or more device variables are in simulation mode (see command 79)
One data byte (123) has to be written to the device.)

	byte no.	description	data type
request data bytes	0	the first byte has to be 123 (decimal)	I
response data bytes	0	echo of requested data byte 0	I
response codes	0	no command specific errors	I
	2	invalid selection	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.88: Command 190: Read current loop error output value
(reads the current loop output error value in mA)

	byte no.	description	data type
request data bytes	none		
response data bytes	0...3	current loop output error value	F
response codes	0	no command specific errors	

Tab. A.89: Command 191: Write current loop error output value
(writes the current loop output error value in mA)

	byte no.	description	data type
request data bytes	0...3	current loop output error value	F
response data bytes	0...3	current loop output error value	F
response codes	0	no command specific errors	
	3	passed parameter too large	
	4	passed parameter too small	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.90: Command 194: Read PV/current loop with sign or absolute
(reads whether the sign of the PV is to be considered for the current loop output
0 - with sign, 1 - absolute)

	byte no.	description	data type
request data bytes	none		
response data bytes	0	PV/current loop with sign or absolute	I
response codes	0	no command specific errors	

Tab. A.91: Command 195: Write PV/current loop with sign or absolute
(writes whether the sign of the PV is to be considered for the current loop output
0 - with sign, 1 - absolute)

	byte no.	description	data type
request data bytes	0	PV/current loop with sign or absolute	I
response data bytes	0	PV/current loop with sign or absolute	I
response codes	0	no command specific errors	
	2	invalid selection	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.92: Command 200: Read FLUXUS serial number
(reads the FLUXUS serial number (16 ASCII characters))

	byte no.	description	data type
request data bytes	none		
response data bytes	0...15	FLUXUS serial number	A
response codes	0	no command specific errors	

Tab. A.93: Command 201: Read FLUXUS firmware version
(reads the FLUXUS firmware version (16 ASCII characters))

	byte no.	description	data type
request data bytes	none		
response data bytes	0...15	FLUXUS firmware version	A
response codes	0	no command specific errors	

Tab. A.94: Command 202: Read HART serial number
(reads the HART serial number (15 ASCII characters))

	byte no.	description	data type
request data bytes	none		
response data bytes	0...14	HART serial number	A
response codes	0	no command specific errors	

Tab. A.95: Command 203: Read HART firmware version
(reads the HART firmware version, the first byte represents the major and the second byte the sub version)

	byte no.	description	data type
request data bytes	none		
response data bytes	0	HART sub version	I
	1	HART major version	I
response codes	0	no command specific errors	

Tab. A.96: Command 230: Clear totalizer
(Sets the totalizer value to zero. It is possible to choose the totalizer of a physical (A, B, C, D), virtual (Z, Y) or all channels(*) by setting the first data byte (channel ID). This first data byte has to be written with the ASCII value of the channel ID (example: channel A = 65 = 0x41).
The second byte represents the totalizer type. It is possible to reset only positive (‘+’), only negative (‘-’) or both (‘*’) totalizers. Similar to the channel ID it is necessary to specify the ASCII value of ‘+’ (43 = 0x2B), ‘-‘(45 = 0x2D) or ‘*’ (42 = 0x2A).)

	byte no.	description	data type
request data bytes	0	channel ID	I
	1	totalizer ID	I
response data bytes	0	echo requested channel ID	I
	1	echo requested totalizer ID	I
response codes	0	no command specific errors	
	2	invalid selection	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.97: Command 240: Read error value delay
(Reads the timeout value, which determines how many seconds have to pass before the status of a device variable changes to poor accuracy and the current loop changes to the current loop output error value.)

	byte no.	description	data type
request data bytes	none		
response data bytes	0	error value delay	I
response codes	0	no command specific errors	

Tab. A.98: Command 241: Write error value delay
(Writes the timeout value, which determines how many seconds have to pass before the status of a device variable changes to poor accuracy and the current loop changes to the current loop output error value.)

	byte no.	description	data type
request data bytes	0	error value delay	I
response data bytes	0	error value delay	I
response codes	0	no command specific errors	
	4	passed parameter too small	
	5	too few data bytes received	
	7	in write protect mode	

Tab. A.99: Command 242: Read input slot configuration

	byte no.	description	data type
request data bytes	none		
response data bytes	0	input slot 0	E
	1	input slot 0 - channel	E
	2	input slot 0 - input value type	E
	3	input slot 0 - unit code of measurement	E
	4	input slot 1	E
	5	input slot 1 - channel	E
	6	input slot 1 - input value type	E
	7	input slot 1 - unit code of measurement	E
	8	input slot 2	E
	9	input slot 2 - channel	E
	10	input slot 2 - input value type	E
	11	input slot 2 - unit code of measurement	E
	12	input slot 3	E
	13	input slot 3 - channel	E
	14	input slot 3 - input value type	E
	15	input slot 3 - unit code of measurement	E
response codes	0	no command specific errors	

Tab. A.100: Command 243: Write input slot configuration
(Up to 4 input slots can be configured at the same time. For this purpose, 4 data bytes or a multitude thereof have to be present in the request and be valid. The configuration is persisted and thus kept after a device restart.)

	byte no.	description	data type
request data bytes	0	input slot x	E
	1	input slot x - channel	E
	2	input slot x - input value type	E
	3	input slot x - unit code of measurement	E
	4	input slot x	E
	5	input slot x - channel	E
	6	input slot x - input value type	E
	7	input slot x - unit code of measurement	E
	8	input slot x	E
	9	input slot x - channel	E
	10	input slot x - input value type	E
	11	input slot x - unit code of measurement	E
	12	input slot x	E
	13	input slot x - channel	E
	14	input slot x - input value type	E
	15	input slot x - unit code of measurement	E
response data bytes	0	input slot x	E
	1	input slot x - channel	E
	2	input slot x - input value type	E
	3	input slot x - unit code of measurement	E
	4	input slot x	E
	5	input slot x - channel	E
	6	input slot x - input value type	E
	7	input slot x - unit code of measurement	E
	8	input slot x	E
	9	input slot x - channel	E
	10	input slot x - input value type	E
	11	input slot x - unit code of measurement	E
	12	input slot x	E
	13	input slot x - channel	E
	14	input slot x - input value type	E
	15	input slot x - unit code of measurement	E
response code	0	no command specific errors	
	2	invalid selection	
	5	too few data bytes received	

Tab. A.100: Command 243: Write input slot configuration
(Up to 4 input slots can be configured at the same time. For this purpose, 4 data bytes or a multitude thereof have to be present in the request and be valid. The configuration is persisted and thus kept after a device restart.)

	byte no.	description	data type
	7	in write protect mode	
	12	Invalid slot number	
	18	invalid unit code	

Tab. A.101: Command 245: Write input slot measuring value
(Up to 4 input slot measured values can be sent to the device at the same time. For this purpose, 6 data bytes or a multitude thereof have to be present in the request and be valid.)

	byte no.	description	data type
request data bytes	0	input slot x	E
	1	input slot x - status	E
	2...5	input slot x - measuring value	F
	6	input slot x	E
	7	input slot x - status	E
	8...11	input slot x - measuring value	F
	12	input slot x	E
	13	input slot x - status	E
	14...17	input slot x - measuring value	F
	18	input slot x	E
	19	input slot x - status	E
	20...23	input slot x - measuring value	F
response data bytes	0	input slot x	E
	1	input slot x - status	E
	2...5	input slot x - measuring value	F
	6	input slot x	E
	7	input slot x - status	E
	8...11	input slot x - measuring value	F
	12	input slot x	E
	13	input slot x - status	E
	14...17	input slot x - measuring value	F
	18	input slot x	E
	19	input slot x - status	E
	20...23	input slot x - measuring value	F
response code	0	no command specific errors	
	2	invalid selection	
	5	too few data bytes received	
	7	in write protect mode	
	8	update failed	
	12	invalid slot number	

Tab. A.102: Input slot

input slot	hexadecimal
1...4	0x00...0x03

Tab. A.103: Channel

channel	hexadecimal
A...D	0x41...0x44
Z...Y	0x5A...0x59
all channels → *	0x2A

Tab. A.104: Input value type

input value type	description	possible units
1	temperature	see unit of measurement, Tab. C.9
2	temperature aux.	see unit of measurement, Tab. C.9
3	pressure	see unit of measurement, Tab. C.8
4	pressure aux.	see unit of measurement, Tab. C.8
5	density	see unit of measurement, Tab. C.12
6	kin. viscosity	mm²/s
7	dyn. viscosity	mPa*s
8	compressibility coefficient	none

Tab. A.105: Command 253: Reset HART specific settings to factory default
(Resets the HART specific default settings. One data byte (1) has to be written to the device.)

	byte no.	description	value
request data bytes	0	the first byte has to be 1 (decimal)	I
response data bytes	0	echo of requested data byte 0	I
response codes	0 2 5 7	no command specific errors invalid selection too few data bytes received in write protect mode	

B Device Variables and Units

The transmitters are multichannel/sensor devices:
• channel A, B, C, D → physical channels
• channel Z, Y → virtual/calculation channels

All device variables listed in Tab. B.1 are available via HART interface.
Defaults are:
• primary process variable (PV) → volumetric flow rate (7)
• secondary process variable (SV) → volumetric flow rate, positive totalizer (8)
• tertiary process variable (TV) → sound speed (5)
• quaternary process variable (QV) → flow velocity (6)
• unit primary process variable → m^3/h (19)
• unit secondary process variable → m^3 (43)
• unit tertiary process variable → m/s (21)
• unit quaternary process variable → m/s (21)

The upper 3 bits of every device variable code represents the channel. The lower 5 bits represents the measuring value of the determined channel.

channel MSB	channel	channel LSB	MeasVal	MeasVal	MeasVal	MeasVal	MeasVal LSB

example: volumetric flow rate of channel B → device variable
code 39 = 0x27 = 00100111

Notice!
Only the first 20 device variables of every channel except the totalizers are mapable to the PV (primary variable).

Tab. B.1: Device variables

device variable code	variable name	unit code	classification	
channel A				
0 (0x00)	fluid temperature T_{fluid} (at the location where the flow rate is measured, supply line or return line)	see Tab. C.9	temperature	64 - 0x40
1 (0x01)	fluid temperature T_{aux} (the other temperature, return line or supply line)	see Tab. C.9	temperature	64 - 0x40
2 (0x02)	fluid pressure p_{fluid} (at the location where the flow rate is measured, supply line or return line)	see Tab. C.8	pressure	65 - 0x41
3 (0x03)	fluid pressure p_{aux} (the other pressure, return line or supply line)	see Tab. C.8	pressure	65 - 0x41
4 (0x04)	signal amplitude	see Tab. C.11	not classified	0 - 0x00
5 (0x05)	sound speed	see Tab. C.5	velocity	67 - 0x43
6 (0x06)	flow velocity	see Tab. C.5	velocity	67 - 0x43
7 (0x07)	volumetric flow rate	see Tab. C.1	volumetric flow rate	66 - 0x42
8 (0x08)	volumetric flow rate, positive totalizer	see Tab. C.2	volume	68 - 0x44
9 (0x09)	volumetric flow rate, negative totalizer	see Tab. C.2	volume	68 - 0x44
10 (0x0A)	standard volumetric flow rate (gas measurement)	see Tab. C.1	volumetric flow rate	66 - 0x42
11 (0x0B)	standard volumetric flow rate, positive totalizer	see Tab. C.2	volume	68 - 0x44

Tab. B.1: Device variables

device variable code	variable name	unit code	classification	
12 (0x0C)	standard volumetric flow rate, negative totalizer	see Tab. C.2	volume	68 - 0x44
13 (0x0D)	mass flow rate	see Tab. C.6	mass flow rate	72 - 0x48
14 (0x0E)	mass flow rate, positive totalizer	see Tab. C.3	mass	71 - 0x47
15 (0x0F)	mass flow rate, negative totalizer	see Tab. C.3	mass	71 - 0x47
16 (0x10)	heat flow	see Tab. C.7	power	79 - 0x4F
17 (0x11)	heat flow, positive totalizer	see Tab. C.4	energy	77 - 0x4D
18 (0x12)	heat flow, negative totalizer	see Tab. C.4	energy	77 - 0x4D
19 (0x13)	concentration	see Tab. C.11	concentration	90 - 0x5A
20 (0x14)	SNR (signal-to-noise ratio)	see Tab. C.10	not classified	0 - 0x00
21 (0x15)	SCNR (signal to clutter plus noise ratio)	see Tab. C.10	not classified	0 - 0x00
22 (0x16)	reserved			
23 (0x17)	reserved			
24 (0x18)	reserved			
25 (0x19)	reserved			
26 (0x1A)	reserved			
27 (0x1B)	reserved			
28 (0x1C)	reserved			
29 (0x1D)	reserved			
30 (0x1E)	reserved			
31 (0x1F)	reserved			
channel B				
32 (0x20)	fluid temperature T_{fluid} (at the location where the flow rate is measured, supply line or return line)	see Tab. C.9	temperature	64 - 0x40
33 (0x21)	fluid temperature T_{aux} (the other temperature, return line or supply line)	see Tab. C.9	temperature	64 - 0x40
34 (0x22)	fluid pressure p_{fluid} (at the location where the flow rate is measured, supply line or return line)	see Tab. C.8	pressure	65 - 0x41
35 (0x23)	fluid pressure p_{aux} (the other pressure, return line or supply line)	see Tab. C.8	pressure	65 - 0x41
36 (0x24)	signal amplitude	see Tab. C.11	not classified	0 - 0x00
37 (0x25)	sound speed	see Tab. C.5	velocity	67 - 0x43
38 (0x26)	flow velocity	see Tab. C.5	velocity	67 - 0x43
39 (0x27)	volumetric flow rate	see Tab. C.1	volumetric flow rate	66 - 0x42
40 (0x28)	volumetric flow rate, positive totalizer	see Tab. C.2	volume	68 - 0x44
41 (0x29)	volumetric flow rate, negative totalizer	see Tab. C.2	volume	68 - 0x44
42 (0x2A)	standard volumetric flow rate (gas measurement)	see Tab. C.1	volumetric flow rate	66 - 0x42
43 (0x2B)	standard volumetric flow rate, positive totalizer	see Tab. C.2	volume	68 - 0x44

Tab. B.1: Device variables

device variable code	variable name	unit code	classification	
44 (0x2C)	standard volumetric flow rate, negative totalizer	see Tab. C.2	volume	68 - 0x44
45 (0x2D)	mass flow rate	see Tab. C.6	mass flow rate	72 - 0x48
46 (0x2E)	mass flow rate, positive totalizer	see Tab. C.3	mass	71 - 0x47
47 (0x2F)	mass flow rate rate, negative totalizer	see Tab. C.3	mass	71 - 0x47
48 (0x30)	heat flow	see Tab. C.7	power	79 - 0x4F
49 (0x31)	heat flow, positive totalizer	see Tab. C.4	energy	77 - 0x4D
50 (0x32)	heat flow, negative totalizer	see Tab. C.4	energy	77 - 0x4D
51 (0x33)	concentration	see Tab. C.11	concentration	90 - 0x5A
52 (0x34)	SNR (signal-to-noise ratio)	see Tab. C.10	not classified	0 - 0x00
53 (0x35)	SCNR (signal to clutter plus noise ratio)	see Tab. C.10	not classified	0 - 0x00
54 (0x36)	reserved			
55 (0x37)	reserved			
56 (0x38)	reserved			
57 (0x39)	reserved			
58 (0x3A)	reserved			
59 (0x3B)	reserved			
60 (0x3C)	reserved			
61 (0x3D)	reserved			
62 (0x3E)	reserved			
63 (0x3F)	reserved			
channel C				
64 (0x40)	fluid temperature T_{fluid} (at the location where the flow rate is measured, supply line or return line)	see Tab. C.9	temperature	64 - 0x40
65 (0x41)	fluid temperature T_{aux} (the other temperature, return line or supply line)	see Tab. C.9	temperature	64 - 0x40
66 (0x42)	fluid pressure p_{fluid} (at the location where the flow rate is measured, supply line or return line)	see Tab. C.8	pressure	65 - 0x41
67 (0x43)	fluid pressure p_{aux} (the other pressure, return line or supply line)	see Tab. C.8	pressure	65 - 0x41
68 (0x44)	signal amplitude	see Tab. C.11	not classified	0 - 0x00
69 (0x45)	sound speed	see Tab. C.5	velocity	67 - 0x43
70 (0x46)	flow velocity	see Tab. C.5	velocity	67 - 0x43
71 (0x47)	volumetric flow rate	see Tab. C.1	volumetric flow rate	66 - 0x42
72 (0x48)	volumetric flow rate, positive totalizer	see Tab. C.2	volume	68 - 0x44
73 (0x49)	volumetric flow rate, negative totalizer	see Tab. C.2	volume	68 - 0x44
74 (0x4A)	standard volumetric flow rate (gas measurement)	see Tab. C.1	volumetric flow rate	66 - 0x42
75 (0x4B)	standard volumetric flow rate, positive totalizer	see Tab. C.2	volume	68 - 0x44

Tab. B.1: Device variables

device variable code	variable name	unit code	classification	
76 (0x4C)	standard volumetric flow rate, negative totalizer	see Tab. C.2	volume	68 - 0x44
77 (0x4D)	mass flow rate	see Tab. C.6	mass flow rate	72 - 0x48
78 (0x4E)	mass flow rate, positive totalizer	see Tab. C.3	mass	71 - 0x47
79 (0x4F)	mass flow rate, negative totalizer	see Tab. C.3	mass	71 - 0x47
80 (0x50)	heat flow	see Tab. C.7	power	79 - 0x4F
81 (0x51)	heat flow, positive totalizer	see Tab. C.4	energy	77 - 0x4D
82 (0x52)	heat flow, negative totalizer	see Tab. C.4	energy	77 - 0x4D
83 (0x53)	concentration	see Tab. C.11	concentration	90 - 0x5A
84 (0x54)	SNR (signal-to-noise ratio)	see Tab. C.10	not classified	0 - 0x00
85 (0x55)	SCNR (signal to clutter plus noise ratio)	see Tab. C.10	not classified	0 - 0x00
86 (0x56)	reserved			
87 (0x57)	reserved			
88 (0x58)	reserved			
89 (0x59)	reserved			
90 (0x5A)	reserved			
91 (0x5B)	reserved			
92 (0x5C)	reserved			
93 (0x5D)	reserved			
94 (0x5E)	reserved			
95 (0x5F)	reserved			
channel D				
96 (0x60)	fluid temperature T_{fluid} (at the location where the flow rate is measured, supply line or return line)	see Tab. C.9	temperature	64 - 0x40
97 (0x61)	fluid temperature T_{aux} (the other temperature, return line or supply line)	see Tab. C.9	temperature	64 - 0x40
98 (0x62)	fluid pressure p_{fluid} (at the location where the flow rate is measured, supply line or return line)	see Tab. C.8	pressure	65 - 0x41
99 (0x63)	fluid pressure p_{aux} (the other pressure, return line or supply line)	see Tab. C.8	pressure	65 - 0x41
100 (0x64)	signal amplitude	see Tab. C.11	not classified	0 - 0x00
101 (0x65)	sound speed	see Tab. C.5	velocity	67 - 0x43
102 (0x66)	flow velocity	see Tab. C.5	velocity	67 - 0x43
103 (0x67)	volumetric flow rate	see Tab. C.1	volumetric flow rate	66 - 0x42
104 (0x68)	volumetric flow rate, positive totalizer	see Tab. C.2	volume	68 - 0x44
105 (0x69)	volumetric flow rate, negative totalizer	see Tab. C.2	volume	68 - 0x44
106 (0x6A)	standard volumetric flow rate (gas measurement)	see Tab. C.1	volumetric flow rate	66 - 0x42
107 (0x6B)	standard volumetric flow rate, positive totalizer	see Tab. C.2	volume	68 - 0x44

Tab. B.1: Device variables

device variable code	variable name	unit code	classification	
108 (0x6C)	standard volumetric flow rate, negative totalizer	see Tab. C.2	volume	68 - 0x44
109 (0x6D)	mass flow rate	see Tab. C.6	mass flow rate	72 - 0x48
110 (0x6E)	mass flow rate, positive totalizer	see Tab. C.3	mass	71 - 0x47
111 (0x6F)	mass flow rate, negative totalizer	see Tab. C.3	mass	71 - 0x47
112 (0x70)	heat flow	see Tab. C.7	power	79 - 0x4F
113 (0x71)	heat flow, positive totalizer	see Tab. C.4	energy	77 - 0x4D
114 (0x72)	heat flow, negative totalizer	see Tab. C.4	energy	77 - 0x4D
115 (0x73)	concentration	see Tab. C.11	concentration	90 - 0x5A
116 (0x74)	SNR (signal-to-noise ratio)	see Tab. C.10	not classified	0 - 0x00
117 (0x75)	SCNR (signal to clutter plus noise ratio)	see Tab. C.10	not classified	0 - 0x00
118 (0x76)	reserved			
119 (0x77)	reserved			
120 (0x78)	reserved			
121 (0x79)	reserved			
122 (0x7A)	reserved			
123 (0x7B)	reserved			
124 (0x7C)	reserved			
125 (0x7D)	reserved			
126 (0x7E)	reserved			
127 (0x7F)	reserved			
channel Z				
128 (0x80)	fluid temperature T_{fluid} (at the location where the flow rate is measured, supply line or return line)	see Tab. C.9	temperature	64 - 0x40
129 (0x81)	fluid temperature T_{aux} (the other temperature, return line or supply line)	see Tab. C.9	temperature	64 - 0x40
130 (0x82)	fluid pressure p_{fluid} (at the location where the flow rate is measured, supply line or return line)	see Tab. C.8	pressure	65 - 0x41
131 (0x83)	fluid pressure p_{aux} (the other pressure, return line or supply line)	see Tab. C.8	pressure	65 - 0x41
132 (0x84)	signal amplitude	see Tab. C.11	not classified	0 - 0x00
133 (0x85)	sound speed	see Tab. C.5	velocity	67 - 0x43
134 (0x86)	flow velocity	see Tab. C.5	velocity	67 - 0x43
135 (0x87)	volumetric flow rate	see Tab. C.1	volumetric flow rate	66 - 0x42
136 (0x88)	volumetric flow rate, positive totalizer	see Tab. C.2	volume	68 - 0x44
137 (0x89)	volumetric flow rate, negative totalizer	see Tab. C.2	volume	68 - 0x44
138 (0x8A)	standard volumetric flow rate (gas measurement)	see Tab. C.1	volumetric flow rate	66 - 0x42
139 (0x8B)	standard volumetric flow rate, positive totalizer	see Tab. C.2	volume	68 - 0x44

Tab. B.1: Device variables

device variable code	variable name	unit code	classification	
140 (0x8C)	standard volumetric flow rate, negative totalizer	see Tab. C.2	volume	68 - 0x44
141 (0x8D)	mass flow rate	see Tab. C.6	mass flow rate	72 - 0x48
142 (0x8E)	mass flow rate, positive totalizer	see Tab. C.3	mass	71 - 0x47
143 (0x8F)	mass flow rate, negative totalizer	see Tab. C.3	mass	71 - 0x47
144 (0x90)	heat flow	see Tab. C.7	power	79 - 0x4F
145 (0x91)	heat flow, positive totalizer	see Tab. C.4	energy	77 - 0x4D
146 (0x92)	heat flow, negative totalizer	see Tab. C.4	energy	77 - 0x4D
147 (0x93)	concentration	see Tab. C.11	concentration	90 - 0x5A
148 (0x94)	SNR (signal-to-noise ratio)	see Tab. C.10	not classified	0 - 0x00
149 (0x95)	SCNR (signal to clutter plus noise ratio)	see Tab. C.10	not classified	0 - 0x00
channel Y				
160 (0xA0)	fluid temperature T_{fluid} (at the location where the flow rate is measured, supply line or return line)	see Tab. C.9	temperature	64 - 0x40
161 (0xA1)	fluid temperature T_{aux} (the other temperature, return line or supply line)	see Tab. C.9	temperature	64 - 0x40
162 (0xA2)	fluid pressure p_{fluid} (at the location where the flow rate is measured, supply line or return line)	see Tab. C.8	pressure	65 - 0x41
163 (0xA3)	fluid pressure p_{aux} (the other pressure, return line or supply line)	see Tab. C.8	pressure	65 - 0x41
164 (0xA4)	signal amplitude	see Tab. C.11	not classified	0 - 0x00
165 (0xA5)	sound speed	see Tab. C.5	velocity	67 - 0x43
166 (0xA6)	flow velocity	see Tab. C.5	velocity	67 - 0x43
167 (0xA7)	volumetric flow rate	see Tab. C.1	volumetric flow rate	66 - 0x42
168 (0xA8)	volumetric flow rate, positive totalizer	see Tab. C.2	volume	68 - 0x44
169 (0xA9)	volumetric flow rate, negative totalizer	see Tab. C.2	volume	68 - 0x44
170 (0xAA)	standard volumetric flow rate (gas measurement)	see Tab. C.1	volumetric flow rate	66 - 0x42
171 (0xAB)	standard volumetric flow rate, positive totalizer	see Tab. C.2	volume	68 - 0x44
172 (0xAC)	standard volumetric flow rate, negative totalizer	see Tab. C.2	volume	68 - 0x44
173 (0xAD)	mass flow rate	see Tab. C.6	mass flow rate	72 - 0x48
174 (0xAE)	mass flow rate, positive totalizer	see Tab. C.3	mass	71 - 0x47
175 (0xAF)	mass flow rate, negative totalizer	see Tab. C.3	mass	71 - 0x47
176 (0xB0)	heat flow	see Tab. C.7	power	79 - 0x4F
177 (0xB1)	heat flow, positive totalizer	see Tab. C.4	energy	77 - 0x4D
178 (0xB2)	heat flow, negative totalizer	see Tab. C.4	energy	77 - 0x4D
179 (0xB3)	concentration	see Tab. C.11	concentration	90 - 0x5A
180 (0xB4)	SNR (signal-to-noise ratio)	see Tab. C.10	not classified	0 - 0x00
181 (0xB5)	SCNR (signal to clutter plus noise ratio)	see Tab. C.10	not classified	0 - 0x00

C Unit IDs

Tab. C.1: Unit IDs - volumetric flow rate

unit of measurement	HART - unit ID
cubic meter per hour (m³/h)	19 - 0x13
cubic meter per day (m³/d)	29 - 0x1D
cubic meter per minute (m³/min)	131 - 0x83
cubic meter per second (m³/s)	28 - 0x1C
liter per hour (l/h)	138 - 0x8A
liter per minute (l/min)	17 - 0x11
liter per second (l/s)	24 - 0x18
mega US gallons per day (MDG)	23 - 0x17
US gallons per hour (USgph)	136 - 0x88
US gallons per minute (USgpm)	16 - 0x10
US gallons per second (USgps)	22 - 0x16
barrel per day (bbl/d)	135 - 0x87
barrel per hour (bbl/h)	134 - 0x86
barrel per minute (bbl/m)	133 - 0x85
barrel per second (bbl/s)	132 - 0x84
cubic feet per day (CFD)	27 - 1B
cubic feet per hour (CFH)	130 - 0x82
cubic feet per minute (CFM)	15 - 0x0F
cubic feet per second (CFS)	26 - 0x1A

Tab. C.2: Unit IDs - volume

unit of measurement	HART - unit ID
cubic meter (m³)	43 - 0x2B
hectoliter (hl)	236 - 0xEC
liter (l)	41 - 0x29
US gallons (USgal)	40 - 0x28
barrel (bbl)	46 - 0x2E

Tab. C.3: Unit IDs - mass

unit of measurement	HART - unit ID
kilogram (kg)	61 - 0x3D
gram (g)	60 - 0x3C
tons (t)	62 - 0x3E
pounds (lb)	63 - 0x3F

Tab. C.4: Unit IDs - heat quantity

unit of measurement	HART - unit ID
megawatt-hour (MWh)	240 - F0 (FLUXUS specific)
kilowatt-hour (kWh)	128 - 0x80
megaJoule (MJ)	164 - 0xA4
MBTU	241 - F1 (FLUXUS specific)

Tab. C.5: Unit IDs - velocity

unit of measurement	HART - unit ID
meter per second (m/s)	21 - x15
inch per second (in/s)	114 - 0x72
feet per second (in/s)	20 - 0x14

Tab. C.6: Unit IDs - mass flow rate

unit of measurement	HART - unit ID
kilogram per second (kg/s)	73 - 0x49
gram per second (g/s)	70 - 0x46
tons per day (t/d)	79 - 0x4F
tons per hour (t/h)	78 - 0x4E
kilogram per hour (kg/h)	75 - 0x4B
kilogram per minute (kg/min)	74 - 0x4A
US pound per day (lb/d)	83 - 0x53
US pound per hour (lb/h)	82 - 0x52
US pound per minute (lb/min)	81 - 0x51
US pound per second (lb/s)	80 - 0x50

Tab. C.7: Unit IDs - heat flow

unit of measurement	HART - unit ID
kilowatt (kW)	127 - 0x7F
MBTU per hour	243 - F3 (FLUXUS specific)

Tab. C.8: Unit IDs - pressure

unit of measurement	HART - unit ID
bar (bar)	7 - 0x07
millibar (mbar)	8 - 0x08
megapascal (MPa)	237 - 0xED
pounds per square inch (psi)	6 - 0x06
millimeter mercury column (mmHg)	5 - 0x05

Tab. C.9: Unit IDs - temperature

unit of measurement	HART - unit ID
degree Celsius (°C)	32 - 0x20
degree Fahrenheit (°F)	33 - 0x21

Tab. C.10: Unit IDs - signal strength

unit of measurement	HART - unit ID
decibel (dB) device revision: 7	244 - 0xF4 (FLUXUS specific)
decibel (dB) device revision: 8	156 - 0x9C

Tab. C.11: Unit IDs - no unit of measurement

unit of measurement	HART - unit ID
no unit	244251 - 0xFB

Tab. C.12: Unit IDs - density

unit of measurement	HART - unit ID
kilogram per cubic meter (kg/m^3)	92 - 0x5C
gram per cubic centimeter (g/cm^3)	91 - 0x5B
US pound per cubic feet (lb/ft^3)	94 - 0x5E
US pound per cubic inch lb/in^3	98 - 0x62