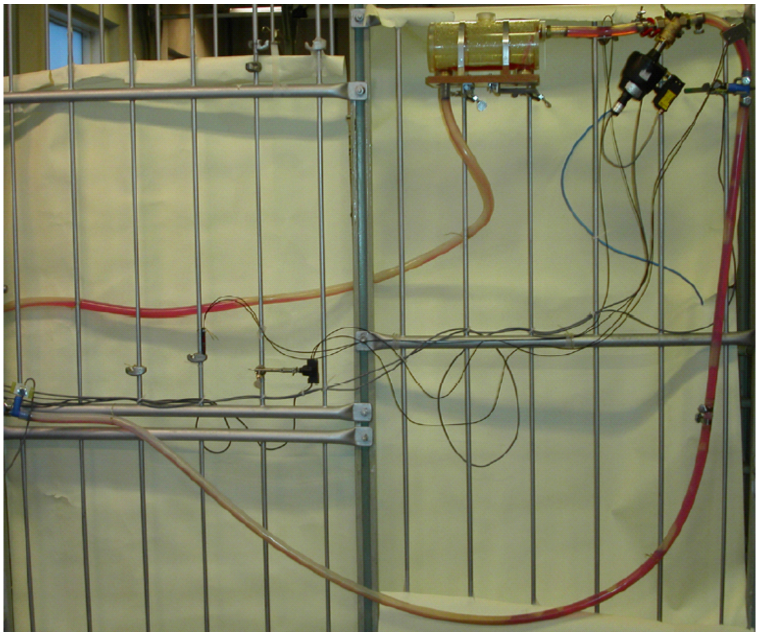

Prosjekt Høsten 2003
Slug regulering i tofase strømning
Eksperimentell verifikasjon

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Sammendrag

I flerfaserørledninger kan det oppstå et strømningsmønster som kalles slug-strømning. Hvis dette strømningsmønsteret oppstår ved et vertikalt løft kalles det riser-indusert slugging. Eksperimentelle forsøk med riser-indusert slugging kan gjennomføres blant annet i flerfase-laboratoriet på Tiller. Det er imidlertid ønskelig å også ha en lett tilgjengelig og rimelig MiniLoop for slike forsøk. Denne oppgaven tok sikte på å bygge en slik loop. Byggingen av MiniLoopen innebar innkjøp av utstyr, laging av beslag, festeanordninger og elektrisk skap for analog input og analog output moduler. LabVIEW 6.1 ble brukt til programmering. Et enkelt grensesnitt ble utviklet hvor brukeren har mulighet til å blant annet velge manuell styring av ventilen, eller styring av ventilen med PID regulator. Trykk, ventilåpning og slugging visualiseres i grensesnittet. Eksperimentelle forsøk ble gjennomført med MiniLoopen og data ble lagret.

Storkaas og Skogestad har utviklet en modell med tre tilstander, som beskriver riser-indusert slugging. Denne forenklede modellen ble brukt til å beskrive slugging i MiniLoopen. Et bifurkasjonsdiagram fra eksperimentelle resultater ble laget. Forenklet modell ble tunet til akseptabel overensstemmelse med eksperimentelle data for lave ventilåpninger. En regulerbarhet-sanalyse ble gjennomført basert på modellen. I regulerbarhetsanalysen ble 5 målepunkter vurdert: Trykk P_1 ved innløp føderør, trykk P_2 oppstrøms separator, tetthet gjennom ventilen (ρ_T), massestrøm gjennom ventilen (W) og volumstrøm gjennom ventilen (Q). PI-regulator ble designet på basis av modellen. Hvilken måling som skulle benyttes i regulatoren ble bestemt fra regulerbarhetsanalysen. Ved å oppnå en *lav* verdi for summen av maksimal topp for sensitivitet- og komplementær funksjonen, ble det funnet regulatorparametre som gav akseptabel regulering. Regulatoren ble deretter testet med Storkaas forenklede modell før den ble implementert på labben.

Takk til...

- Veileder Espen Storkaas, som gjorde det enkelt å stille spørsmål og som gav gode svar. Tusen takk for all hjelp!!
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- Veileder Heidi Sivertsen, som hjalp til i oppstartsfasen med MiniLoopens slange-geometri og tanker. Takker også for kommentarer til rapporten!
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- Statoil v/ Ingvild Berg og Torgrim Aas, for råd angående utstyr og bygging av miniloop. Tusen takk!
- Ole Ivar Hovin v/verksted kjeller K4, som lagde beslag og feste for el.skap og separator.

Innhold

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Kapittel 1

Innledning

Flerfase- og reguleringsteknikken som har blitt utviklet de siste 20 årene muliggjør transport av flerfasestrømning over lange avstander. Ubehandlede brønnstrømmer kan via undervannsinstallasjoner samles for separasjon slik at behovet for komplette separasjonsanlegg ute på det enkelte felt reduseres. Dette sparer oljeindustrien for store summer. Det gjenstår imidlertid store teknologiske utfordringer innen flerfasetransport og regulering. En av disse er slug-strømning som kan oppstå når gass- og væske fase har ulik hastighet (hydrodynamisk slugging), og som et resultat av rørets geometri (terreng slugging og riser-indusert slugging). Spesielt terreng- og riserindusert slugging skaper problemer når den ankommer produksjonsenheten ettersom disse sluggene kan vokse seg meget store, og ofte innebærer kraftige trykksvingninger. Disse svingningene i trykk og strømningsrate gir store forstyrrelser for kompressor og innløp separator, som igjen kan resultere i henholdsvis unødvendig fakling og ikke-optimal separering (i verste fall flooding). Andre ugunstige konsekvenser er slitasje på utstyr som kan resultere i uforutsette driftsstopp.

Kraftig slugging kan unngås ved å øke trykkfallet over topside choke ventil. Økt trykkfall gir imidlertid lavere oljeutbytte og er ingen optimal løsning sett ut fra et økonomisk perspektiv. Andre løsninger er installering av slugfangere. Ved bruk av aktiv regulering kan man operere med stabil strømning under forhold som ellers ville gitt kraftig slugging. Dette medfører mindre behov for utstyr topside, høyere produksjon, høyere olje-gjenvinning og mindre slitasje på utstyr [1], [2], [3].

Det er viktig å vurdere valg av modell for slug-strømingen ut fra et regulerings-perspektiv. Konvensjonelle modeller for flerfase strøm er PDE basert. Målet med regulering er å stabilisere et ustabilt operasjonspunkt, og den relevante tidsskala er hastigheten til hvordan ustabiliteten utvikler seg. En omfattende beskrivelse med PDE modell er derfor unødvendig kompleks, og en enklere modell kan brukes [4], [5]. Ettersom store utfordringer fremdeles gjenstår innen flerfase regulering eksisterer det et behov for videre undersøkelse, simulering og modellering. Denne oppgaven tar utgangspunkt i [5] og en tofase-loop i lab-skala for en eksperimentell verifikasjon av Espen Storkaas forenklede modell for riser-indusert slug-strømning.

Kapittel 2

Teori

2.1 Riser-indusert slugging og modellering

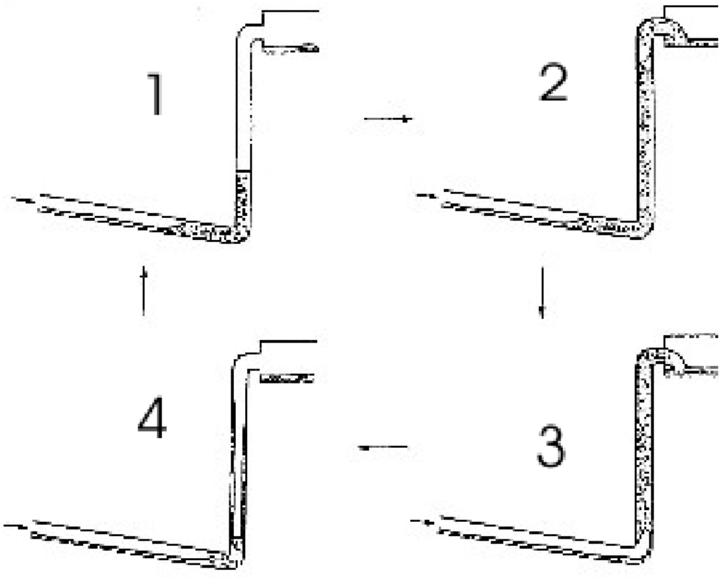
2.1.1 Slug-strømning

Dersom en slug dannes ved et vertikalt løft fra havbunnen opp til plattformen (riseren) defineres slug-strømningen som riser-indusert slug. Først samles væsken i bunnpunktet til riseren. En forutsetning for slugging er at gass- og væskehastigheten er lav nok til at en væskeansamling finner sted. Når væskeansamlingen har blitt stor nok, vil den blokkere for gasstrømmen i bunnpunktet av riseren, og en kontinuerlig væskeslug dannes. Trinn 2 er at væskeslugen vil vokse så lenge trykkøkningen oppstrøms slugen er lavere enn økningen av tyngden til væskesøylen i riseren. Trinn 3 er når trykket oppstrøms slugen blir større enn tyngden til væskesøylen i riseren, og gassen vil begynne å penetrere væsken i riseren og presse væsken ut. Dette resulterer i et trykkfall, gassen vil ekspandere og tettheten i riseren reduseres. Ettersom væske og gass har forlatt riseren er ikke gasshastigheten stor nok til å dra med seg væske. Væsken vil derfor renne ned i bunnen av riseren (trinn 4), og en ny væskeansamling begynner å vokse.

2.1.2 Storkaas slug-modell

For en mer detaljert beskrivelse av Storkaas slug-modell se [5]. Storkaas modell fokuserer på å beskrive strømningens makro-skala oppførsel som inkluderer:

- løsningenes stabilitet og operasjonelle forhold som funksjon av choke ventilens åpning
- overgang til stabilitet

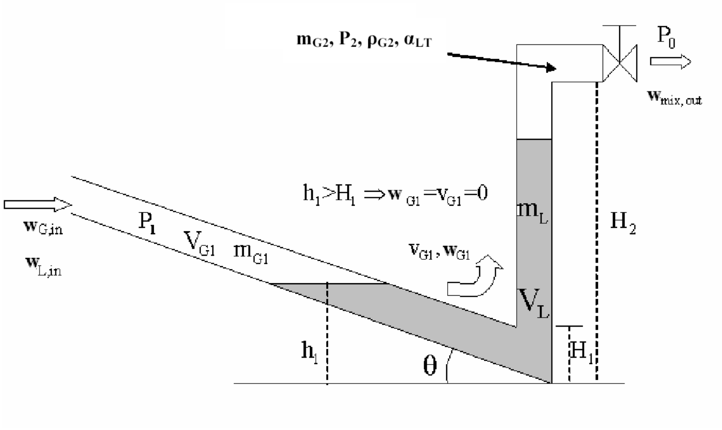


Figur 2.1: Periodisk oppførsel av slug-strømning ved vertikalt løft

- en ustabil stasjonær løsning ved samme åpning for choke ventil hvor krafting slugging forekommer
- amplitude og frekvens av svingningene

Antagelser for modellen er:

- konstant væskenivå i føderøret (neglisjert dynamikk i væske nivået) Dette gir:
  - Konstant gassvolum oppstrøms (volum variasjoner pga. varierende væskenivå i bunnpunktet av riseren er neglisjert)
- Kun et kontrollvolum for væsken (som inkluderer riser og del av føde røret)
- To kontrollvolum for gass, separert av bunnpunktet i riseren med trykk-strømning sammenheng
- Ideell gasslov
- Stasjonær trykkbalanse mellom riser og fødepunkt
- Forenklet ventil-modell for gass og væske som forlater riseren
- Konstant temperatur



Figur 2.2: Storkaas slug-modell.

2.2 Regulerbahetsanalyse SISO systemer

De fundamentale begrensningene SISO-systemer er utsatt for undersøkes ved en inn- og utdata regulerbarhetsanalyse. All teori om regulerbarhetsanalyse er hentet fra [6].

> Input-output controllability of a plant is the ability to achieve acceptable control performance. Proper scaling, output and disturbance variables prior to this analysis is critical. [6]

2.2.1 Sensitivitet- og komplementær sensivitetfunksjon

For SISO defineres sensitivitetsfunkjsonen (S) og komplementær sensivitetsfunksjonen (T):

$$L = GK \tag{2.1}$$

$$S = \frac{1}{1+L} \tag{2.2}$$

$$T = \frac{L}{1+L} \tag{2.3}$$

$$S + T = 1 \tag{2.4}$$

[6] definerer lukket sløyfe båndbredde ω_B, som frekvensen hvor $|S(j\omega|$ først krysser $1/\sqrt{2} = 0.707 \approx -3dB$ nedenfra. Alternativt kan lukket sløyfe båndbredde ω_{BT}, defineres som den høyeste frekvensen hvor $|T(j\omega|$ krysser $1/\sqrt{2} = 0.707 \approx -3dB$ ovenfra.

Kryssfrekvensen ω_C defineres som frekvensen hvor $|L(j\omega_C|$ først krysser 1 ovenfra. ω_C ligger vanligvis mellom ω_B og ω_{BT}. I de tilfellene hvor ω_B ogω_{BT} er forskjellige kan følgende regler brukes:

- Tilbakekobling er effektiv og øker ytelsen for $|S| < 0.7$ for frekvenser opp til ω_B.
- I intervallet $[\omega_B, \omega_{BT}]$ påvirker regulering systemets respons men øker ikke ytelsen. Dersom $|S| > 1$ vil ytelsen reduseres.
- Ved $\omega > \omega_{BT}$ er $S \approx 1$ og tilbakekopling har ingen betydelig effekt på responsen.

Ved forstyrrelser i en tilbakeregulerings-struktur ønskes lav S og høy T for å minske sensiviteten for forstyrrelsene. For å redusere sensitiviteten for støy er det viktig å ha lav T og høy S. Støy er generelt et problem ved høye frekvenser, og forstyrrelser et problem ved lave:

- For lave frekvenser er det ideellt med $S \approx 0$ og $T \approx 1$ ($|L| > 1$ for lave $\omega < \omega_C$)
- For høye frekvenser er det ideellt med $S \approx 1$ og $T \approx 0$ ($|L| < 1$ for høye $\omega > \omega_C$)

Maksimal topp av sensitivitet- og komplementær funksjonen er definert som,

$$M_S = \max_{\omega} |S(j\omega| \qquad M_T = \max_{\omega} |T(j\omega| \tag{2.5}$$

Generelt kreves $M_S < 2$ ($6dB$) og $M_T < 1.25$ ($2dB$). En høy verdi av M_S og M_T (> 4) indikerer dårlig ytelse og robusthet. For stabilitet og ytelse ønskes M_S rundt 1.

2.2.2 Begrensninger forårsaket av ustabile poler og nullpunkter

Linære dynamiske systemer kan beskrives som $\dot{x} = Ax + Bu$. Systemet er stabilt hvis og bare hvis alle polene ligger i det venstre halvplan (LHP), $Re\{_i(A)\} < 0 \ \ \forall\ i$

Ustabile poler trenger tilbakeregulering for stabilisering. RHP poler gir en nedre grense for båndbredden i systemet. [6] gir en nedre grense for RHP poler p ved

$$\omega_C > 2p \tag{2.6}$$

mens for imaginær pol

$$\omega_C > 1.15|p| \tag{2.7}$$

RHP nullpunkter gir invers respons og en øvre begrensning i båndbredden i tilbakereguleringssystemet. Fra klassisk reguleringsanalyse vil lukket sløyfe poler gå mot åpen sløyfe nullpunkter når forsterking ved tilbakeregulering går mot uendelig. Dette resulterer i ustabilitet og båndbredde begrensning ved høy forsterkning. Øvre båndbredde grense for systemer med RHP nullpunkter er
Reell nullpunkt z_n

$$\omega_B \approx \omega_C < \frac{z_n}{2} \tag{2.8}$$

Komleks nullpunkt z_n:

$$\omega_B \approx \omega_C < \begin{cases} |z_n|/4 & Re(z) \gg Im(z) \\ |z_n|/2.8 & Re(z) = Im(z) \\ |z_n| & Re(z) \ll Im(z) \end{cases} \tag{2.9}$$

RHP nullpunkter nær origo skaper de største begrensningene i båndbredden. Regulering er vanskeligere med nullpunkter lokalisert nærme origo enn nullpunkter nærme imaginær akse [6].

Når både RHP poler og nullpunkter eksisterer i et system vil de nevnte øvre og nedre båndbredde grensene gjøre stabilisering umulig. Dette kan synliggjøres ved å betrakte et system bestående av et ustabilt komplekst pol-par med dominerende imaginær del ($Re(p) \ll Im(p)$), størrelse $|p|$ og et enkelt RHP nullpunkt z_n. For å oppfylle båndbredde begrensningene og oppnå akseptabel ytelse og robusthet kreves tilnærmet

$$z_n > 2.3|p| \tag{2.10}$$

Kapittel 3

Resultater og Diskusjon

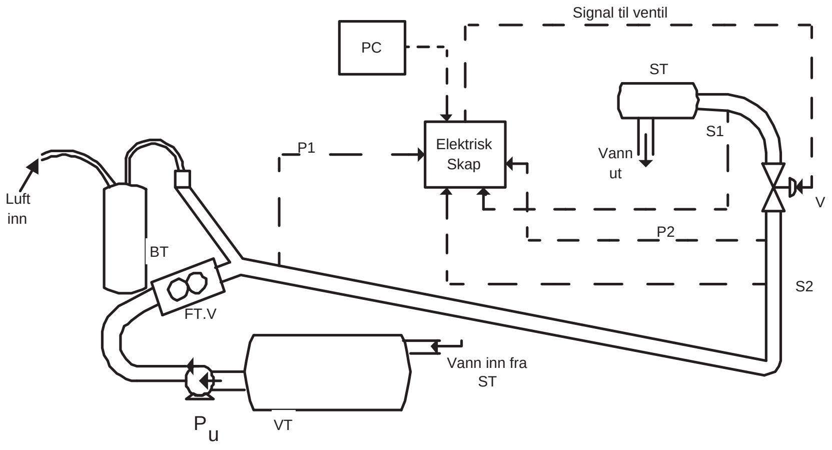
3.1 Bygging av MiniLoop

Første oppgave i prosjektet var å bestille utstyr og bygge MiniLoopen. For oversikt over leverandører se Tab.A.1.

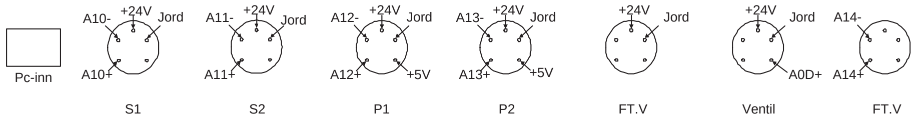
Tabell 3.1: Forkortelser teknisk utstyr

Betegnelse	Type
FT.V	Ratemåler vann,Gemu 3021
V	Ventil (Gemu 554 m/Joucamatic aktuator)
P1	Trykksensor (MPX5100DP) innløp føderør
P2	Trykksensor (MPX5100DP) oppstrøms separator
S1	Slugsensor (E3X-DA-N)
S2	Slugsensor (E3X-DA-N)
P_u	Pumpe Eheim 1060
VT	Vanntank
BT	Buffertank
ST	Separator

- *Slugsensorene* (Fig. 3.4) er to fiberoptiske sensorer av typen E3X-DA-N. De måler mengden lys som sendes fra en fiber til en annen gjennom slangen i miniloopen. Slugsensorene gir ut et spenningssignal mellom $1-5$ V avhengig av hvor mye lys som går gjennom dens fiberoptiske kabel. Det er derfor meget viktig at de fiberoptiske kablene monteres rett ovenfor hverandre. For å løse dette problemet ble en aluminium-plate bøyet til å passe rundt slangen. Hull ble borret gjennom og gjenget for



Figur 3.1: Skisse over mini-loop



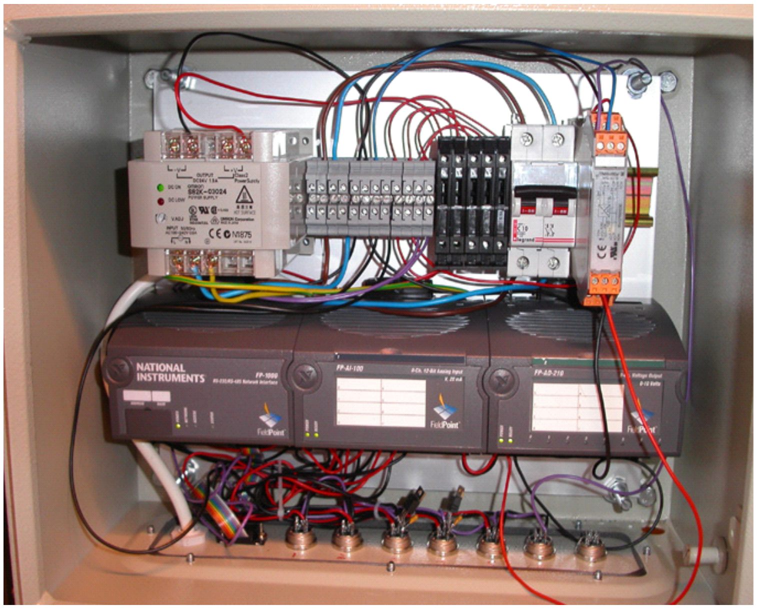
Figur 3.2: Koblinger mellom El.skap og miniloop

økt nøyaktighet. Ettersom det er liten tid igjen av prosjektarbeidet, og disse målingene ikke er kritiske for denne oppgaven er det ikke foretatt noe mer med målingene som slugsensorene registrerer. LabVIEW programmet logger dermed bare spenningssignalene. Videre arbeid av MiniLoopen vil dermed bli å vurdere slugsensorenes plassering samt å analysere spenningssignalene nærmere.

- *Ratemåleren for vann* (Fig. 3.5) er plassert rett før blandepunktet. Den gir ut et signal på 4-20 mA som kan avleses på display eller i LabView-programmet.

- *Pumpen* (Fig. 3.6) som brukes er en vanlig akvariepumpe. Maks kapasitet er 38 l/min og pumpen kan maks motarbeide en væskesøyle på 3,1 meter. Den tåler ikke å pumpe luft over lengre tid.

- *Reguleringsventilen* (Fig. 3.7) er plassert ved inngangen til separatortanken. Ventilen krever en 24 volts spenningsforsyning og styres med et signal til aktuatoren på 4-20 mA. Forholdet mellom strømsignalet til ventilens aktuator og ventilens åpning i prosent er linær. Ventilen krever mellom 4 og 8 bar trykk for å motvirke fjærkraften. Luftuttaket på labben $K4-301$ ble benyttet, og koblet til ventilens aktuator.

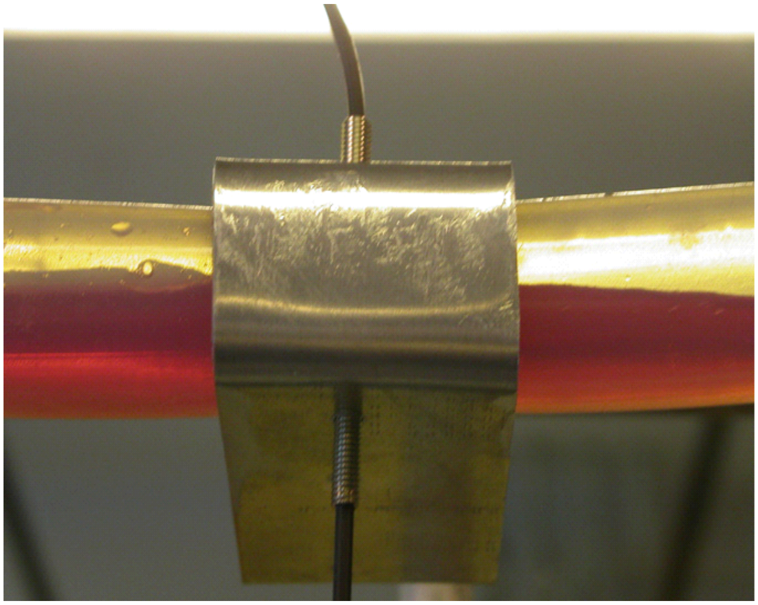


Figur 3.3: Vanntett elektrisk skap

Luftuttaket ble også benyttet til innløp gass i føderøret.

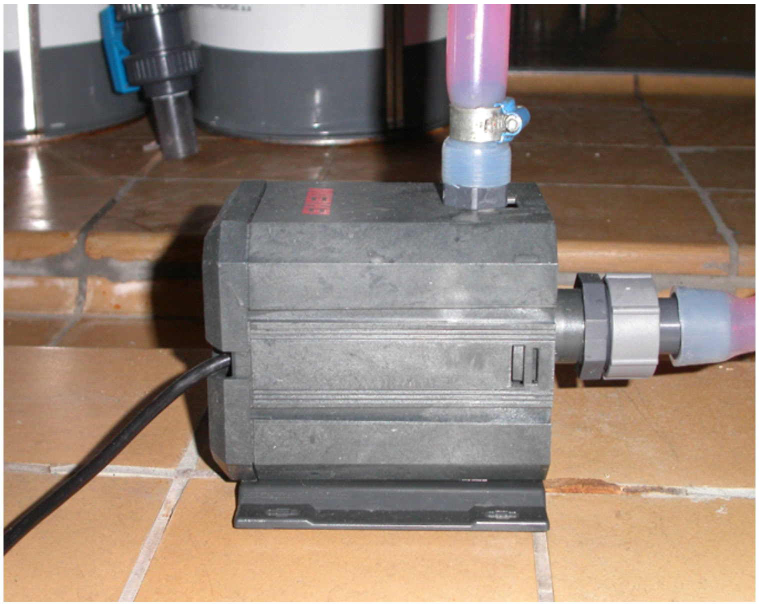
- *Trykkmålerene* (Fig. 3.8) er to av Motorolas differensielle trykkmålere som gir ut $0.2-4.5$ V ved trykk $0-100$ kPa. Forholdet mellom spenning og trykk er linært.

Fig. 3.9 viser frontpanelet i programmet miniloop.vi. Programmet visualiserer trykktransientene, ventilåpning og slugamplituden. Volumstrøm vann [l/min] og tiden [sek] vises i en indikator. Brukeren har mulighet til å justere ventilåpningen via slide-baren, velge hvor ofte data skal skrives til fil og om PID-regulator skal brukes. Dersom brukeren velger å regulere on-line må forsterkning, integraltidskonstant og tidskonstanten til den deriverte spesifiseres. For å unngå unødvendig ventilbruk har brukeren mulighet til å spesifisere sensitiviteten for ventilen. Sensitiviteten oppgis i prosent ventilåpning. Dersom 1 % velges vil programmet sammenligne regulatorens utsignal for iterasjon i med utsignal for iterasjon $i-1$, og hvis forskjellen mellom disse verdiene er større enn oppgitt sensitivitet velges regulatorens verdi for iterasjon i. Dersom regulatorens utsignal ikke endrer seg nok i forhold til spesifisert sensitivitet er det heller ikke nødvendig å skrive denne verdien til ventilen, og verdi for iterasjon $i-1$ beholdes som regulatorens utsignal. Dette har konsekvenser for regulatorens integraltid, men det antas at betydningen er neglisjerbar. Ettersom trykket oppstrøms separator er følsomt for støy velges



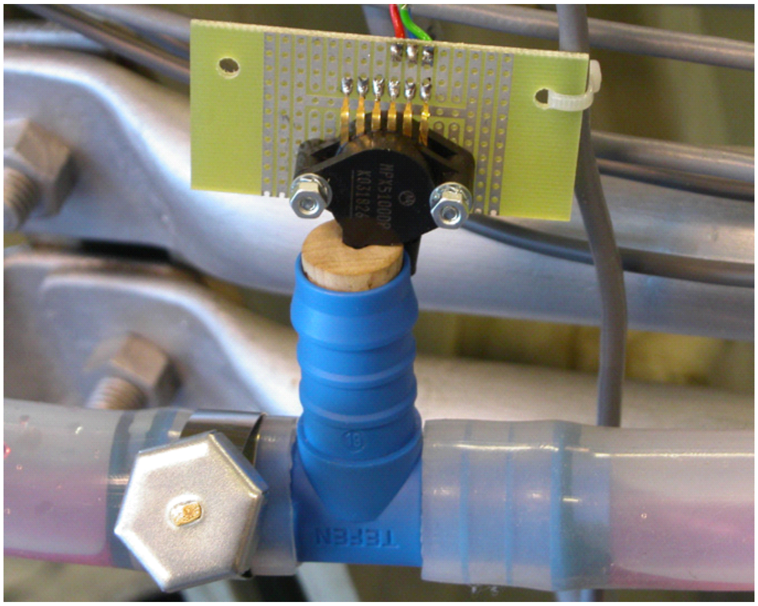
Figur 3.4: Slugsensor - fiberoptisk kabel

Figur 3.5: Ratemåler vann



Figur 3.6: Pumpe

Figur 3.7: Reguleringsventil oppstrøms separator



Figur 3.8: Differensiell trykkmåler

P_1 (trykk ved innløp føderør) som måleverdi slik at setpunktet gis for P_1 (støy for trykksensor omtales nærmere på side 19 og ved Fig. A.13 side 31). Programmet lagrer data til txt-fil. Dersom dataene skal lagres til fil, er det viktig at brukeren benytter den "store" stopp knappen laget i programmet, og ikke LabVIEW's egendefinerte stopp-funksjon . Ved bruk av den "store" stopp knappen vil LabVIEW foreta en kontrollert avslutning av programmet, gå ut av while-loopen og lagre data til ønsket filnavn.txt. Hvordan data lagres til fil er vist i Tab. 3.2.

Tabell 3.2: Struktur for lagring av data

Ts [msek]	$S1$ [V]	$S2$ [V]	P_1 [barg]	P_2 [barg]	Q [l/min]	SP [barg]	z [-]
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...

Fig. 3.10 viser den grafiske programmeringen som bygger opp miniloop.vi . Programmeringen kan deles inn i følgende hoveddeler:

- Kommunikasjon med FielPoint modulene, PC, målesensorer og reguleringsventil. Det er her brukt predefinerte funksjoner i LabVIEW med

Kp [1/bar] -30

TI [s] 10

Td [s] 0.0

Sp [barg] 0.120

Sensitivity valve [%] 1.0 (only for Controller On)

Samplings pr [msek] 100

ValveOpening 100

P1 [barg] 0.135

P2 [barg] 0.02

SP [barg] 0.12

z [-] 99.99

Flowrate Water 0.01 l/min

Time 129.4 [s]

Figur 3.9: Grafisk brukergrensesnitt ved bruk av minloop.VI navn: FP open.vi, FP read.vi og FP write.vi.

- Case-struktur hvor ”true” er regulator på og ”false” er regulator av.
- Konvertering av spenning- og strømsignaler og visualisering.

Programmets bruk av VI blokker kan sees fra Fig. 3.11.

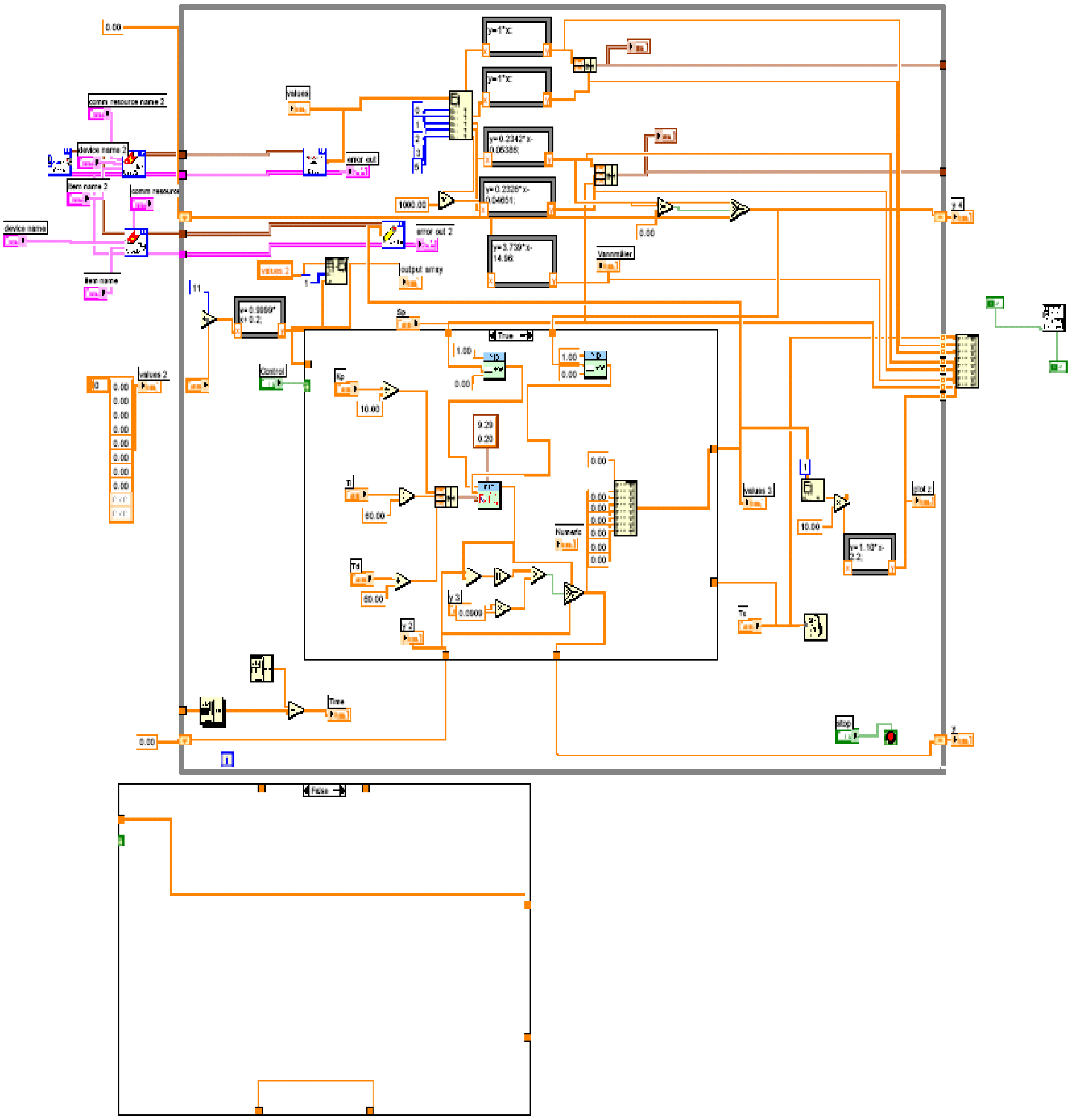
3.2 MiniLoop-Eksperimentelle data

Fig. 3.12 viser et bifurkasjonsdiagram for MiniLoopen. Nærmere beskrivelse og forklaring for diagrammet er gitt under kap. ”Storkaas forenklede modell” side 15. I en analyse av eksperimentelle data ble det oppdaget en trykkavhengig innstrømning av vann i føderøret. Fig. 3.13 viser sammenhengen mellom volumstrøm vann inn i føderøret og trykket oppstrøms. Fra Fig. 3.13 ble det gjort en linær tilpasning til dataene ettersom ratemåleren hadde problemer med å måle lave verdier for volumstrømmen. Fra Fig. A.4-A.12 er trykkfallet over reguleringsventilen lavt. Det antas dermed konstant innstrømning av luft i føderøret.

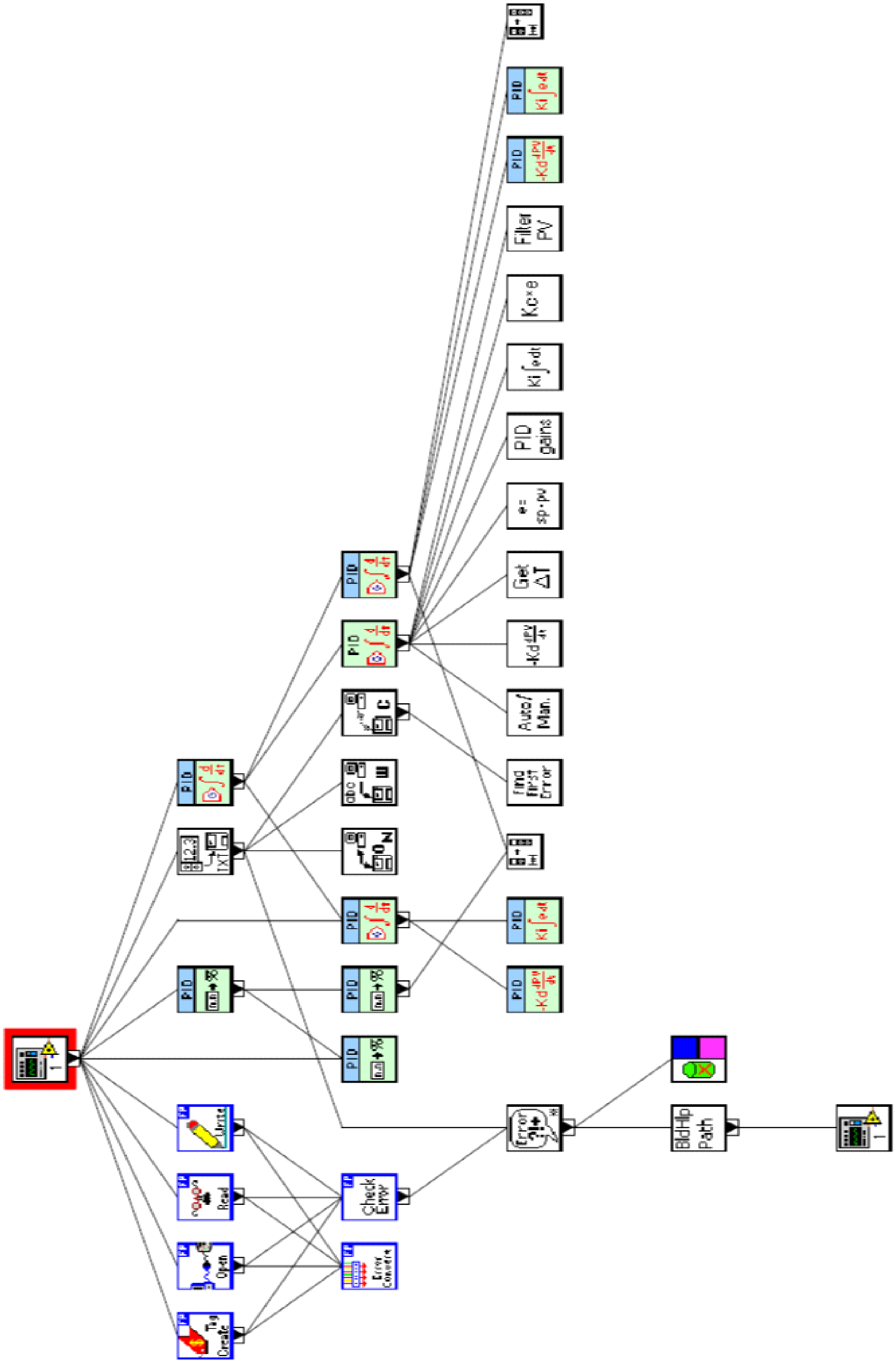
3.3 Storkaas forenklede modell

Den forenklede slug-modellen som er benyttet baserer seg blant annet på en trykkavhengig volumstrøm vann inn i føderøret og konstant innstrømning med luft. Alle beregninger som utføres benytter samme trykk-enhet som rådata fra labview programmet (barg). I regulerbarhetsanalysen velges det ut et operasjonspunkt som det sees nærmere på. Fig. 3.14 viser et bifurkasjonsdiagram for MiniLoopen. Røde linjer er data fra Storkaas forenklede modell, mens blå prikker angir eksperimentelle data. De røde stiplede linjene indikerer systemets ustabile stasjonære punkter. Til venstre for bifurkasjonspunktet ($z \approx 20\%$) er punktene stabile, mens de er ustabile til høyre for bifurkasjonspunktet. De røde heltrukne linjene representerer maksimum og minimum trykk-verdier for åpen sløyfe trykk-syklus.

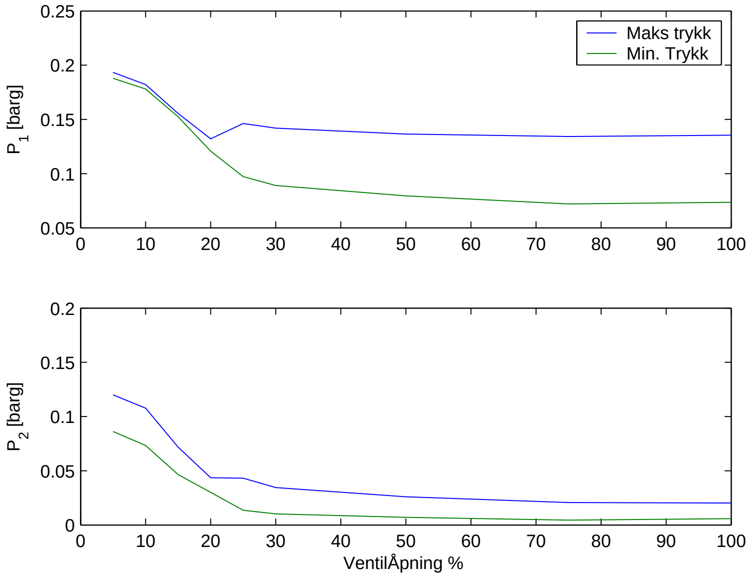
For at regulatoren skal fungere tilfredsstillende må ventilens aktuator kunne påvirke prosessen betydelig. Ved høy til medium ventilåpning er trykkfallet over ventilen for lavt til at en liten endring i ventilens åpning skal kunne påvirke prosessen merkbart. Det betyr at det eneste interessante operasjonsområde er fra lav til medium ventilåpning. Det kan også sees fra bifurkasjonsdiagrammet, som viser små endringer for høy til medium ventilåpning. I



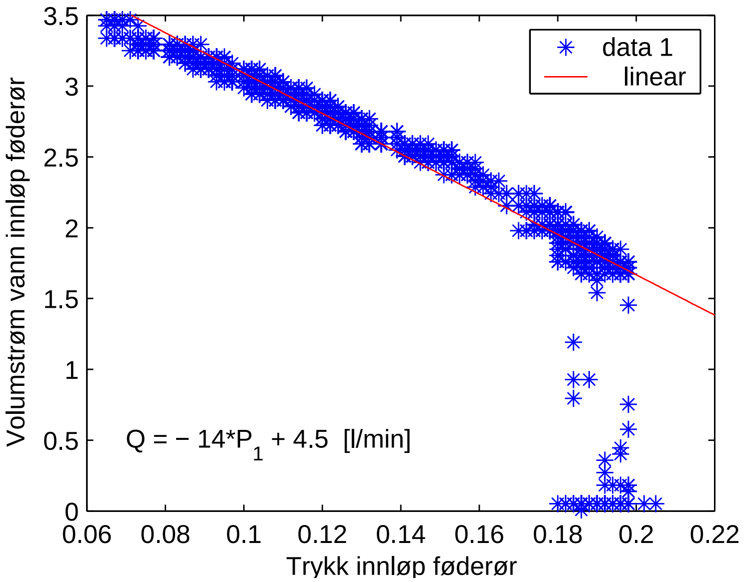
Figur 3.10: Grafisk programmering i LabVIEW



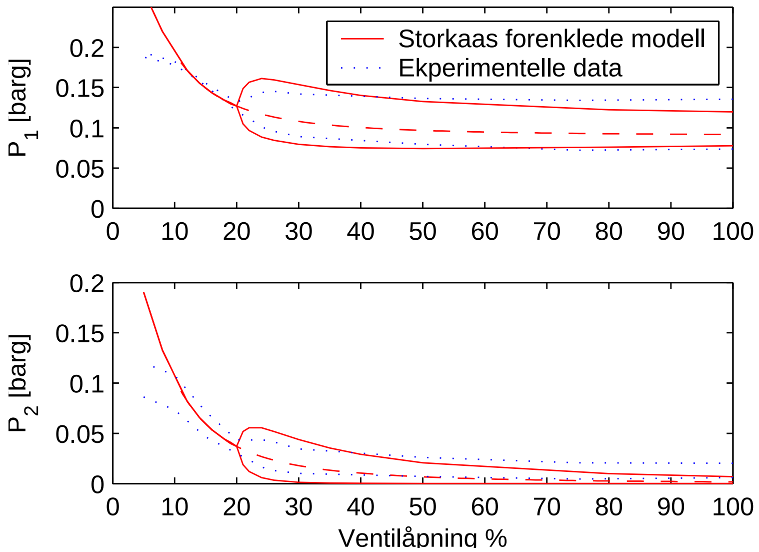
Figur 3.11: Program struktur - VI hiarki



Figur 3.12: Bifurkasjonsdiagram for MiniLoop



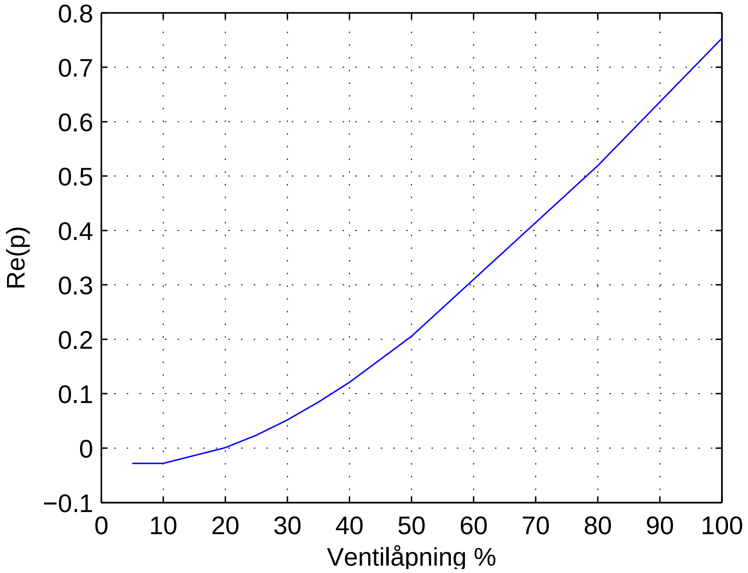
Figur 3.13: Trykkavhengig volumstrœm



Figur 3.14: Bifurkasjons diagram for MiniLoop for Storkaas forenklede modell

tuningen av Storkaas modell er det derfor lagt vekt på å tilpasse bifurkasjonsdiagrammet for lave ventilåpninger. Det ustabile stasjonære område er viktigere enn det stabile område med trykk-svingninger, ettersom målet er å oppnå stasjonær strømning med regulering i et ustabilt område. Den stasjonære del i Fig. 3.14 er i akseptabel overensstemmelse med eksperimentelle data. Trykksensor P_2 oppstrøms separatoren måler lave verdier for differensielle trykk og er følsom for støy. Det er ca. 15 cm i høydeforskjell mellom trykksensorens plassering og reguleringsventilen som bl.a. kan forklare hvorfor den ustabile stasjonære løsningen for P_2 ved Storkaas forenklede modell krysser den eksperimentelle P_2-minimumlinja. Det eksisterer også flere andre usikkerheter. Antatt konstant gasstrøm inn og justerings-parameterene i Espen Storkaas modell medfører en viss usikkerhet. Resultatet blir et bifurkasjonsdiagram for P_2 som avviker fra eksperimentelle data, mer enn hva bifurkasjonsdiagrammet for P_1 gjør.

Reell del av den "verste" polen (som ligger lengst inne i det høyre halvplan) er evaluert for systemet med ulike ventilåpninger i Fig. 3.15. Polene forsvinner lengre inn i RHP (right half plane) med økende ventilåpning. Ved $z \approx 20\%$ er 2 av polene på den imaginære akse. Dette stemmer med bifurkasjonsdiagrammet som tydelig viser at systemet blir stabilt for $z \leq 20\%$ og ustabilt for $z > 20\%$. Se Tab. A.3 for data.



Figur 3.15: Reell del av den ”verste” polen

3.4 Regulerbarhetsanalyse

3.4.1 Begrensninger forårsaket av ustabile poler og nullpunkter

Denne analysen tar utgangspunkt i en linearisert modell rundt et typisk ustabilt operasjonspunkt. Derfor velges operasjonspunkt $z = 30\%$. Systemet er ustabilt for denne ventilåpningen ved åpen sløyfe ettersom det finnes et komplekst polpar i RHP. Dette kan sees ut fra Fig. 3.15, som tydelig viser at for ventilåpninger større enn 20% vil reell del av den ”verste ” polen være i RHP. RHP-poler gir en nedre grense for båndbredden i systemet. Fra Fig. 3.15 vil dermed kravet om minimum båndbredde øke med økende ventilåpning. Polene kan flyttes med tilbakekobling for å gjøre systemet stabilt. RHP nullpunkter gir inversrespons og en øvre begrensning i båndbredden. For å oppnå stabilitet med en fornuftig ytelse kreves

$$\omega_C > 1.15|p| \qquad z_n > 2.3|p| \tag{3.1}$$

Trykket oppstøms gir et enkelt LHP (left half plane) nullpunkt. Dette gir ingen fundamentale regulerings problemer, slik at P_1 vil være et bra valg av måleverdi for enkel regulering med et målepunkt. Denne måleverdien kan imidlertid være vanskelig å oppnå offshore, og andre måleverdier bør derfor også vurderes. Fra båndbredde begrensningene gitt i lign. 2.10 kan det ikke eksistere RHP nullpunkter som er mindre enn ca. 0.9104 for ventilåpning 30%.

Tabell 3.3: Ulike målepunkter

Målepunkt	Enhet	Beskrivelse
P_1	[bar]	Oppstrøms trykk (innløp føderør)
P_2	[bar]	Nedstrøms trykk foran choke ventil
ρ_T	$\frac{kg}{m^3}$	Tetthet gjennom ventil
W	$\frac{kg}{s}$	Total massestrøm gjennom ventil
Q	$\frac{m^3}{s}$	Total volumstrøm gjennom ventil

Tabell 3.4: Systemets poler

Ventilåpning	λ_1	λ_2	λ_3	RHP-pol lengde
$z = 30\%$	-29.0407	$0.0520 + 0.3924i$	$0.0520 + 0.3924i$	0.3958

Tabell 3.5: Nullpunkter for systemet ved operasjonspunkt for ventil 30%

P_1	P_2	ρ_T	W	Q
-0.3228	5.5953	$0.0306 + 0.0528i$	-46.4772	-9.2966
	0.9429	$0.0306 - 0.0528i$	$-0.0130 + 0.0884i$	-0.2900
			$-0.0130 - 0.0884i$	-0.0865

Tabell 3.6: Begrensninger i båndbredden.

Grenser	ventil 30%
$z_n >$	0.9104
$\omega_C >$	0.4552

Nullpunktene er gitt i Tab.3.5. ρ_T kan åpenbart ikke brukes som måleverdi pga. for lave nullpunkt-verdier. Fra Tab. A.2 minker det "verste" nullpunktet for trykk P_2 med økende ventilåpning. Ved oppgitt operasjonspunkt på 30% åpning er imidlertid nullpunktet høyere enn 0.9104, slik at regulerbarhetsanalysen ikke utelukker P_2 som måling for å stabilisere systemet. Modellen i artikkelen [7] oppnår nullpunkter for P_2 som er mindre enn kravet for akseptabel regulering, og konkluderer med at trykket P_2 ikke er egnet som måleverdi for å stabilisere systemet. Det eksisterer imidlertid en del usikkerheter i eksperiementelle data og data fra Storkaas forenklede modell (som omtales på side 19). Liten differanse mellom nullpunkt-grense og nullpunkt ved 30% gjør det derfor vanskelig å trekke en konklusjon om P_2 er aktuell som måleverdi til regulator fra en ren regulerbarhetsanalyse. På grunn av allerede nevnte usikkerheter anbefales dermed andre målinger for regulering.

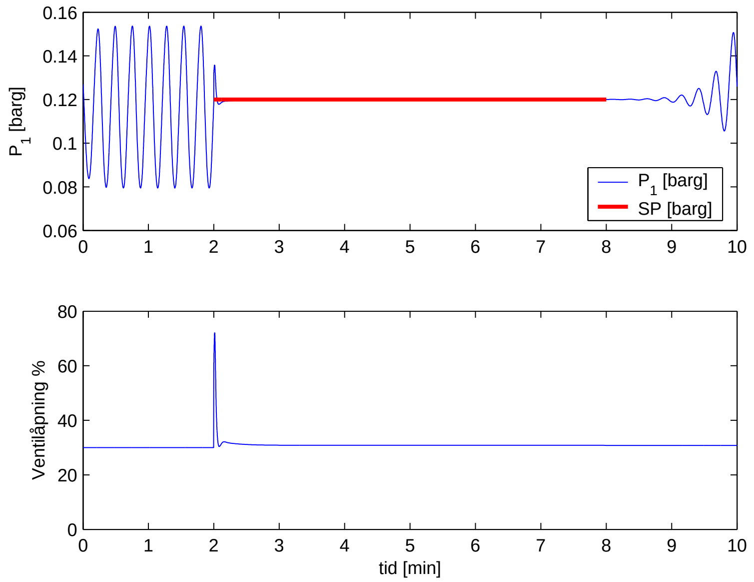
Volumstrøm Q eller massestrøm W er bedre alternativer. Begge har LHP nullpunkter nær imaginær akse. Det er dermed mulig å stabilisere systemet med hver av disse som måleverdier i en enkel regulering, men pga. for lite integralvirkning vil systemet drifte vekk fra referanseverdien. Det er mulig å unngå avvik fra referansen ved stasjonær tilstand ved bruk av en kaskadestruktur [7].

MiniLoopen har bare regulering med P_1 som måleverdi. Selv om regulering med P_1 gir gode resultater kan det være ønskelig med anlyse av andre alternativer, siden verdi for P_1 kan være vanskelig å oppnå offshore. Videre arbeid med MiniLoopen kan bli å oppnå verdier for volumstrøm og massestrøm fra slugsensorene og regulere med disse som prosessvariabler. Arbeid med dette er ikke prioritert i denne oppgaven.

3.5 Regulering

3.5.1 Espen Storkaas modell - PI regulering med P_1 som måleverdi

Fra regulerbarhetsanalysen vil den beste målingen til regulatoren være trykket oppstrøms, P_1. Fig. 3.16 viser åpen sløyfe de 2 første minuttene ved ventilåpning på 30%. Regulatoren settes på etter 2 minutter med referanse lik 0.12 barg. Etter 8 minutter slås regulatoren av. Reguleringen er god med P_1 som måling, ventilbruken er akseptabel og responsen er rask. Modellen viser tydelig at regulatoren stabiliserer strømningen ved en ventilåpning som befinner seg i det ustabile området ved åpen sløyfe (Se bifurkasjonsdiagram i Fig. 3.14 og "verste pol" i Fig. 3.15). Strømningen følger referanse-trykket frem til ca. 9 minutter hvor de karakteristiske trykksvingningene for riser-



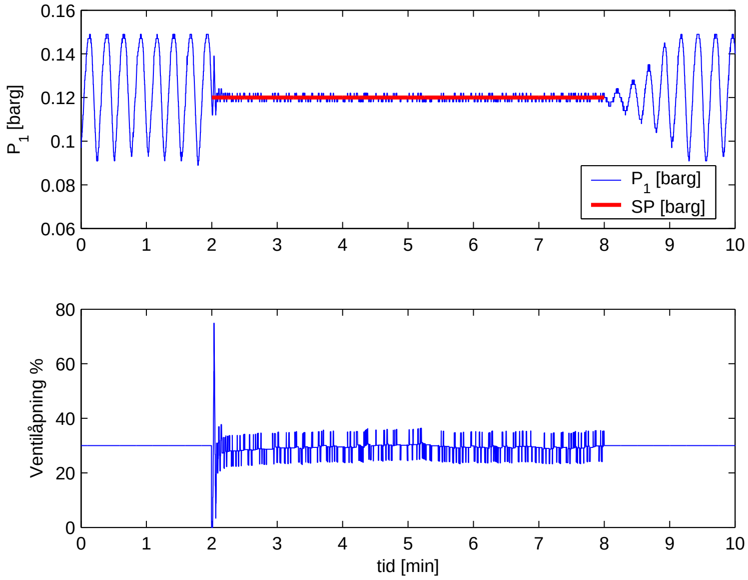
Figur 3.16: PI-regulering med trykk P_1 som måleverdi for Storkaas forenklede modell.

indusert slugging igjen kan sees.

Forsterkning og integraltidskonstanten ble funnet ved å oppnå en *lav* verdi for summen av maksimal topp for sensitivitet- og komplementær funksjonen. Det ble forsøkt med ulike verdier for forsterkning og integraltid som gav lav verdi for $M_S + M_T$ *og* akseptabel regulering. Med forsterkning $Kc = -25\ bar^{-1}$ og $\tau_I = 10$s ble $M_S = 1.0387$ og $M_T = 1.2619$ og reguleringen var god. Trykk P_2, volumstrøm gjennom ventilen, og massestrøm gjennom ventilen er vist for Storkaas forenklede modell i Fig. A.15. Tab. 3.7 viser regulator parametre for både Storkaas forenklede modell og eksperimentell verifikasjon.

Tabell 3.7: Regulatorparametre og maksimal toppverdier

K_p [bar^{-1}]	τ_I [s]	τ_D [s]	SP [barg]	M_S	M_T
-25	10	0	0.12	1.0387	1.2619



Figur 3.17: PI-regulering med trykk P_1 som måleverdi for eksperimentell MiniLoop

3.5.2 PI-regulering med P_1 som måleverdi for eksperimentell MiniLoop

Fig. 3.17 viser åpen sløyfe de 2 første minuttene ved ventilåpning på 30%. Regulatoren settes på etter 2 minutter med referanse lik 0.12 barg. Etter 8 minutter slås regulatoren av. Figuren viser tydelig at regulatoren stabiliserer strømningen ved en ventilåpning, som befinner seg i det ustabile området ved åpen sløyfe. Ventilbruken er større enn for den forenklede modellen, og systemet oppnår trykkamplitudene for åpen sløyfe raskere enn regulering med forenklet modell når regulatoren slås av. Storkaas forenklede modell er uten støy slik at trykket holder seg nær referansen over lengre tid enn for eksperimentell MiniLoop når regulatoren slås av. Fig. 3.16 og Fig. 3.17 viser forøvrig en god overensstemmelse.

3.6 Forslag til videre arbeid

- Når en enkel PI-regulator klarer å stabilisere systemet vil det være interessant å kunne sammenligne resultatet med en mer avansert LQG-regulator.

- MiniLoopen har bare regulering med P_1 som måleverdi. Selv om regulering med P_1 gir gode resultater kan det være ønskelig med anlyse av andre alternativer, siden måleverdi for P_1 kan være vanskelig å oppnå offshore. Videre arbeid med MiniLoopen kan bli å oppnå verdier for volumstrøm og massestrøm fra slugsensorene og bruke disse som måleverdier til regulator. Arbeid med dette er ikke prioritert i denne oppgaven.

- Skifte ut vannet i MiniLoopen og tilsette for eksempel litt frostvæske for å hindre algevekst.
- Overføring av miniloop.vi til Matlab og Simulink for on-line regulering. Matlab åpner muligheter for mer avansert regulering.
- Regulatoren ble tunet til akseptabel regulering. Bedre tuning av regulatoren kan oppnås.
- MiniLoopen mangler gassratemåler. Alternativer til dyre industrielle ratemålere for gass bør undersøkes nærmere.

Kapittel 4

Konklusjon

Eksperimentelle data fra MiniLoopen ved bifurkasjonsdiagrammet i Fig. 3.12 viser den samme trenden som bifurkasjonsdiagrammer gitt i [7],[5],[4]. Espen Storkaas forenklede modell viser god tilpasning til eksperimentelle data fra MiniLoopen.

Trykk P_1 er den beste måleverdien for SISO regulering. P_2 som måleverdi anbefales ikke. Eksperimentelle data for P_2 er følsomme for støy. Det gir usikkerhet i målingen og en regulerbarhetsanalyse som gir liten differanse mellom nullpunkt-grense for båndbredde og nullpunkt for trykksensor P_2. Volumstrøm Q eller massestrøm W er bedre alternativer. Begge har LHP nullpunkter nær imaginær akse. Det er dermed mulig å stabilisere systemet med hver av disse som måleverdi, men systemet vil drifte bort fra referansen dersom SISO regulator benyttes [7].

PI-regulator med forsterkning $Kc = -25\ bar^{-1}$ og $\tau_I = 10$ s stabiliserer strømningen i et ustabilt område for åpen sløyfe. Storkaas forenklede modell med PI-regulator stemmer bra med den eksperimentelle reguleringen. Reguleringen er god med P_1 som måleverdi, ventilbruken er akseptabel og responsen er rask. Espen Storkaas forenklede slug-modell viser at regulatorer basert på modellen er i stand til å stabilisere strømningen for riser-indusert slugging.

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[6] S. Skogestad and I. Postlethwaite, *Multivariable Feedback Control- Analysis and Design.* John Wiley & Sons Ltd., second ed., 2001.

[7] E. Storkaas and S. Skogestad, "Cascade control of unstable systems with application to stabilization of slug flow," June 2003.

Tillegg A

Tofase MiniLoop

A.1 Leverandører

En oversikt over de ulike leverandørene er gitt i Tab. A.1

A.2 Kalibrering

A.2.1 Trykkmålere

Trykkmåler ved innløp føderør viste 0.23 V ved referanse atmosfærisk trykk. Sammenhengen mellom trykk og spenning ut er linært. Definerer $x = [0.23 \;\; 4.5]$ V og $y = [0 \;\; 1]$ bar hvor x er spenning og y er trykk. Fig. A.1 viser kalibreringen av trykksensoren ved innløpet. Trykkmåler oppstrøms separator viste 0.20 V ved referanse atmosfærisk trykk. Definerer dermed $x = [0.20 \;\; 4.5]$ V og $y = [0 \;\; 1]$ bar hvor x er spenning og y er trykk. Fig. A.2 viser kalibreringen og konverteringen fra spenning til trykk for trykksensor oppstrøms separator.

A.2.2 Ratemåler vann

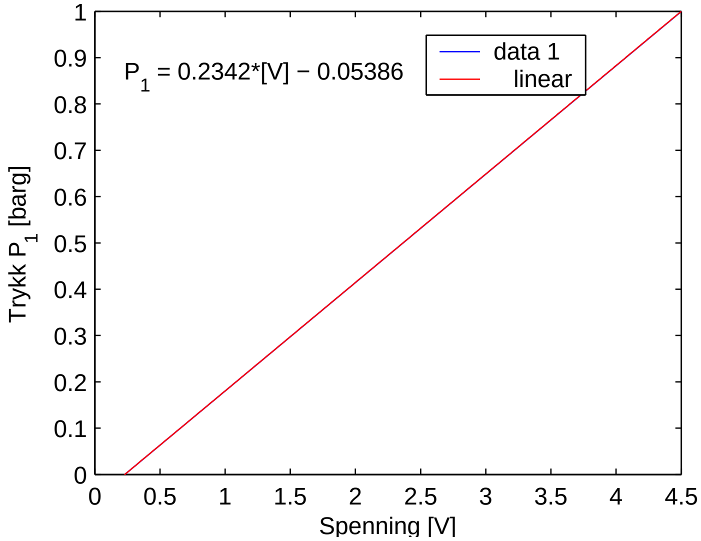
For data-logging av volumstrøm vann ble følgende punkter funnet etter ratemålerens kalibrering fra leverandøren, $x = [4.0 \;\; 7.37]$ mA og $y = [0 \;\; 12.6]$ l/min.

A.2.3 Reguleringsventil

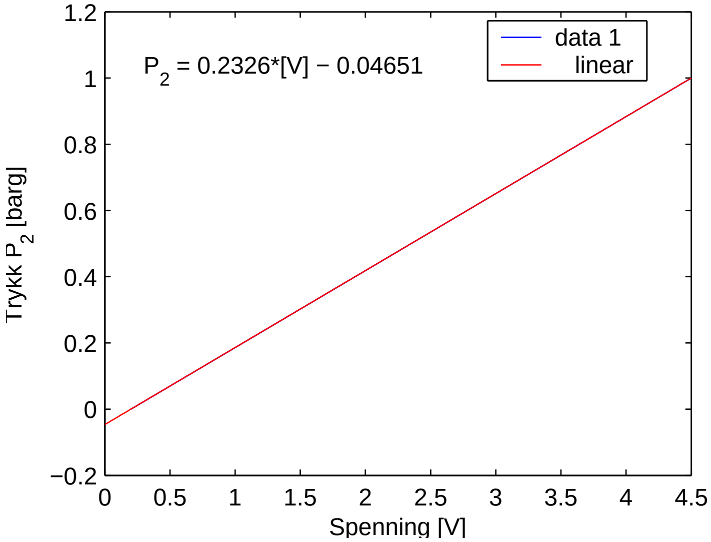
Reguleringsventilen styres av et strømsignal mellom $4 - 20$ mA. Det ble funnet vha. av multimeter at styringssignalet egentlig var $3.8 - 21.8$ mA. Dette ble korregert i LabVIEW programmet slik at ventilen ved 4 mA tilsvarer 0% åpning og 20 mA tilsvarer 100% åpning.

Tabell A.1: Teknisk utstyr (priser er oppgitt eks. MVA)

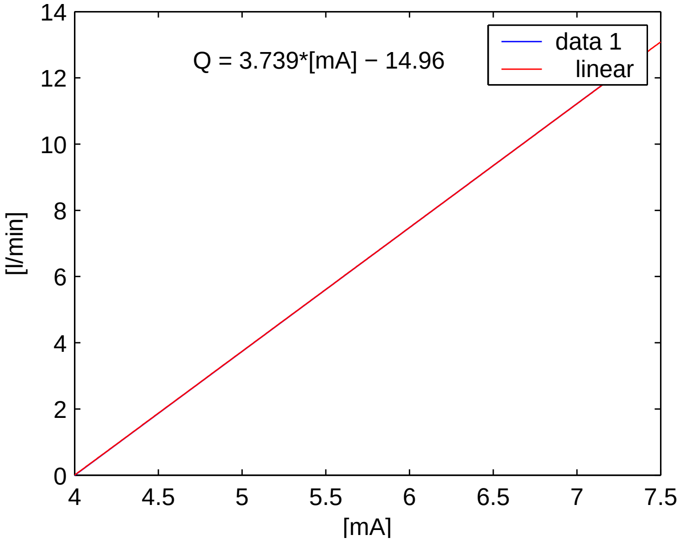
Utstyr	Type	Levert av	Pris [NOK]
Ratemåler vann (FV.T)	Gemu 3021	J.S. Cock P.O.BOX 68 Stovner N-0913 OSLO Tel:+47 22 21 51 00	3991
V-1	Gemu 554		4502
AI-Modul	FP-AI-100	National Instruments P.O.BOX 177 N-1386 Asker Tel:+47 66 90 76 60	2745
AO-Modul	FP-AO-210		3555
Termineringsbase	FP-TB-2		1512
Nettverks-Modul	FP-1000		3105
Signalomformer	MICROANALOG DC/DC select	JF.Knudtzen AS P.O.BOX 160 N-1378 Nesbru Tel:+47 66 98 33 50	1550
PT	MPX5100DP	Silica/Avnet Nortec AS P.O.BOX 63 N-1371 Asker Tel:+47 66 77 36 00	796 (tot.inkl.mva)
Pumpe	Eheim 1060	Dyrebutikken City Syd	1566(inkl.mva)
S-1/S-2	E3X-DA-N	Omron P.O.BOX 109 Bryn N-0611 OSLO Tel:+47 22 65 75 00	2825(inkl.mva)



Figur A.1: Kalibrering av trykkmåler innløp føderør og konvertering av spenning til trykk



Figur A.2: Kalibrering av trykkmåler oppstrøms separator og konvertering av spenning til trykk



Figur A.3: Konvertering av strømsignal til volumstrøm

A.3 MiniLoop - Eksperimentelle data

A.3.1 Filtrerte data

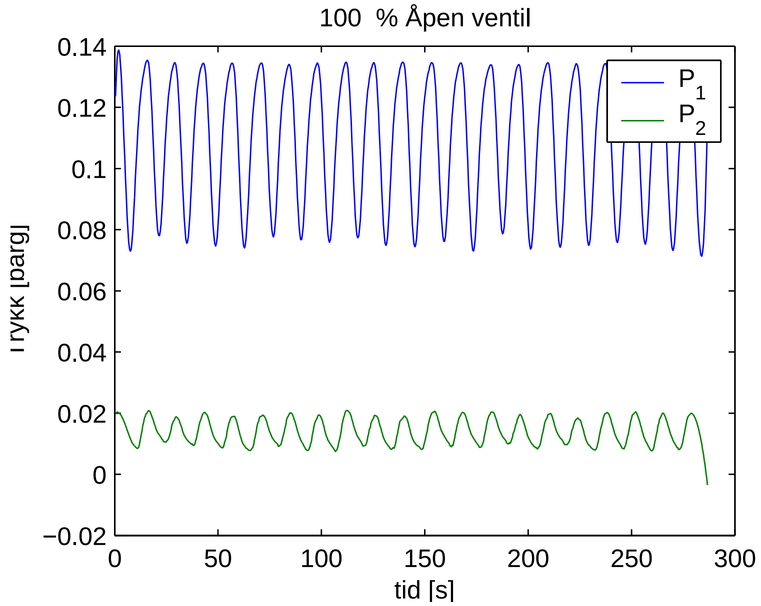
Eksperimentelle data uten regulering ble lagret.Fig. A.4, A.5, A.6, A.7, A.8, A.9, A.10, A.11 og Fig. A.12 viser trykk transientene ved ulike ventilåpninger etter at systemet har stabilisert seg for gitt ventilåpning.

A.3.2 Rådata

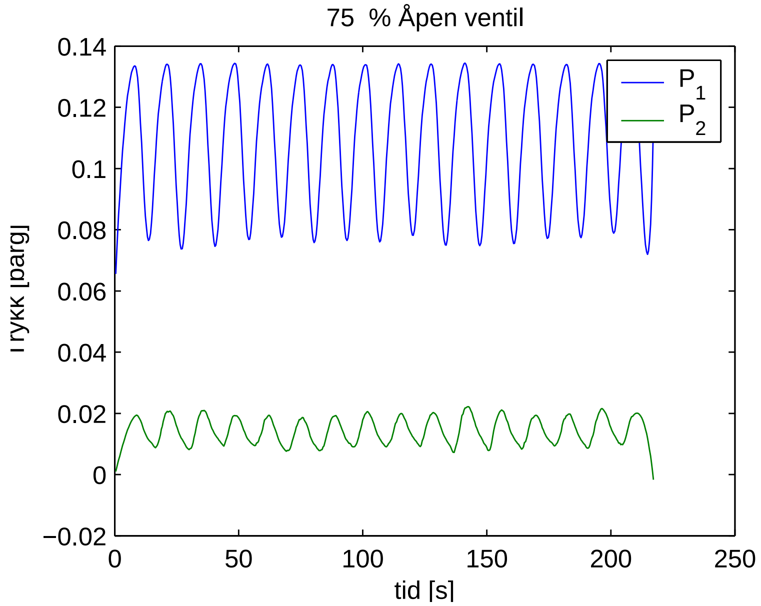
Fig. A.13 viser det ”verste” eksempelet av målestøy for trykksensor P_2.

Savitzky-Golay filter ble brukt. Fra Matlab Help:

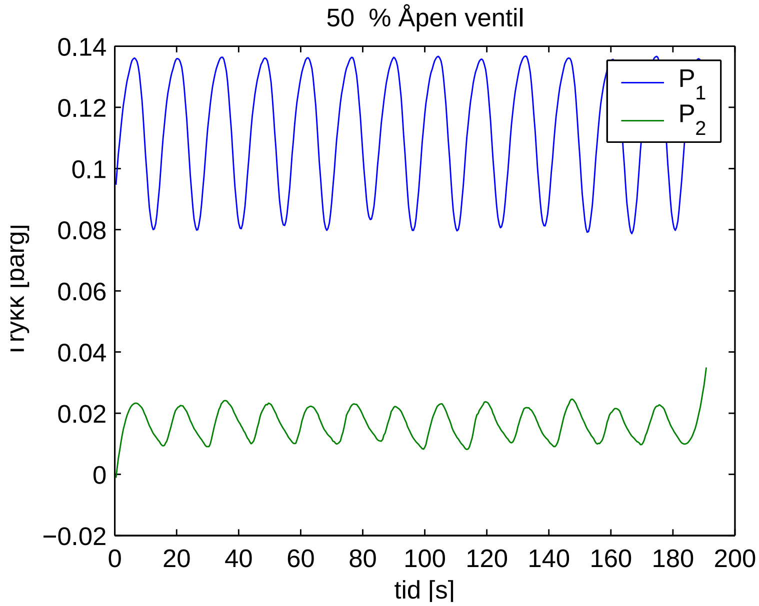
> Savitzky-Golay filters are optimal in the sense that they minimize the least-squares error in fitting a polynomial to frames of noisy data.
>
> `y = sgolayfilt(x,k,f) applies a Savitzky-Golay FIR smoothing filter to the data in vector x.If x is a matrix, sgolayfilt operates on each column. The polynomial order k must be less than the frame size, f, which must be odd. If k = f-1, the filter produces no smoothing.`



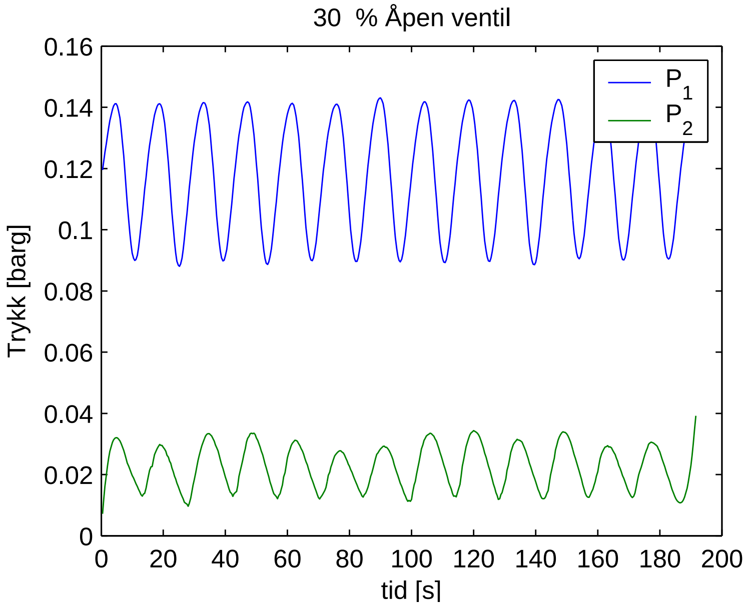
Figur A.4: Trykk data uten regulering, ventilåpning 100%



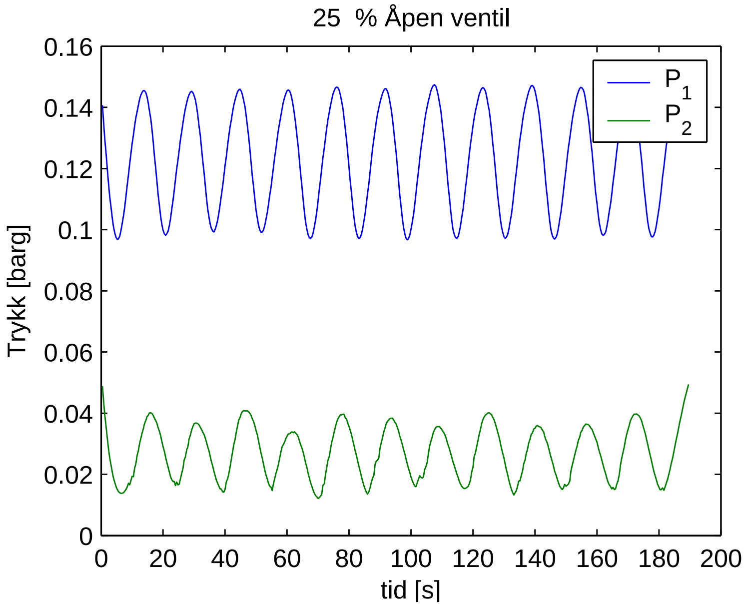
Figur A.5: Trykk data uten regulering, ventilåpning 75%



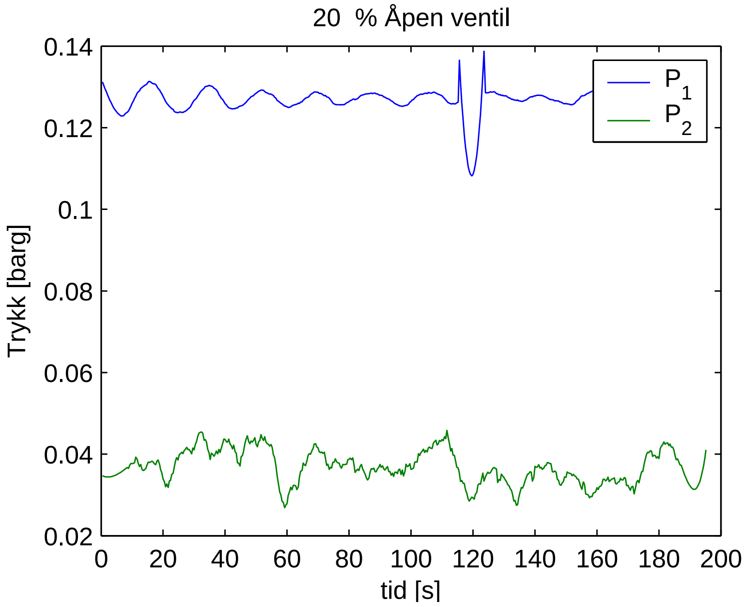
Figur A.6: Trykk data uten regulering, ventilåpning 50%



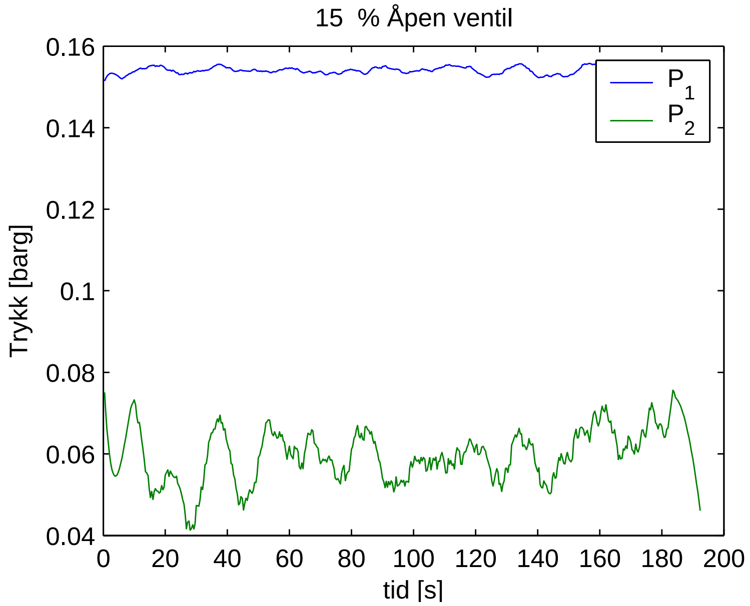
Figur A.7: Trykk data uten regulering, ventilåpning 30%



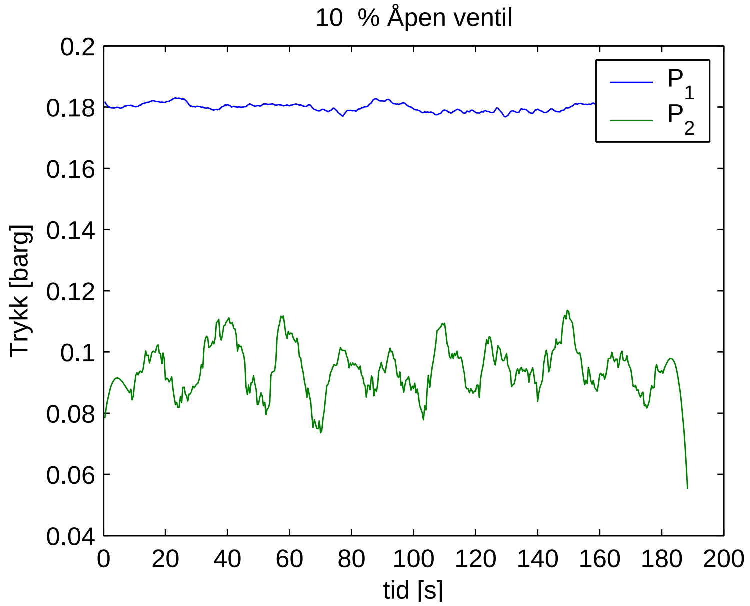
Figur A.8: Trykk data uten regulering, ventilåpning 25%



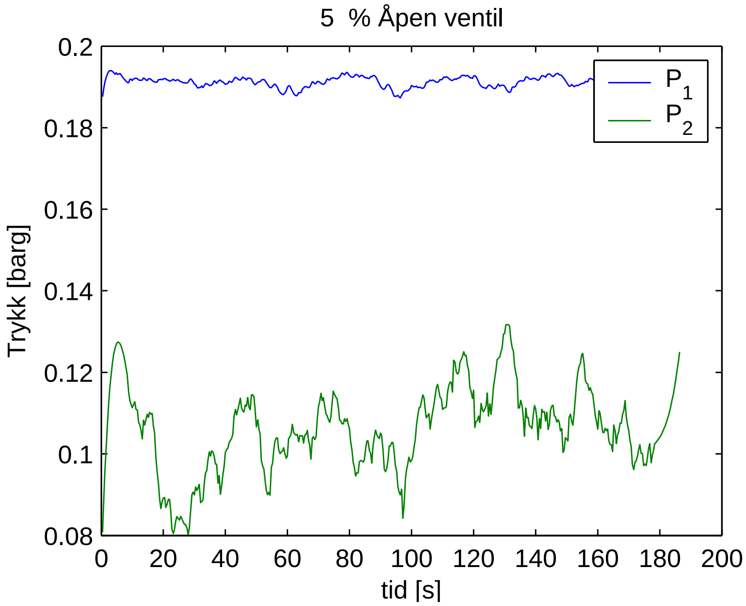
Figur A.9: Trykk data uten regulering, ventilåpning 20%



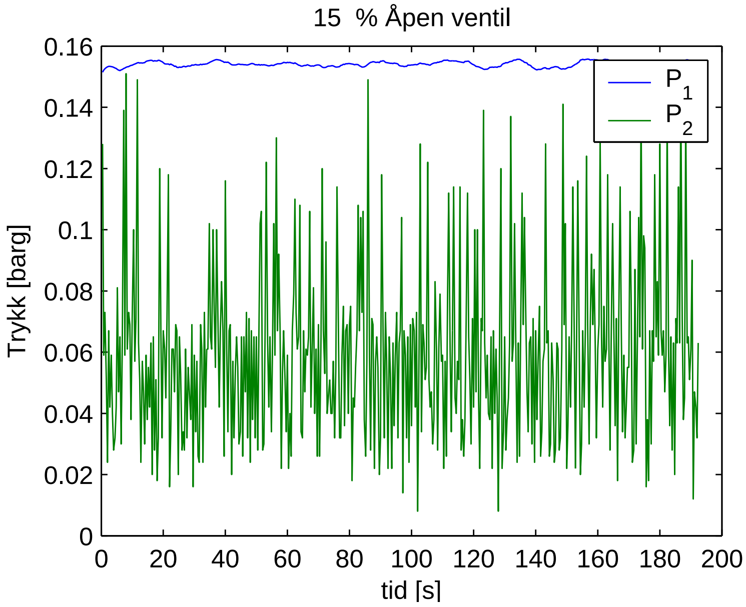
Figur A.10: Trykk data uten regulering, ventilåpning 15%



Figur A.11: Trykk data uten regulering, ventilåpning 10%



Figur A.12: Trykk data uten regulering, ventilåpning 5%



Figur A.13: Trykk data uten regulering og filter

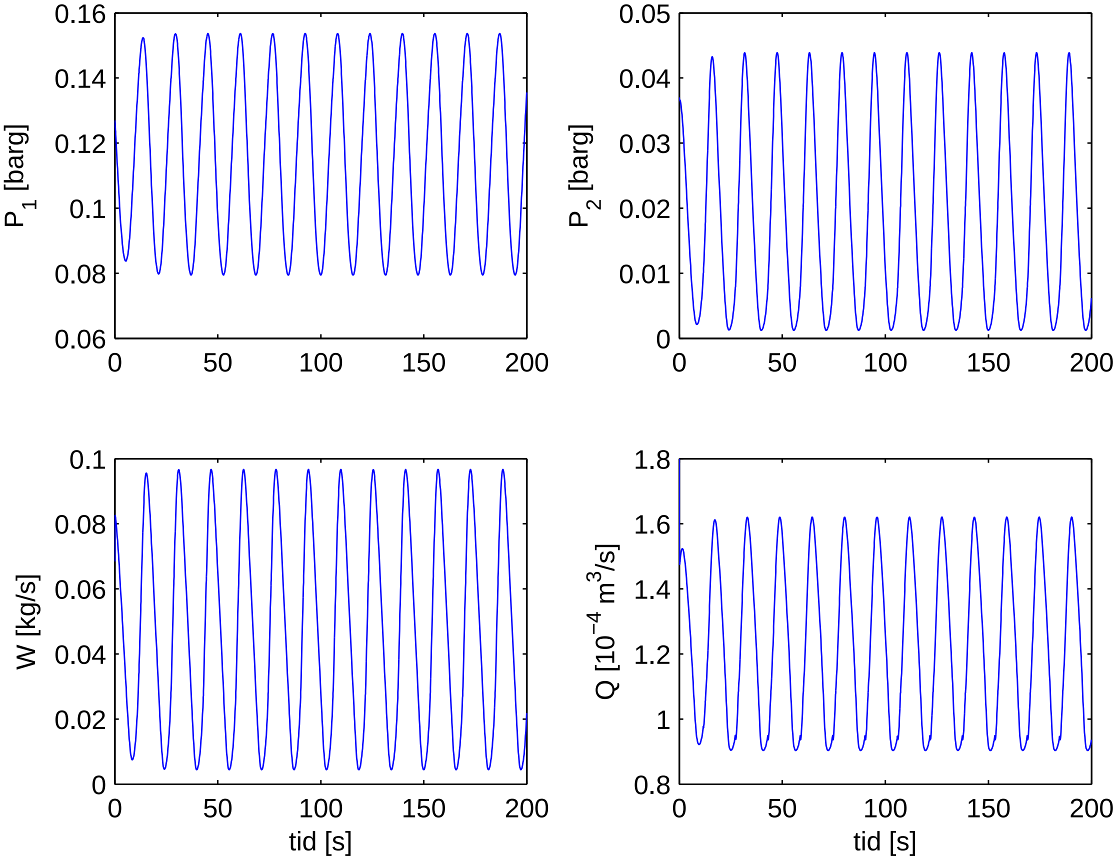
A.4 Data fra Storkaas forenklede modell

Tabell A.2: Nullpunkter for systemet ved operasjonspunkt z

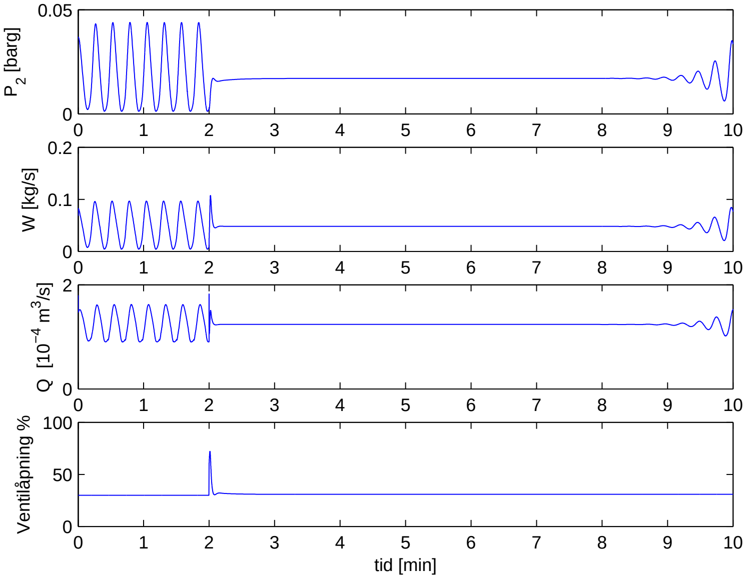
Ventilåpning	P_1	P_2	ρ_T	W	Q
$z = 5\%$	-0.2786	$2.0125 + 0.7382i$	$0.0235 + 0.0728i$	-46.6987	-8.8827
		$2.0125 - 0.7382i$	$0.0235 - 0.0728i$	$-0.0137 + 0.0973i$	-0.2430
				$-0.0137 - 0.0973i$	-0.1063
$z = 10\%$	-0.2786	$2.0125 + 0.7382i$	$0.0235 + 0.0728i$	-46.6987	-8.8827
		$2.0125 - 0.7382i$	$0.0235 - 0.0728i$	$-0.0137 + 0.0973i$	-0.2430
				$-0.0137 - 0.0973i$	-0.1063
$z = 20\%$	-0.3126	4.9620	$0.0288 + 0.0578i$	-46.5039	-9.1868
		1.0314	$0.0288 - 0.0578i$	$-0.0131 + 0.0902i$	-0.2794
				$-0.0131 - 0.0902i$	-0.0901
$z = 25\%$	-0.3190	5.3702	$0.0299 + 0.0547i$	-46.4859	-9.2554
		0.9717	$0.0299 - 0.0547i$	$-0.0130 + 0.0890i$	-0.2861
				$-0.0130 - 0.0890i$	-0.0878
$z = 30\%$	-0.3228	5.5953	$0.0306 + 0.0528i$	-46.4772	-9.2966
		0.9429	$0.0306 - 0.0528i$	$-0.0130 + 0.0884i$	-0.2900
				$-0.0130 - 0.0884i$	-0.0865
$z = 35\%$	-0.3251	5.7325	$0.0310 + 0.0517i$	-46.4722	-9.3231
		0.9266	$0.0310 - 0.0517i$	$-0.0130 + 0.0880i$	-0.2924
				$-0.0130 - 0.0880i$	-0.0857
$z = 40\%$	-0.3267	5.8221	$0.0313 + 0.0509i$	-46.4691	-9.3409
		0.9165	$0.0313 - 0.0509i$	$-0.0130 + 0.0878i$	-0.2940
				$-0.0130 - 0.0878i$	-0.0852
$z = 50\%$	-0.3286	5.9282	$0.0317 + 0.0499i$	-46.4655	-9.3627
		0.9049	$0.0317 - 0.0499i$	$-0.0130 + 0.0875i$	-0.2959
				$-0.0130 - 0.0875i$	-0.0846
$z = 80\%$	-0.3307	6.0440	$0.0320 + 0.0488i$	-46.4617	-9.3872
		0.8929	$0.0320 - 0.0488i$	$-0.0130 + 0.0871i$	-0.2981
				$-0.0130 - 0.0871i$	-0.0840
$z = 100\%$	-0.3313	6.0707	$0.0321 + 0.0486i$	-46.4610	-9.3930
		0.8904	$0.0321 - 0.0486i$	$-0.0130 + 0.0871i$	-0.2987
				$-0.0130 - 0.0871i$	-0.0838

Tabell A.3: Poler for systemet ved operasjonspunkt z

Ventilåpning	Poler
$z = 5\%$	-28.2729
	-0.0281 + 0.1867i
	-0.0281 - 0.1867i
$z = 10\%$	-28.2729
	-0.0281 + 0.1867i
	-0.0281 - 0.1867i
$z = 20\%$	-28.5182
	0.0007 + 0.2826i
	0.0007 - 0.2826i
$z = 25\%$	-28.7533
	0.0239 + 0.3379i
	0.0239 - 0.3379i
$z = 30\%$	-29.0407
	0.0520 + 0.3924i
	0.0520 - 0.3924i
$z = 35\%$	-29.3789
	0.0845 + 0.4449i
	0.0845 - 0.4449i
$z = 40\%$	-29.7669
	0.1211 + 0.4949i
	0.1211 - 0.4949i
$z = 50\%$	-30.6895
	0.2054 + 0.5853i
	0.2054 - 0.5853i
$z = 80\%$	-34.5795
	0.5191 + 0.7636i
	0.5191 - 0.7636i
$z = 100\%$	-38.0562
	0.7530 + 0.7977i
	0.7530 - 0.7977i



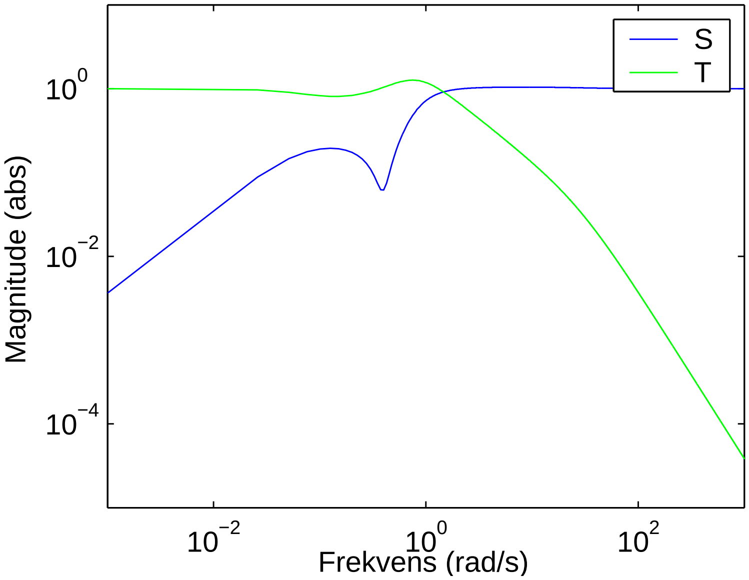
Figur A.14: Åpen sløyfe for ventilåpning 30%. Storkaas forenklede modell.



Figur A.15: PI regulering med Storkaas forenklede modell og trykk P_1 som måleverdi

A.5 Regulering

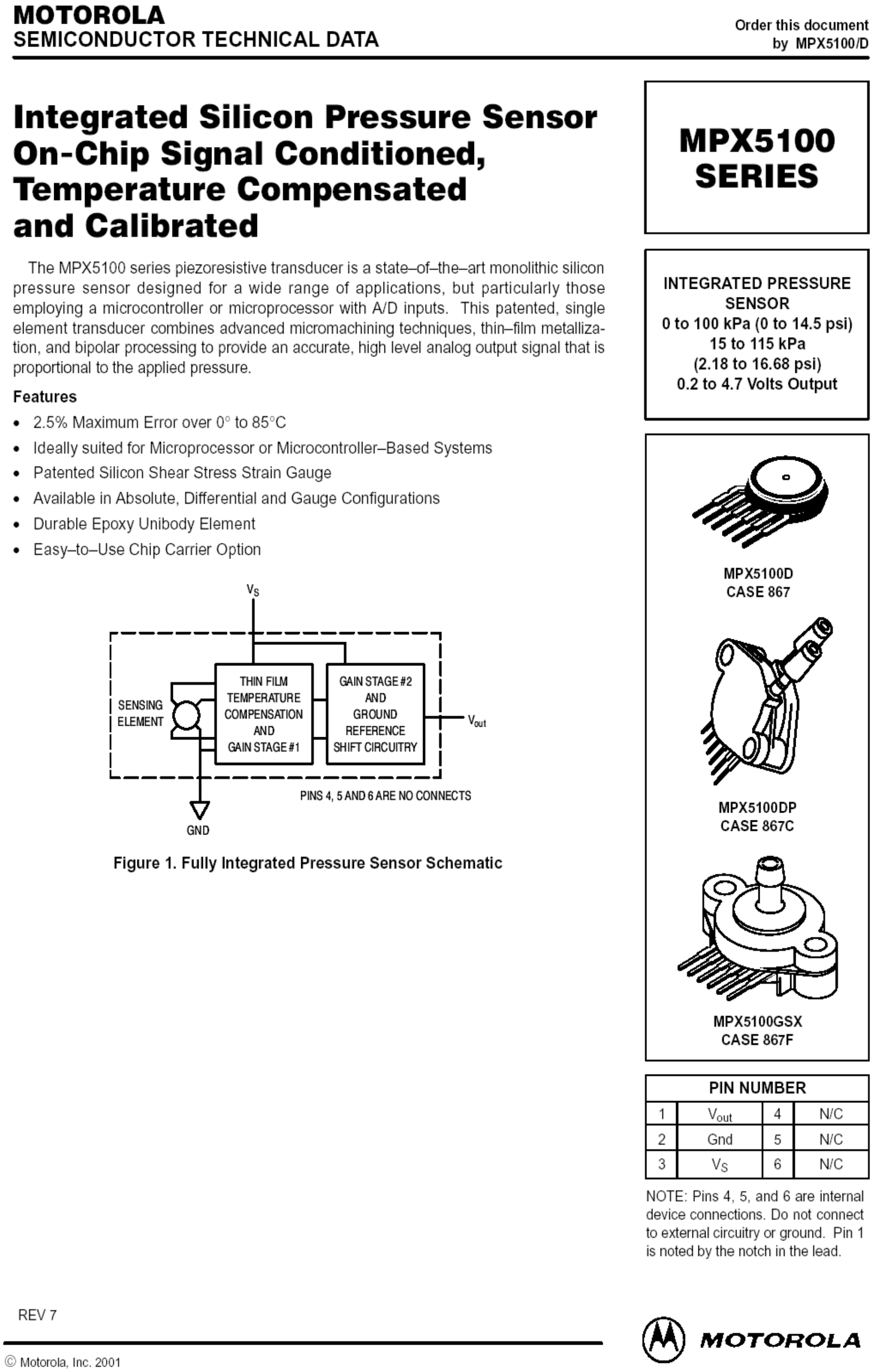
Fig. A.16 viser sensitivitet-og komplementær sensivitetfunksjonen for PI regulering av Storkaas forenklede modell med P_1 som prosessvariabel ved operasjonspunkt $z = 30\%$. Fig.A.15 viser data fra Storkaas forenklede modell ved definert operasjonspunkt for PI regulator og gitte parametre i Tab. 3.7.



Figur A.16: PI regulering med Storkaas forenklede modell med parametre som i Tab. 3.7

Tillegg B

Data-ark



MOTOROLA
SEMICONDUCTOR TECHNICAL DATA

Order this document
by MPX5100/D

Integrated Silicon Pressure Sensor On-Chip Signal Conditioned, Temperature Compensated and Calibrated

The MPX5100 series piezoresistive transducer is a state–of–the–art monolithic silicon pressure sensor designed for a wide range of applications, but particularly those employing a microcontroller or microprocessor with A/D inputs. This patented, single element transducer combines advanced micromachining techniques, thin–film metallization, and bipolar processing to provide an accurate, high level analog output signal that is proportional to the applied pressure.

Features

- 2.5% Maximum Error over 0° to 85°C
- Ideally suited for Microprocessor or Microcontroller–Based Systems
- Patented Silicon Shear Stress Strain Gauge
- Available in Absolute, Differential and Gauge Configurations
- Durable Epoxy Unibody Element
- Easy–to–Use Chip Carrier Option

Figure 1. Fully Integrated Pressure Sensor Schematic

MPX5100 SERIES

INTEGRATED PRESSURE SENSOR
0 to 100 kPa (0 to 14.5 psi)
15 to 115 kPa
(2.18 to 16.68 psi)
0.2 to 4.7 Volts Output

MPX5100D
CASE 867

MPX5100DP
CASE 867C

MPX5100GSX
CASE 867F

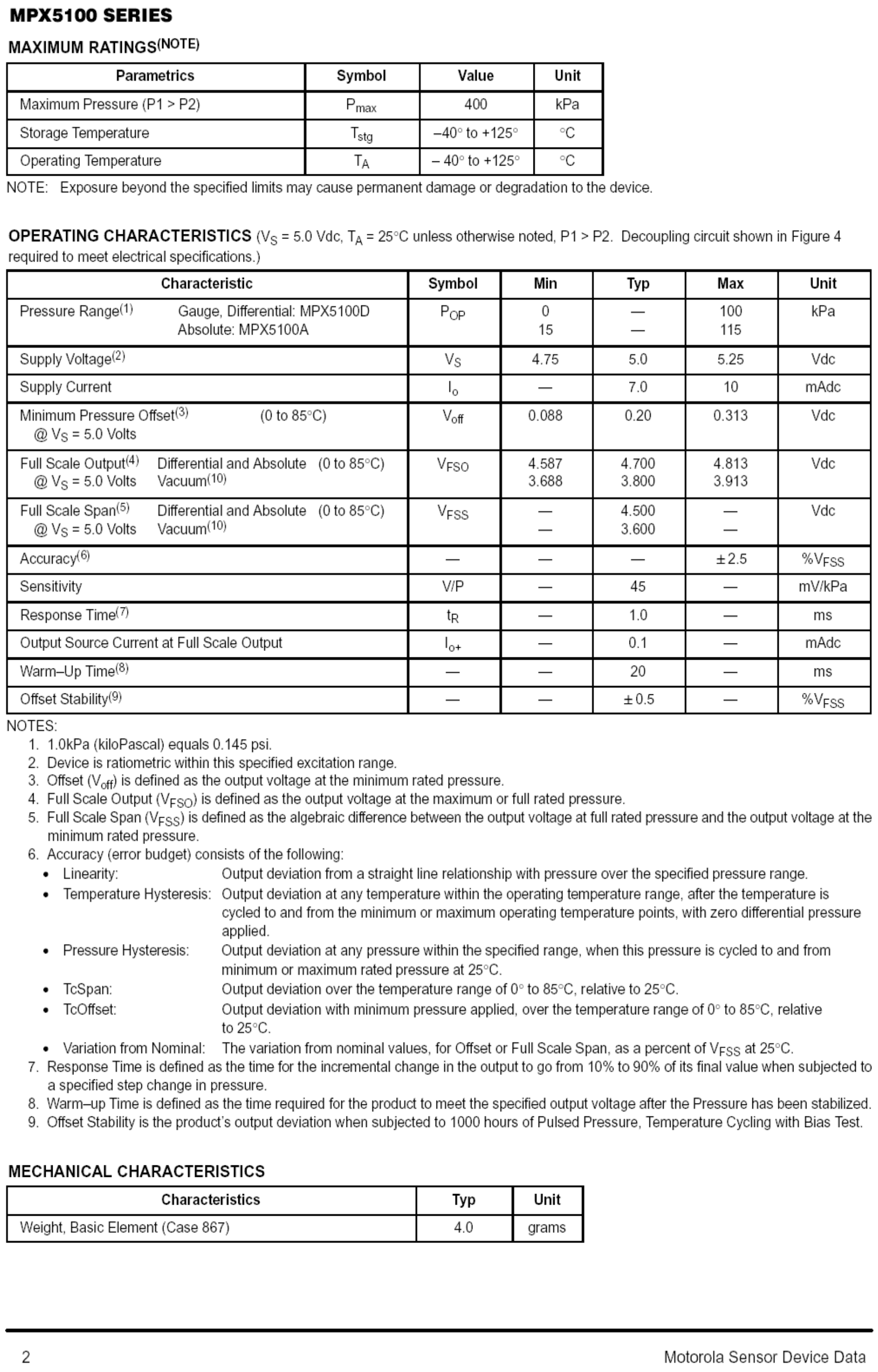
PIN NUMBER			
1	V_{out}	4	N/C
2	Gnd	5	N/C
3	V_S	6	N/C

NOTE: Pins 4, 5, and 6 are internal device connections. Do not connect to external circuitry or ground. Pin 1 is noted by the notch in the lead.

REV 7

MOTOROLA

Figur B.1: Data-ark Trykksensor



MPX5100 SERIES

MAXIMUM RATINGS(NOTE)

Parametrics	Symbol	Value	Unit
Maximum Pressure (P1 > P2)	P_{max}	400	kPa
Storage Temperature	T_{stg}	–40° to +125°	°C
Operating Temperature	T_A	– 40° to +125°	°C

NOTE: Exposure beyond the specified limits may cause permanent damage or degradation to the device.

OPERATING CHARACTERISTICS (V_S = 5.0 Vdc, T_A = 25°C unless otherwise noted, P1 > P2. Decoupling circuit shown in Figure 4 required to meet electrical specifications.)

Characteristic		Symbol	Min	Typ	Max	Unit
Pressure Range(1)	Gauge, Differential: MPX5100D Absolute: MPX5100A	P_{OP}	0 15	— —	100 115	kPa
Supply Voltage(2)		V_S	4.75	5.0	5.25	Vdc
Supply Current		I_o	—	7.0	10	mAdc
Minimum Pressure Offset(3) @ V_S = 5.0 Volts	(0 to 85°C)	V_{off}	0.088	0.20	0.313	Vdc
Full Scale Output(4) @ V_S = 5.0 Volts	Differential and Absolute (0 to 85°C) Vacuum(10)	V_{FSO}	4.587 3.688	4.700 3.800	4.813 3.913	Vdc
Full Scale Span(5) @ V_S = 5.0 Volts	Differential and Absolute (0 to 85°C) Vacuum(10)	V_{FSS}	— —	4.500 3.600	— —	Vdc
Accuracy(6)		—	—	—	± 2.5	$\%V_{FSS}$
Sensitivity		V/P	—	45	—	mV/kPa
Response Time(7)		t_R	—	1.0	—	ms
Output Source Current at Full Scale Output		I_{o+}	—	0.1	—	mAdc
Warm–Up Time(8)		—	—	20	—	ms
Offset Stability(9)		—	—	± 0.5	—	$\%V_{FSS}$

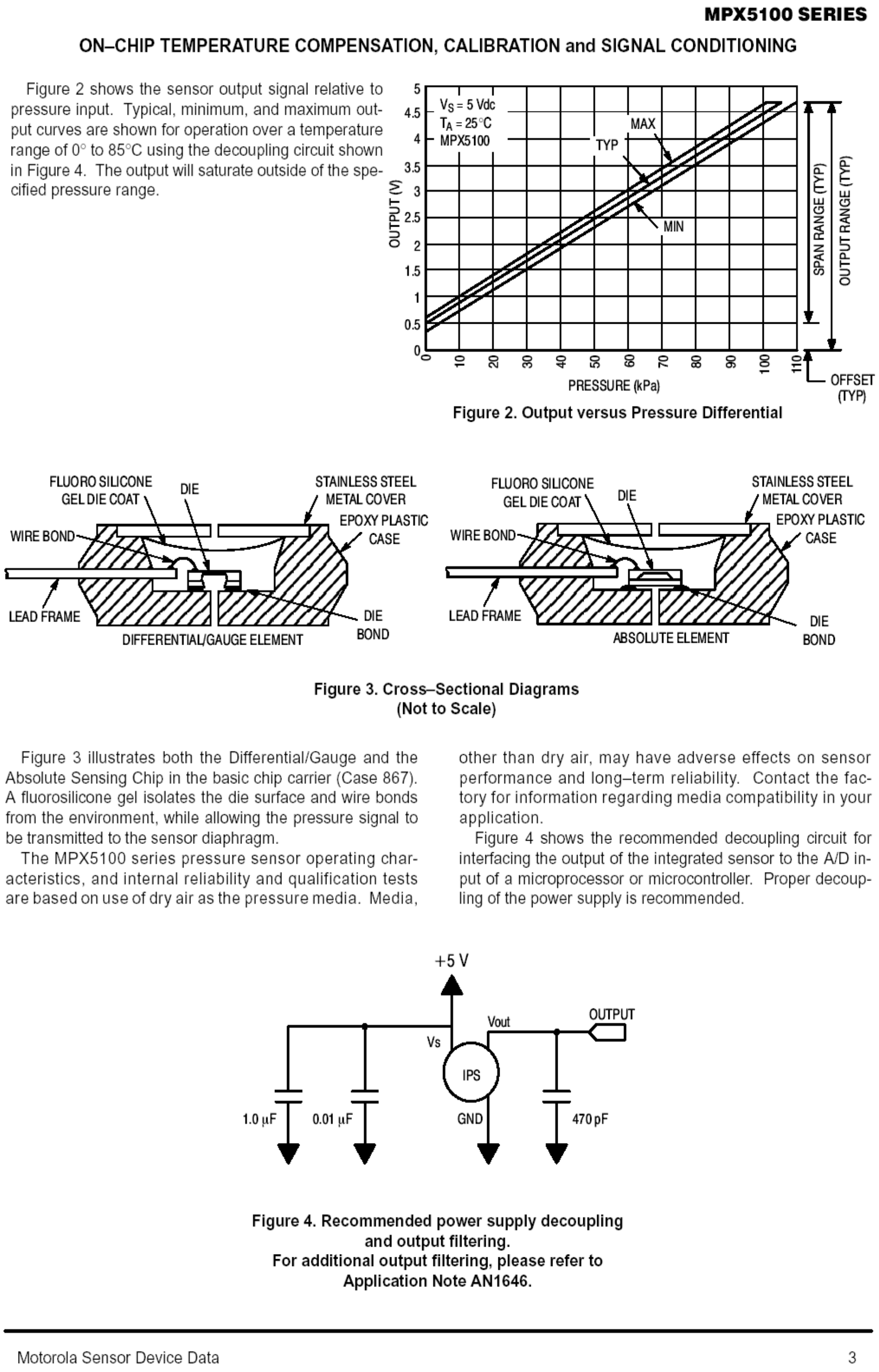
NOTES:

1. 1.0kPa (kiloPascal) equals 0.145 psi.
2. Device is ratiometric within this specified excitation range.
3. Offset (V_{off}) is defined as the output voltage at the minimum rated pressure.
4. Full Scale Output (V_{FSO}) is defined as the output voltage at the maximum or full rated pressure.
5. Full Scale Span (V_{FSS}) is defined as the algebraic difference between the output voltage at full rated pressure and the output voltage at the minimum rated pressure.
6. Accuracy (error budget) consists of the following:
   - Linearity: Output deviation from a straight line relationship with pressure over the specified pressure range.
   - Temperature Hysteresis: Output deviation at any temperature within the operating temperature range, after the temperature is cycled to and from the minimum or maximum operating temperature points, with zero differential pressure applied.
   - Pressure Hysteresis: Output deviation at any pressure within the specified range, when this pressure is cycled to and from minimum or maximum rated pressure at 25°C.
   - TcSpan: Output deviation over the temperature range of 0° to 85°C, relative to 25°C.
   - TcOffset: Output deviation with minimum pressure applied, over the temperature range of 0° to 85°C, relative to 25°C.
   - Variation from Nominal: The variation from nominal values, for Offset or Full Scale Span, as a percent of V_{FSS} at 25°C.
7. Response Time is defined as the time for the incremental change in the output to go from 10% to 90% of its final value when subjected to a specified step change in pressure.
8. Warm–up Time is defined as the time required for the product to meet the specified output voltage after the Pressure has been stabilized.
9. Offset Stability is the product's output deviation when subjected to 1000 hours of Pulsed Pressure, Temperature Cycling with Bias Test.

MECHANICAL CHARACTERISTICS

Characteristics	Typ	Unit
Weight, Basic Element (Case 867)	4.0	grams

Figur B.2: Data-ark Trykksensor



ON–CHIP TEMPERATURE COMPENSATION, CALIBRATION and SIGNAL CONDITIONING

Figure 2 shows the sensor output signal relative to pressure input. Typical, minimum, and maximum output curves are shown for operation over a temperature range of 0° to 85°C using the decoupling circuit shown in Figure 4. The output will saturate outside of the specified pressure range.

Figure 2. Output versus Pressure Differential

Figure 3. Cross–Sectional Diagrams
(Not to Scale)

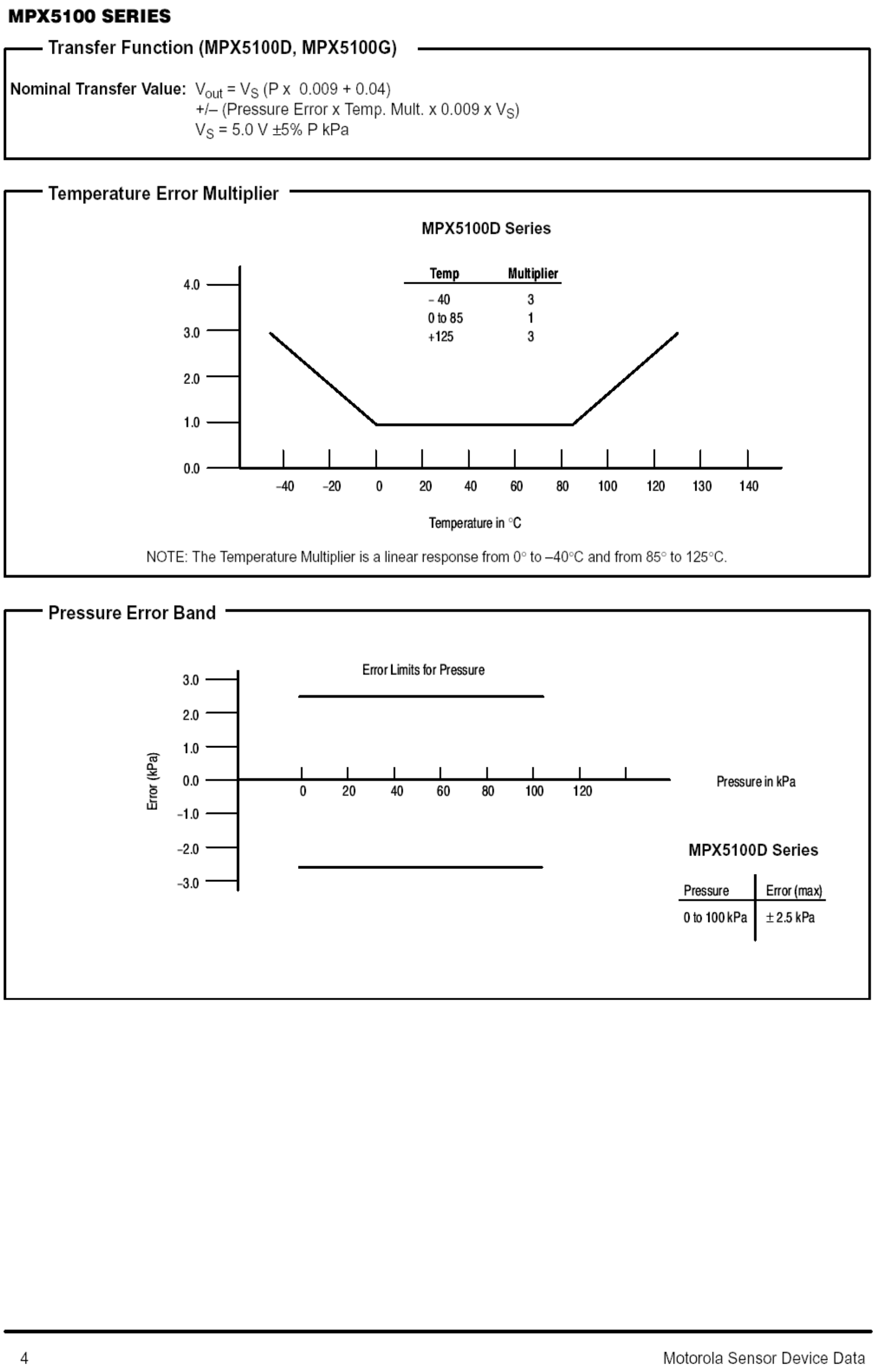
Figure 3 illustrates both the Differential/Gauge and the Absolute Sensing Chip in the basic chip carrier (Case 867). A fluorosilicone gel isolates the die surface and wire bonds from the environment, while allowing the pressure signal to be transmitted to the sensor diaphragm.

The MPX5100 series pressure sensor operating characteristics, and internal reliability and qualification tests are based on use of dry air as the pressure media. Media, other than dry air, may have adverse effects on sensor performance and long–term reliability. Contact the factory for information regarding media compatibility in your application.

Figure 4 shows the recommended decoupling circuit for interfacing the output of the integrated sensor to the A/D input of a microprocessor or microcontroller. Proper decoupling of the power supply is recommended.

Figure 4. Recommended power supply decoupling and output filtering.
For additional output filtering, please refer to Application Note AN1646.

Figur B.3: Data-ark Trykksensor



MPX5100 SERIES

Transfer Function (MPX5100D, MPX5100G)

Nominal Transfer Value: $V_{out} = V_S$ (P x 0.009 + 0.04)
+/– (Pressure Error x Temp. Mult. x 0.009 x V_S)
V_S = 5.0 V ±5% P kPa

Temperature Error Multiplier

MPX5100D Series

Temp	Multiplier
– 40	3
0 to 85	1
+125	3

NOTE: The Temperature Multiplier is a linear response from 0° to –40°C and from 85° to 125°C.

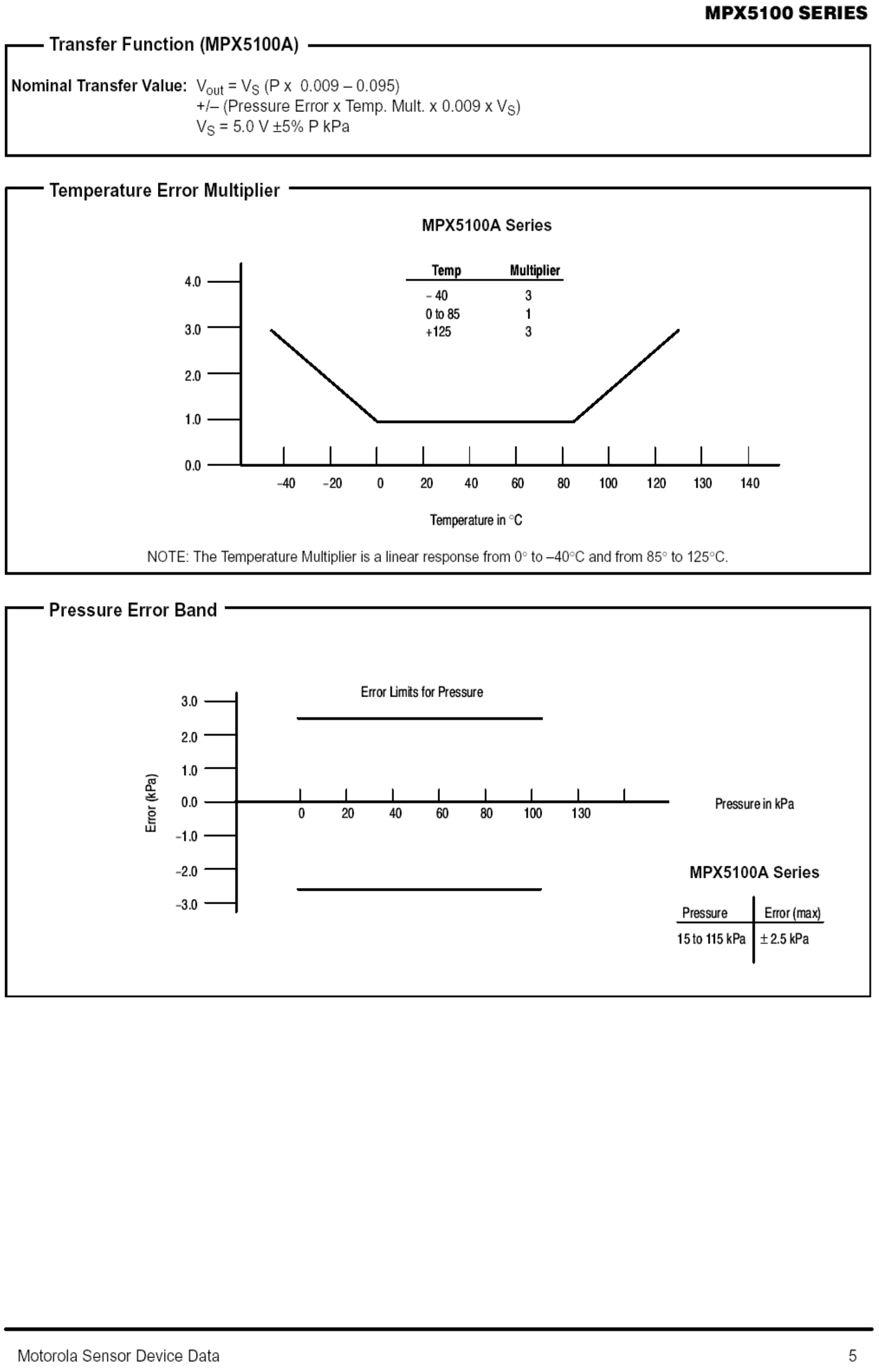
Pressure Error Band

MPX5100D Series

Pressure	Error (max)
0 to 100 kPa	± 2.5 kPa

4 Motorola Sensor Device Data

Figur B.4: Data-ark Trykksensor



MPX5100 SERIES

Transfer Function (MPX5100A)

Nominal Transfer Value: $V_{out} = V_S$ (P x 0.009 – 0.095)
+/– (Pressure Error x Temp. Mult. x 0.009 x V_S)
V_S = 5.0 V ±5% P kPa

Temperature Error Multiplier

MPX5100A Series

Temp	Multiplier
– 40	3
0 to 85	1
+125	3

NOTE: The Temperature Multiplier is a linear response from 0° to –40°C and from 85° to 125°C.

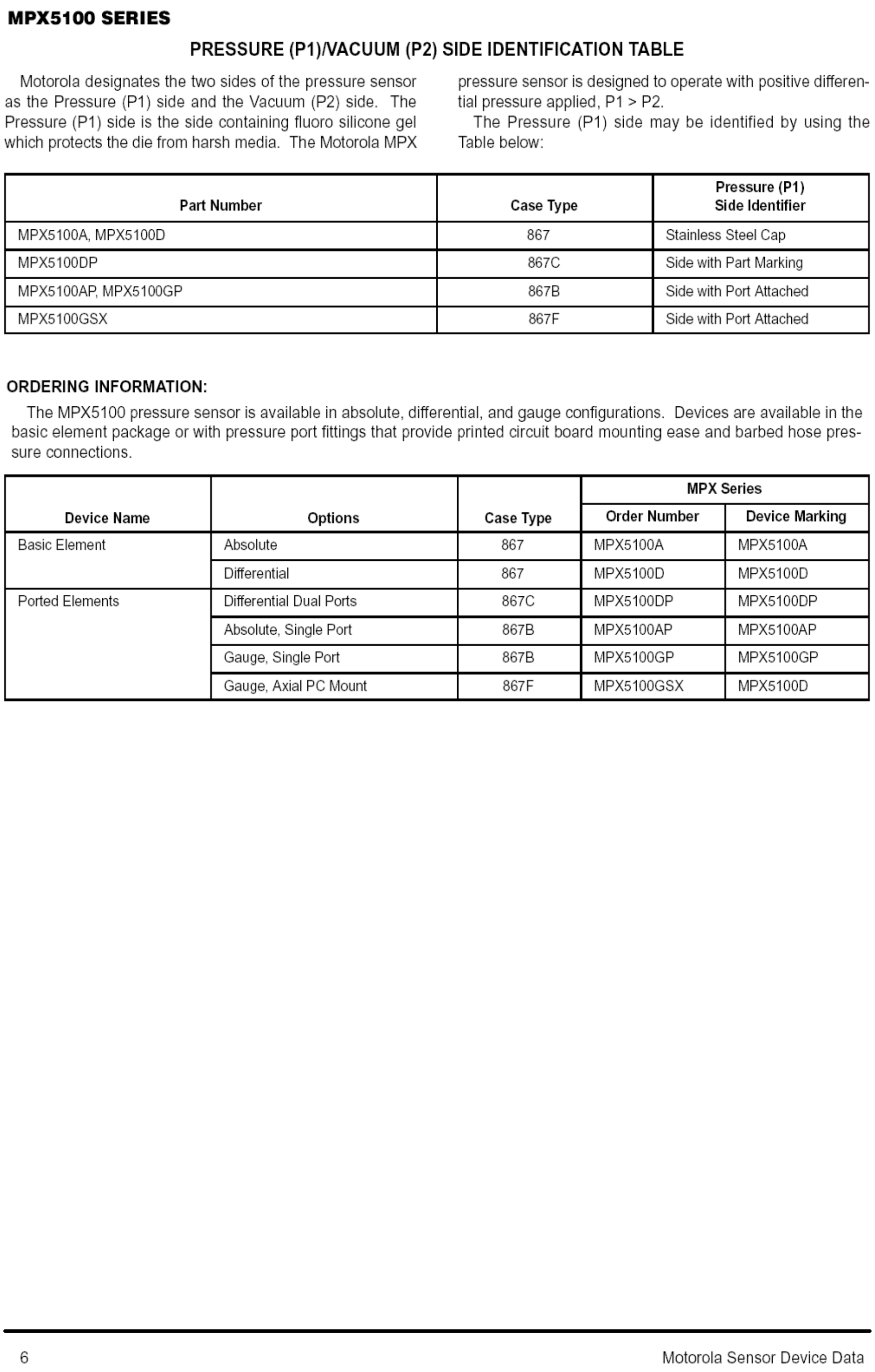
Pressure Error Band

MPX5100A Series

Pressure	Error (max)
15 to 115 kPa	± 2.5 kPa

Motorola Sensor Device Data 5

Figur B.5: Data-ark Trykksensor



MPX5100 SERIES

PRESSURE (P1)/VACUUM (P2) SIDE IDENTIFICATION TABLE

Motorola designates the two sides of the pressure sensor as the Pressure (P1) side and the Vacuum (P2) side. The Pressure (P1) side is the side containing fluoro silicone gel which protects the die from harsh media. The Motorola MPX pressure sensor is designed to operate with positive differential pressure applied, P1 > P2.

The Pressure (P1) side may be identified by using the Table below:

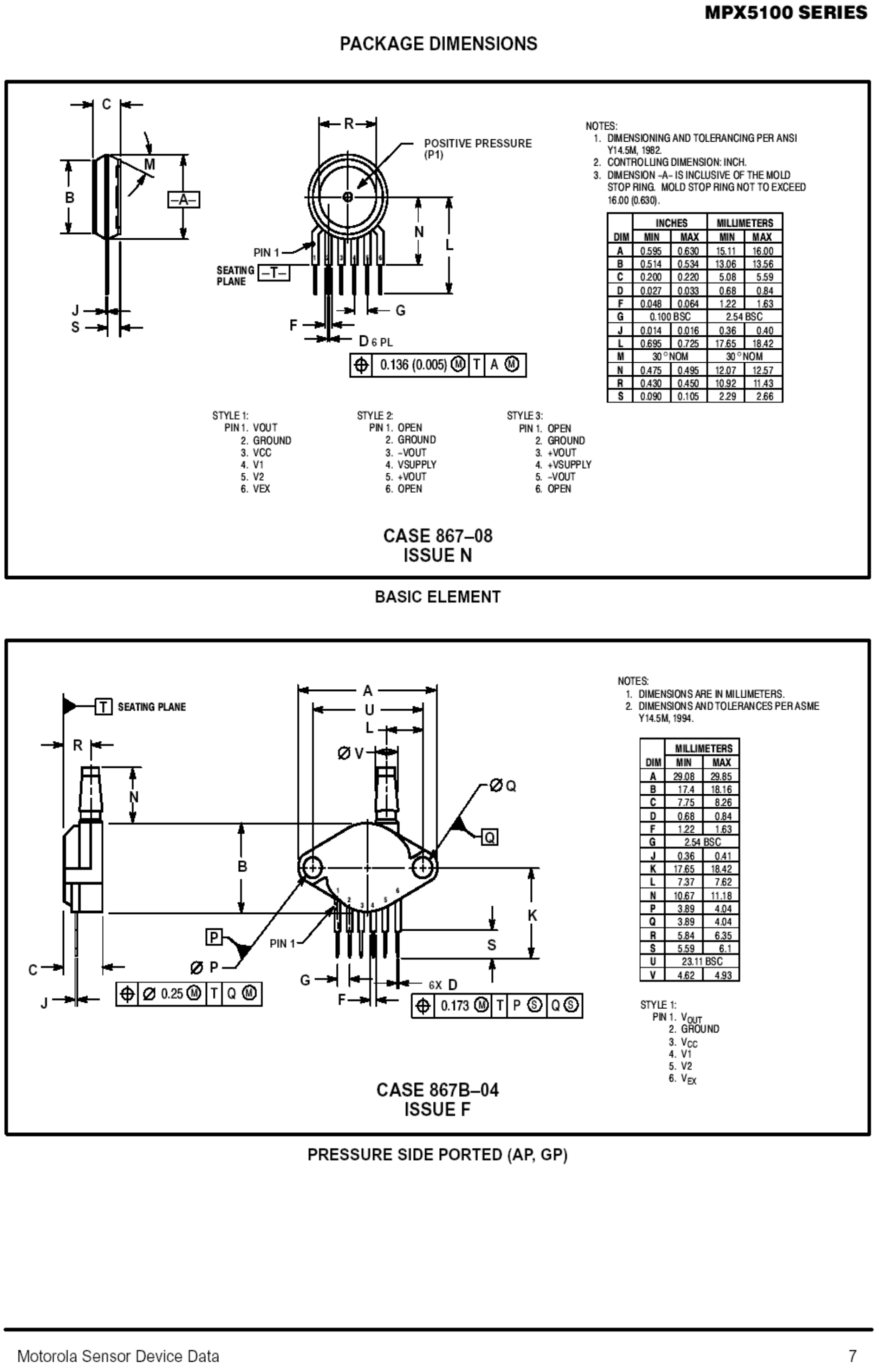
Part Number	Case Type	Pressure (P1) Side Identifier
MPX5100A, MPX5100D	867	Stainless Steel Cap
MPX5100DP	867C	Side with Part Marking
MPX5100AP, MPX5100GP	867B	Side with Port Attached
MPX5100GSX	867F	Side with Port Attached

ORDERING INFORMATION:

The MPX5100 pressure sensor is available in absolute, differential, and gauge configurations. Devices are available in the basic element package or with pressure port fittings that provide printed circuit board mounting ease and barbed hose pressure connections.

Device Name	Options	Case Type	MPX Series	
			Order Number	Device Marking
Basic Element	Absolute	867	MPX5100A	MPX5100A
	Differential	867	MPX5100D	MPX5100D
Ported Elements	Differential Dual Ports	867C	MPX5100DP	MPX5100DP
	Absolute, Single Port	867B	MPX5100AP	MPX5100AP
	Gauge, Single Port	867B	MPX5100GP	MPX5100GP
	Gauge, Axial PC Mount	867F	MPX5100GSX	MPX5100D

Figur B.6: Data-ark Trykksensor



MPX5100 SERIES

PACKAGE DIMENSIONS

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION –A– IS INCLUSIVE OF THE MOLD STOP RING. MOLD STOP RING NOT TO EXCEED 16.00 (0.630).

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.595	0.630	15.11	16.00
B	0.514	0.534	13.06	13.56
C	0.200	0.220	5.08	5.59
D	0.027	0.033	0.68	0.84
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
J	0.014	0.016	0.36	0.40
L	0.695	0.725	17.65	18.42
M	30° NOM		30° NOM	
N	0.475	0.495	12.07	12.57
R	0.430	0.450	10.92	11.43
S	0.090	0.105	2.29	2.66

STYLE 1:
PIN 1. VOUT
2. GROUND
3. VCC
4. V1
5. V2
6. VEX

STYLE 2:
PIN 1. OPEN
2. GROUND
3. –VOUT
4. VSUPPLY
5. +VOUT
6. OPEN

STYLE 3:
PIN 1. OPEN
2. GROUND
3. +VOUT
4. +VSUPPLY
5. –VOUT
6. OPEN

CASE 867–08
ISSUE N

BASIC ELEMENT

NOTES:
1. DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994.

	MILLIMETERS	
DIM	MIN	MAX
A	29.08	29.85
B	17.4	18.16
C	7.75	8.26
D	0.68	0.84
F	1.22	1.63
G	2.54 BSC	
J	0.36	0.41
K	17.65	18.42
L	7.37	7.62
N	10.67	11.18
P	3.89	4.04
Q	3.89	4.04
R	5.84	6.35
S	5.59	6.1
U	23.11 BSC	
V	4.62	4.93

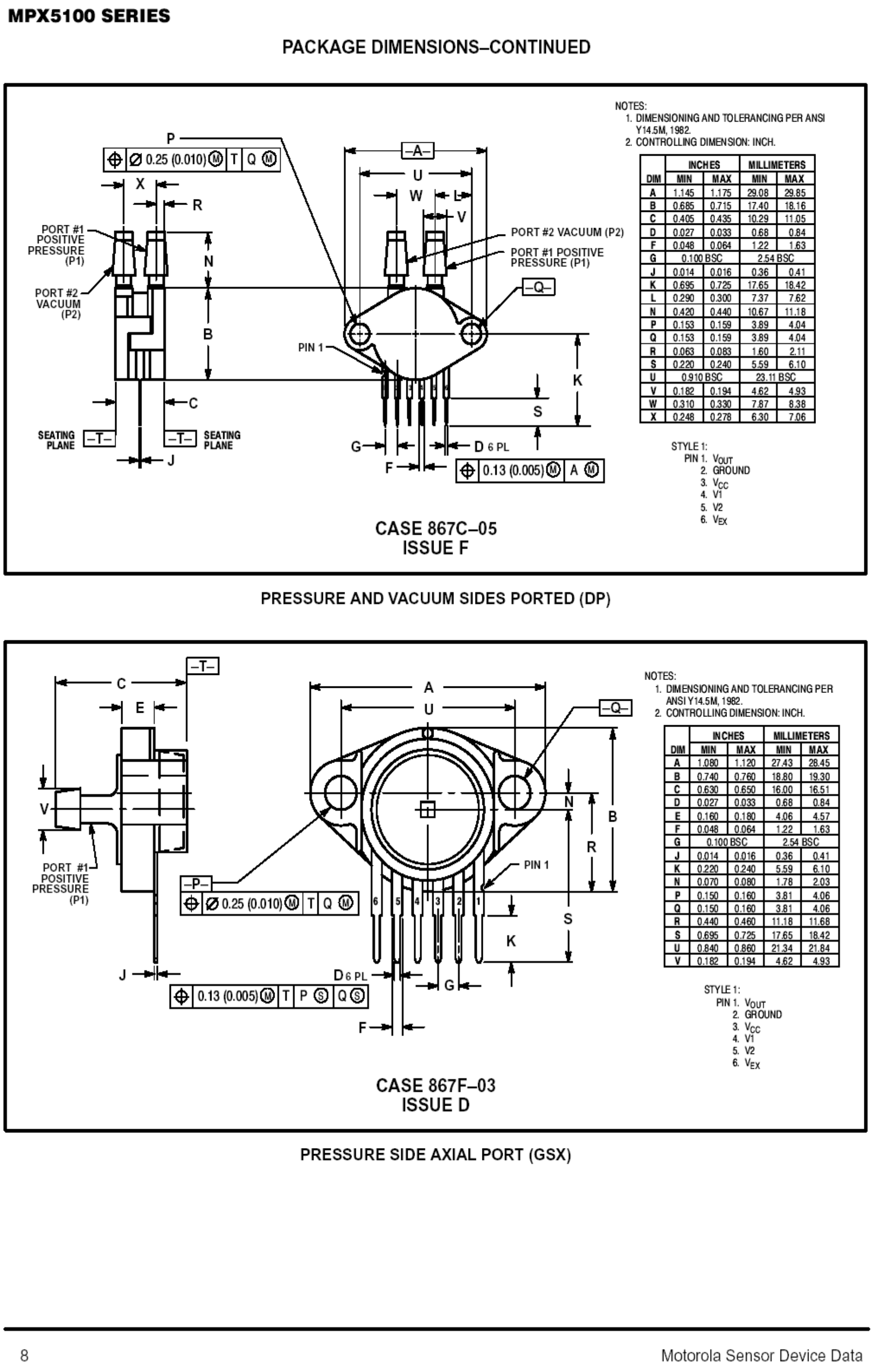
STYLE 1:
PIN 1. V_{OUT}
2. GROUND
3. V_{CC}
4. V1
5. V2
6. V_{EX}

CASE 867B–04
ISSUE F

PRESSURE SIDE PORTED (AP, GP)

Motorola Sensor Device Data 7

Figur B.7: Data-ark Trykksensor



MPX5100 SERIES

PACKAGE DIMENSIONS–CONTINUED

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	1.145	1.175	29.08	29.85
B	0.685	0.715	17.40	18.16
C	0.405	0.435	10.29	11.05
D	0.027	0.033	0.68	0.84
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
J	0.014	0.016	0.36	0.41
K	0.695	0.725	17.65	18.42
L	0.290	0.300	7.37	7.62
N	0.420	0.440	10.67	11.18
P	0.153	0.159	3.89	4.04
Q	0.153	0.159	3.89	4.04
R	0.063	0.083	1.60	2.11
S	0.220	0.240	5.59	6.10
U	0.910 BSC		23.11 BSC	
V	0.182	0.194	4.62	4.93
W	0.310	0.330	7.87	8.38
X	0.248	0.278	6.30	7.06

STYLE 1:
PIN 1. V_{OUT}
2. GROUND
3. V_{CC}
4. V1
5. V2
6. V_{EX}

CASE 867C–05
ISSUE F

PRESSURE AND VACUUM SIDES PORTED (DP)

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	1.080	1.120	27.43	28.45
B	0.740	0.760	18.80	19.30
C	0.630	0.650	16.00	16.51
D	0.027	0.033	0.68	0.84
E	0.160	0.180	4.06	4.57
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
J	0.014	0.016	0.36	0.41
K	0.220	0.240	5.59	6.10
N	0.070	0.080	1.78	2.03
P	0.150	0.160	3.81	4.06
Q	0.150	0.160	3.81	4.06
R	0.440	0.460	11.18	11.68
S	0.695	0.725	17.65	18.42
U	0.840	0.860	21.34	21.84
V	0.182	0.194	4.62	4.93

STYLE 1:
PIN 1. V_{OUT}
2. GROUND
3. V_{CC}
4. V1
5. V2
6. V_{EX}

CASE 867F–03
ISSUE D

PRESSURE SIDE AXIAL PORT (GSX)

8 Motorola Sensor Device Data

Figur B.8: Data-ark Trykksensor

Datasheet

MICROANALOG
Analog Signal Conditioners

MICROANALOG DC/DC select
MICROANALOG THERMO select
MICROANALOG PT100 select

NEW

MICROANALOG sets a new standard in signal conditioning and isolating. In a package with a thickness of only 6.1mm (0.24 in.) you'll find:

- Wide range of standard functions
- Easy installation
- 3-Way Isolation between Input, Output, and Supply voltage
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- DIP-Switch selectable
- Supply voltage cross-connectable
- Low Power Consumption

These features make MICROANALOG a space saving alternative for your signal conditioning applications.

3 modules with cross-connections for supply voltage

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Richmond, Virginia 23236
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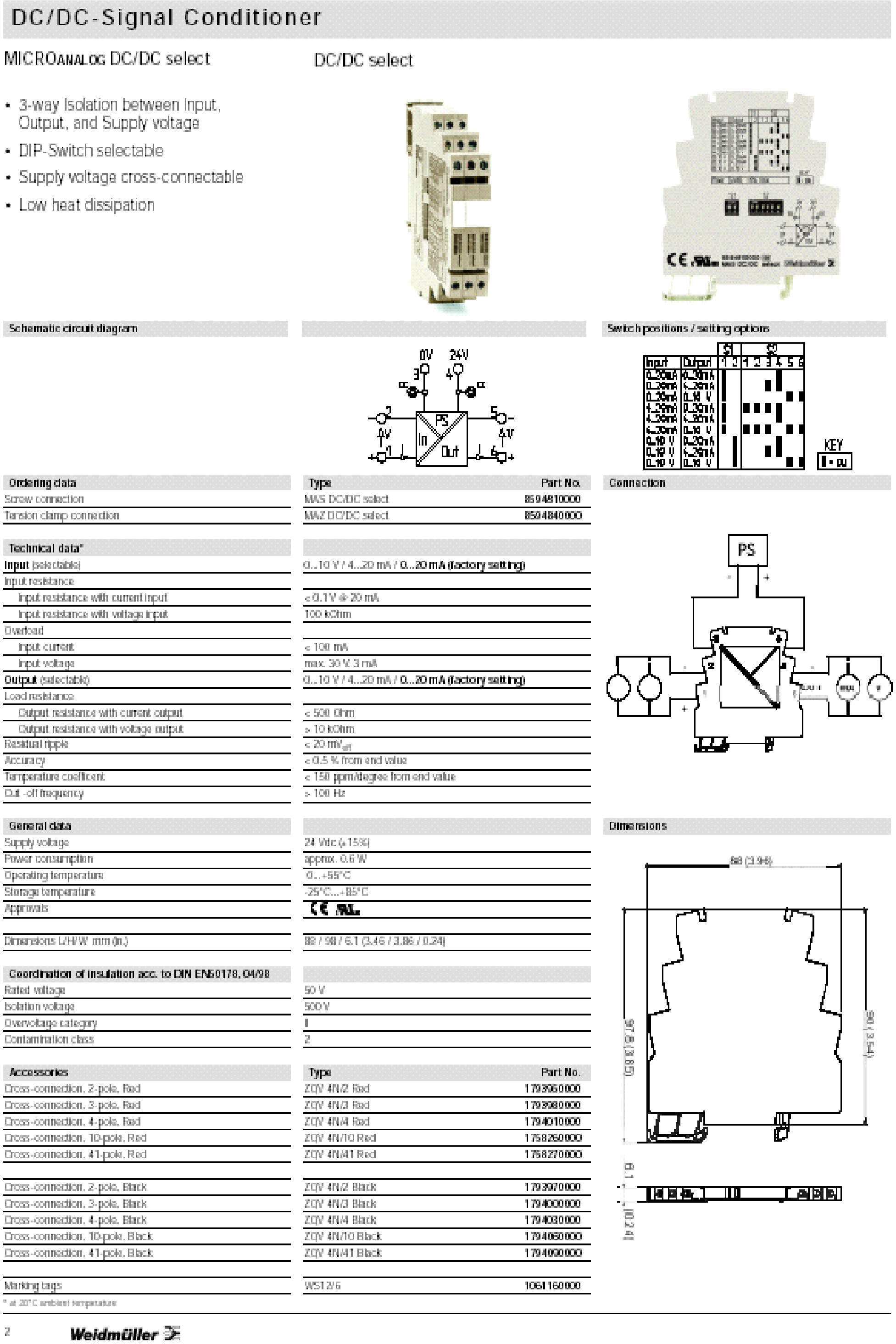
Facsimile: (804) 379-2593
Email: info@weidmuller.com
Website: www.weidmuller.com

Canada
Weidmuller Ltd.
10 Spy Court
Markham, Ontario L3R-5H6
Telephone: (800) 268-4080
Facsimile: (905) 475-2798
Email: info1@weidmuller.ca
Website: www.weidmuller.ca

Mexico
Weidmuller, S.A. de C.V.
5 Sur No. 4311
Col. Huexotitla
72534 Puebla, Pue. Mexico
Telephone: (22) 37 2549
Facsimile: (22) 43 1981
Email: weidmull@acnet.net

Weidmüller

Figur B.9: Data-ark Signalomformer



DC/DC-Signal Conditioner

MICROANALOG DC/DC select

DC/DC select

- 3-way Isolation between Input, Output, and Supply voltage
- DIP-Switch selectable
- Supply voltage cross-connectable
- Low heat dissipation

Schematic circuit diagram

Switch positions / setting options

Input	Output	S1 1	S1 2	S2 1	S2 2	S2 3	S2 4	S2 5	S2 6
0...20mA	0...20mA	▮					▮		
0...20mA	4...20mA	▮				▮	▮		
0...20mA	0...10 V	▮						▮	▮
4...20mA	0...20mA	▮		▮	▮	▮	▮		
4...20mA	4...20mA	▮					▮		
4...20mA	0...10 V	▮		▮	▮	▮		▮	▮
0...10 V	0...20mA		▮				▮		
0...10 V	4...20mA		▮			▮	▮		
0...10 V	0...10 V		▮					▮	▮

KEY
▮ = on

Ordering data	Type	Part No.
Screw connection	MAS DC/DC select	8594810000
Tension clamp connection	MAZ DC/DC select	8594840000

Connection

PS

Technical data*	
Input (selectable)	0...10 V / 4...20 mA / **0...20 mA (factory setting)**
Input resistance	
Input resistance with current input	< 0.1 V @ 20 mA
Input resistance with voltage input	100 kOhm
Overload	
Input current	< 100 mA
Input voltage	max. 30 V, 3 mA
Output (selectable)	0...10 V / 4...20 mA / **0...20 mA (factory setting)**
Load resistance	
Output resistance with current output	< 500 Ohm
Output resistance with voltage output	> 10 kOhm
Residual ripple	< 20 mV_{eff}
Accuracy	< 0.5 % from end value
Temperature coefficent	< 150 ppm/degree from end value
Cut -off frequency	> 100 Hz

General data	
Supply voltage	24 Vdc (±15%)
Power consumption	approx. 0.6 W
Operating temperature	0...+55°C
Storage temperature	-25°C...+85°C
Approvals	CE UL
Dimensions L/H/W mm (in.)	88 / 98 / 6.1 (3.46 / 3.86 / 0.24)

Dimensions

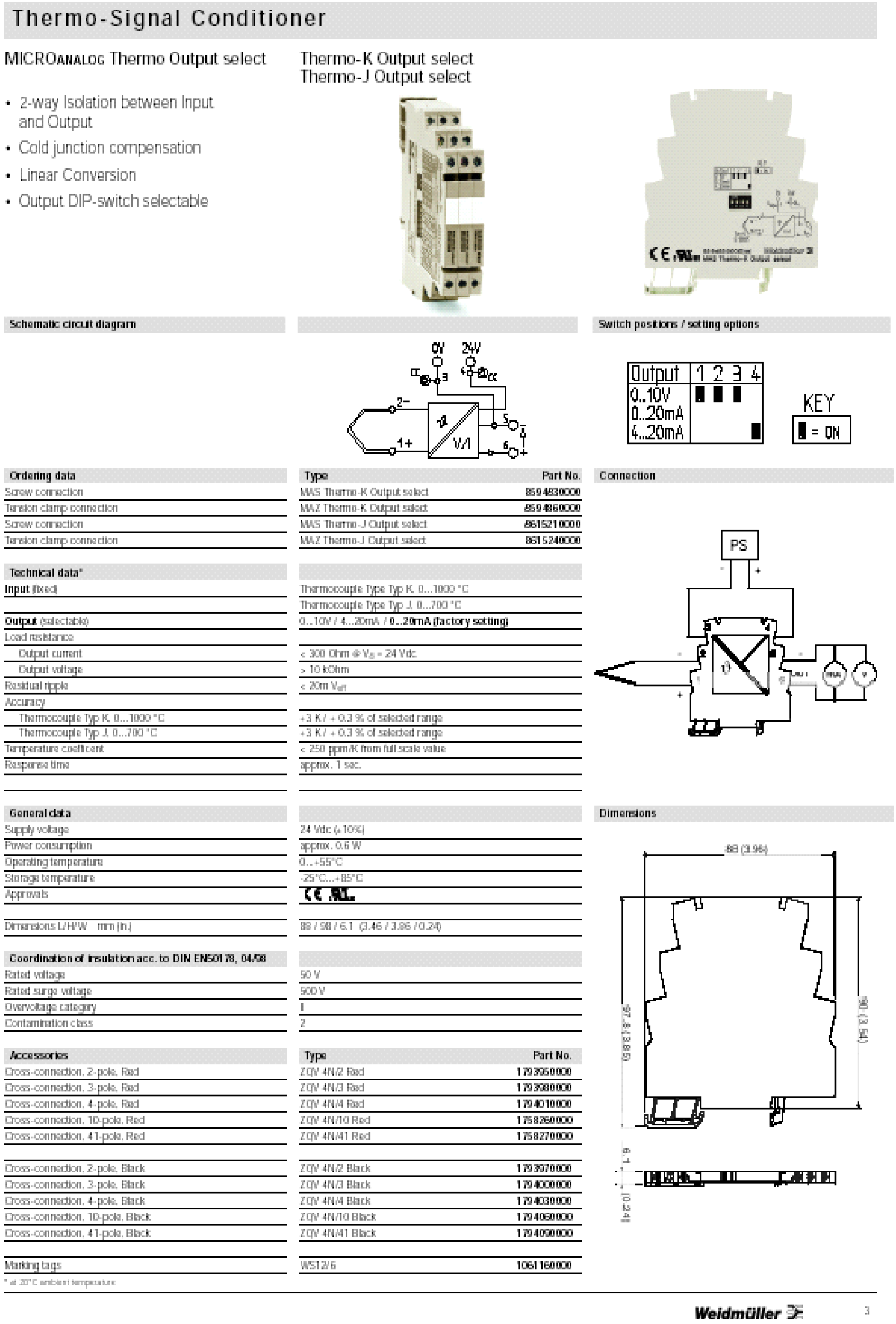
Coordination of insulation acc. to DIN EN50178, 04/98	
Rated voltage	50 V
Isolation voltage	500 V
Overvoltage category	II
Contamination class	2

Accessories	Type	Part No.
Cross-connection, 2-pole, Red	ZQV 4N/2 Red	1793960000
Cross-connection, 3-pole, Red	ZQV 4N/3 Red	1793980000
Cross-connection, 4-pole, Red	ZQV 4N/4 Red	1794010000
Cross-connection, 10-pole, Red	ZQV 4N/10 Red	1758260000
Cross-connection, 41-pole, Red	ZQV 4N/41 Red	1758270000
Cross-connection, 2-pole, Black	ZQV 4N/2 Black	1793970000
Cross-connection, 3-pole, Black	ZQV 4N/3 Black	1794000000
Cross-connection, 4-pole, Black	ZQV 4N/4 Black	1794030000
Cross-connection, 10-pole, Black	ZQV 4N/10 Black	1794060000
Cross-connection, 41-pole, Black	ZQV 4N/41 Black	1794090000
Marking tags	WS12/6	1061160000

* at 20°C ambient temperature

2 Weidmüller

Figur B.10: Data-ark Signalomformer



Thermo-Signal Conditioner

MICROANALOG Thermo Output select

Thermo-K Output select
Thermo-J Output select

- 2-way Isolation between Input and Output
- Cold junction compensation
- Linear Conversion
- Output DIP-switch selectable

Schematic circuit diagram

Switch positions / setting options

Output	1	2	3	4
0..10V	■	■	■	
0..20mA				
4..20mA				■

KEY ■ = ON

Ordering data	Type	Part No.
Screw connection	MAS Thermo-K Output select	8594830000
Tension clamp connection	MAZ Thermo-K Output select	8594860000
Screw connection	MAS Thermo-J Output select	8615210000
Tension clamp connection	MAZ Thermo-J Output select	8615240000

Technical data*	
Input (fixed)	Thermocouple Type Typ K, 0...1000 °C
	Thermocouple Type Typ J, 0...700 °C
Output (selectable)	0...10V / 4...20mA / **0...20mA (factory setting)**
Load resistance	
Output current	< 300 Ohm @ V_S = 24 Vdc
Output voltage	> 10 kOhm
Residual ripple	< 20m V_{eff}
Accuracy	
Thermocouple Typ K, 0...1000 °C	±3 K / ± 0.3 % of selected range
Thermocouple Typ J, 0...700 °C	±3 K / ± 0.3 % of selected range
Temperature coefficent	< 250 ppm/K from full scale value
Response time	approx. 1 sec.

General data	
Supply voltage	24 Vdc (±10%)
Power consumption	approx. 0.6 W
Operating temperature	0...+55°C
Storage temperature	-25°C...+85°C
Approvals	CE UL
Dimensions L/H/W mm (in.)	88 / 98 / 6.1 (3.46 / 3.86 / 0.24)

Coordination of insulation acc. to DIN EN50178, 04/98	
Rated voltage	50 V
Rated surge voltage	500 V
Overvoltage category	II
Contamination class	2

Accessories	Type	Part No.
Cross-connection, 2-pole, Red	ZQV 4N/2 Red	1793960000
Cross-connection, 3-pole, Red	ZQV 4N/3 Red	1793980000
Cross-connection, 4-pole, Red	ZQV 4N/4 Red	1794010000
Cross-connection, 10-pole, Red	ZQV 4N/10 Red	1758260000
Cross-connection, 41-pole, Red	ZQV 4N/41 Red	1758270000
Cross-connection, 2-pole, Black	ZQV 4N/2 Black	1793970000
Cross-connection, 3-pole, Black	ZQV 4N/3 Black	1794000000
Cross-connection, 4-pole, Black	ZQV 4N/4 Black	1794030000
Cross-connection, 10-pole, Black	ZQV 4N/10 Black	1794060000
Cross-connection, 41-pole, Black	ZQV 4N/41 Black	1794090000
Marking tags	WS12/6	1061160000

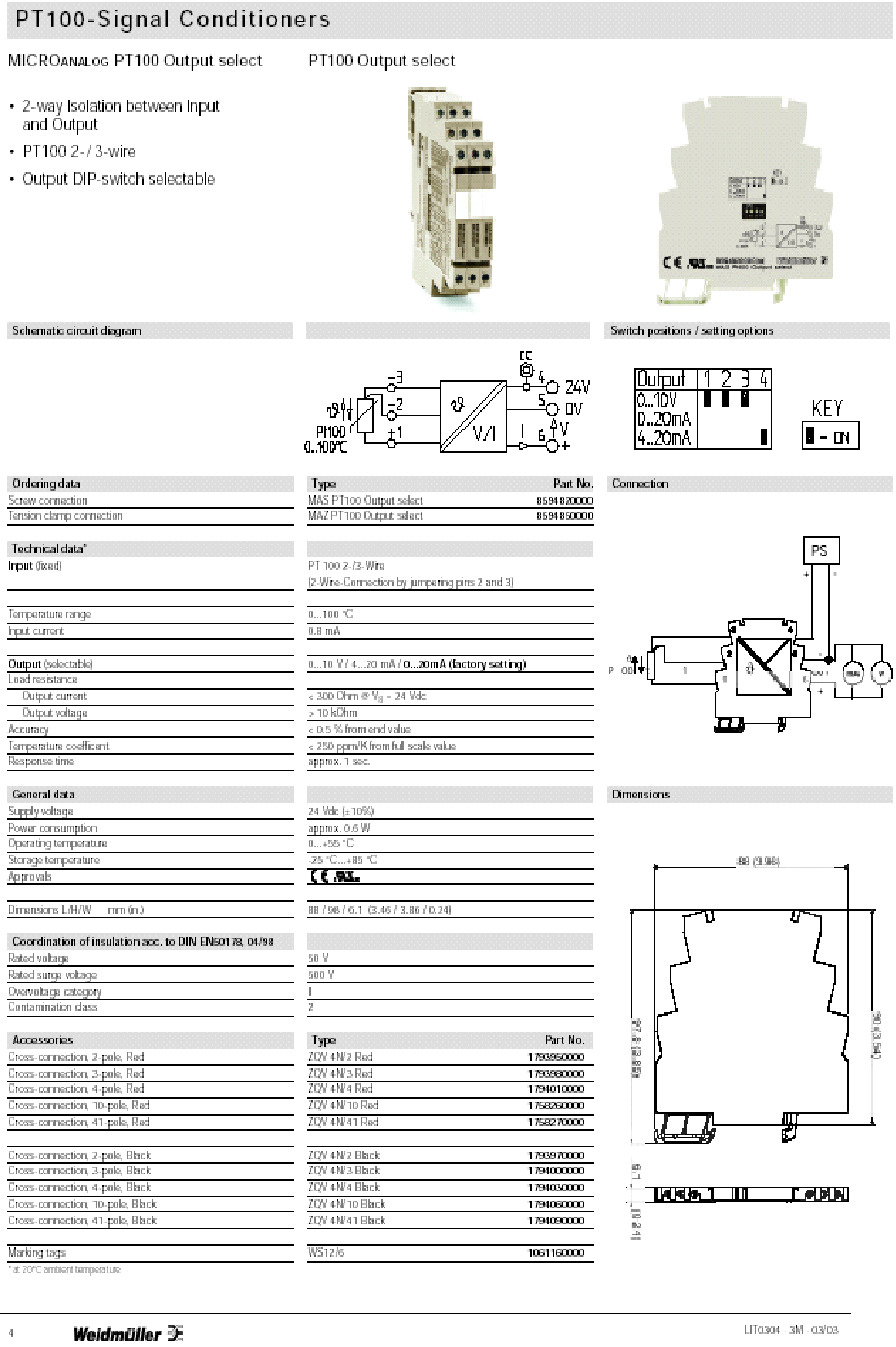
* at 20°C ambient temperature

Connection

Dimensions

Weidmüller 3

Figur B.11: Data-ark Signalomformer



PT100-Signal Conditioners

MICROanalog PT100 Output select

PT100 Output select

- 2-way Isolation between Input and Output
- PT100 2- / 3-wire
- Output DIP-switch selectable

Schematic circuit diagram

Switch positions / setting options

Output	1	2	3	4
0...10V	▮	▮	▮	
0..20mA				
4..20mA				▮

KEY
▮ - ON

Ordering data	Type	Part No.
Screw connection	MAS PT100 Output select	8594820000
Tension clamp connection	MAZ PT100 Output select	8594850000

Technical data*	
Input (fixed)	PT 100 2-/3-Wire (2-Wire-Connection by jumpering pins 2 and 3)
Temperature range	0...100 °C
Input current	0.8 mA
Output (selectable)	0...10 V / 4...20 mA / **0...20mA (factory setting)**
Load resistance	
Output current	< 300 Ohm @ V_S = 24 Vdc
Output voltage	> 10 kOhm
Accuracy	< 0.5 % from end value
Temperature coefficent	< 250 ppm/K from full scale value
Response time	approx. 1 sec.

General data	
Supply voltage	24 Vdc (±10%)
Power consumption	approx. 0.6 W
Operating temperature	0...+55 °C
Storage temperature	-25 °C...+85 °C
Approvals	CE UL
Dimensions L/H/W mm (in.)	88 / 98 / 6.1 (3.46 / 3.86 / 0.24)

Coordination of insulation acc. to DIN EN50178, 04/98	
Rated voltage	50 V
Rated surge voltage	500 V
Overvoltage category	I
Contamination class	2

Accessories	Type	Part No.
Cross-connection, 2-pole, Red	ZQV 4N/2 Red	1793950000
Cross-connection, 3-pole, Red	ZQV 4N/3 Red	1793980000
Cross-connection, 4-pole, Red	ZQV 4N/4 Red	1794010000
Cross-connection, 10-pole, Red	ZQV 4N/10 Red	1758260000
Cross-connection, 41-pole, Red	ZQV 4N/41 Red	1758270000
Cross-connection, 2-pole, Black	ZQV 4N/2 Black	1793970000
Cross-connection, 3-pole, Black	ZQV 4N/3 Black	1794000000
Cross-connection, 4-pole, Black	ZQV 4N/4 Black	1794030000
Cross-connection, 10-pole, Black	ZQV 4N/10 Black	1794060000
Cross-connection, 41-pole, Black	ZQV 4N/41 Black	1794090000
Marking tags	WS12/6	1061160000

* at 20°C ambient temperature

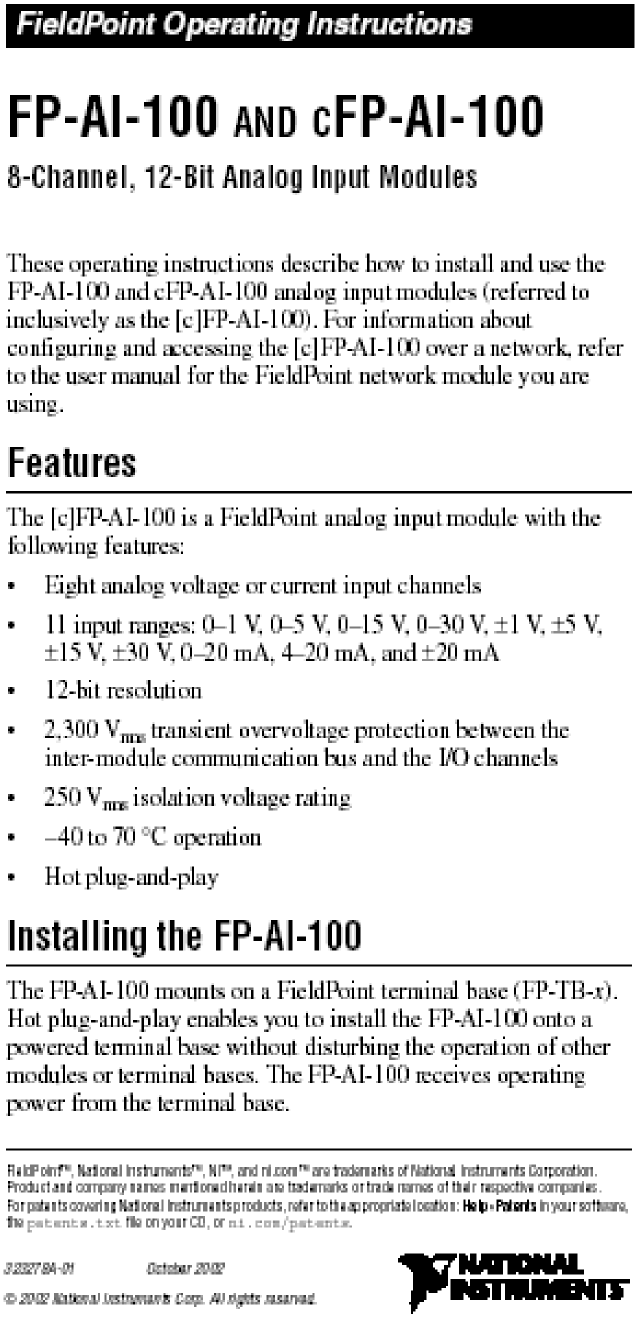
Connection

Dimensions

4 Weidmüller

LIT0304 · 3M · 03/03

Figur B.12: Data-ark Signalomformer



FieldPoint Operating Instructions

FP-AI-100 AND cFP-AI-100

8-Channel, 12-Bit Analog Input Modules

These operating instructions describe how to install and use the FP-AI-100 and cFP-AI-100 analog input modules (referred to inclusively as the [c]FP-AI-100). For information about configuring and accessing the [c]FP-AI-100 over a network, refer to the user manual for the FieldPoint network module you are using.

Features

The [c]FP-AI-100 is a FieldPoint analog input module with the following features:

- Eight analog voltage or current input channels
- 11 input ranges: 0–1 V, 0–5 V, 0–15 V, 0–30 V, ±1 V, ±5 V, ±15 V, ±30 V, 0–20 mA, 4–20 mA, and ±20 mA
- 12-bit resolution
- 2,300 V_{rms} transient overvoltage protection between the inter-module communication bus and the I/O channels
- 250 V_{rms} isolation voltage rating
- –40 to 70 °C operation
- Hot plug-and-play

Installing the FP-AI-100

The FP-AI-100 mounts on a FieldPoint terminal base (FP-TB-*x*). Hot plug-and-play enables you to install the FP-AI-100 onto a powered terminal base without disturbing the operation of other modules or terminal bases. The FP-AI-100 receives operating power from the terminal base.

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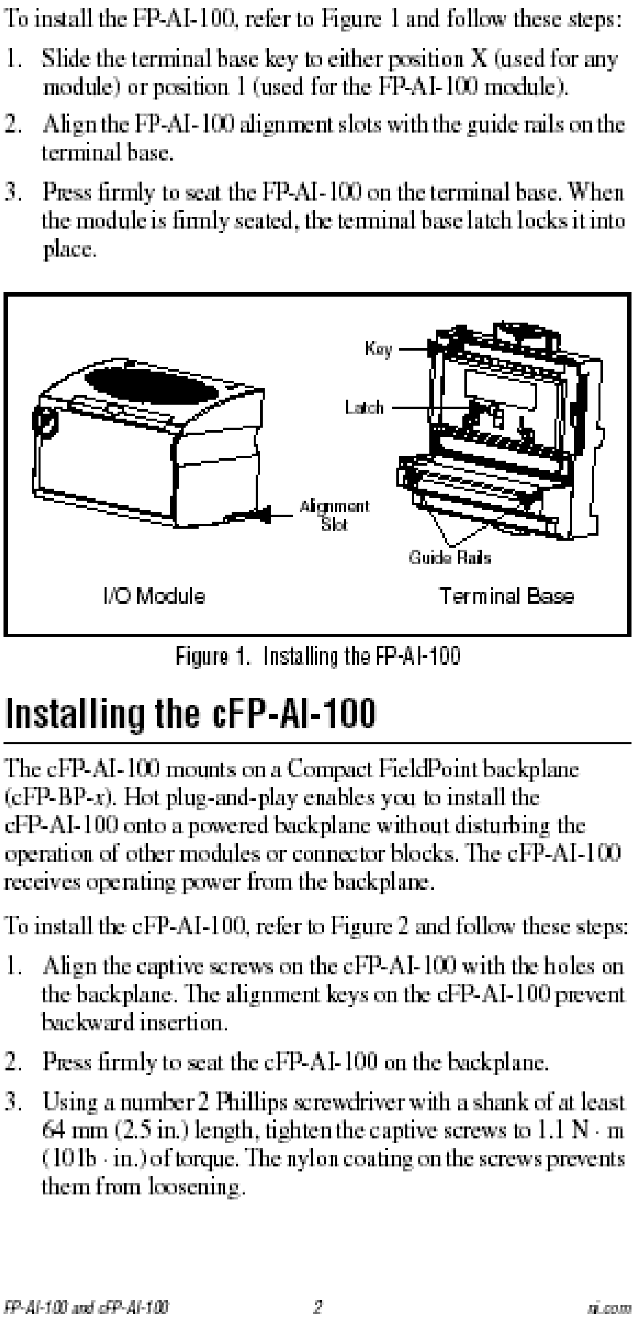
323278A-01 *October 2002*

Figur B.13: Data-ark FieldPoint Analog Input



To install the FP-AI-100, refer to Figure 1 and follow these steps:

1. Slide the terminal base key to either position X (used for any module) or position 1 (used for the FP-AI-100 module).
2. Align the FP-AI-100 alignment slots with the guide rails on the terminal base.
3. Press firmly to seat the FP-AI-100 on the terminal base. When the module is firmly seated, the terminal base latch locks it into place.

Figure 1. Installing the FP-AI-100

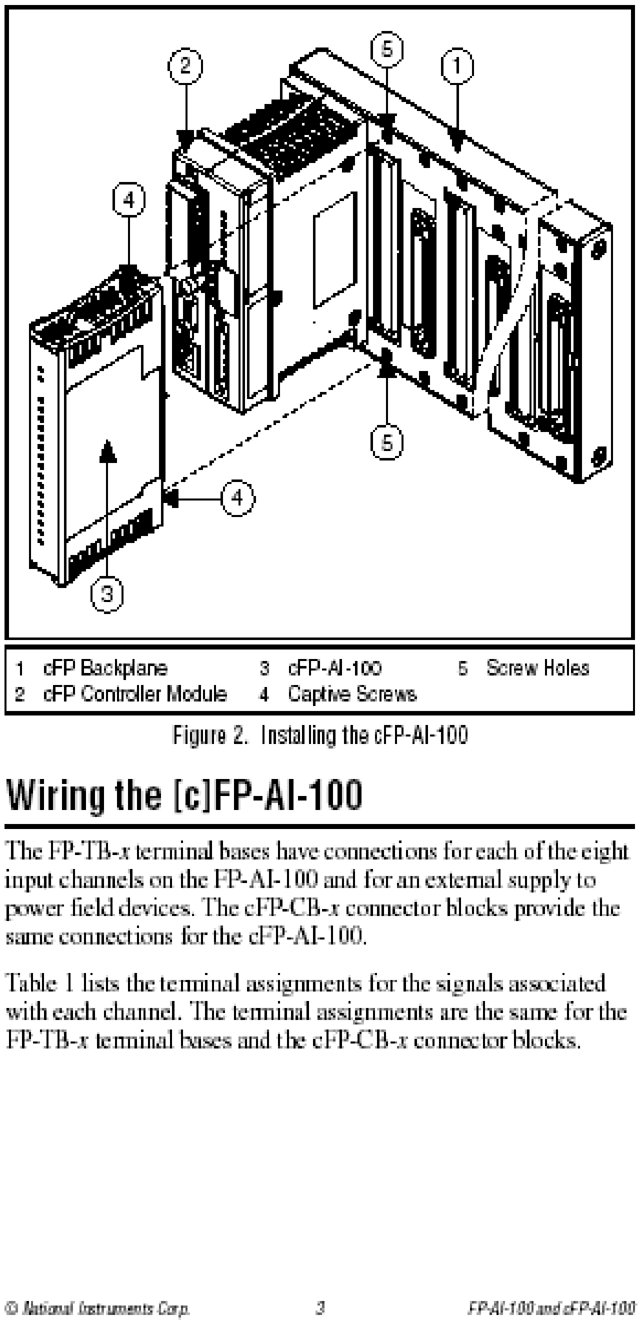
Installing the cFP-AI-100

The cFP-AI-100 mounts on a Compact FieldPoint backplane (cFP-BP-*x*). Hot plug-and-play enables you to install the cFP-AI-100 onto a powered backplane without disturbing the operation of other modules or connector blocks. The cFP-AI-100 receives operating power from the backplane.

To install the cFP-AI-100, refer to Figure 2 and follow these steps:

1. Align the captive screws on the cFP-AI-100 with the holes on the backplane. The alignment keys on the cFP-AI-100 prevent backward insertion.
2. Press firmly to seat the cFP-AI-100 on the backplane.
3. Using a number 2 Phillips screwdriver with a shank of at least 64 mm (2.5 in.) length, tighten the captive screws to 1.1 N · m (10 lb · in.) of torque. The nylon coating on the screws prevents them from loosening.

Figur B.14: Data-ark FieldPoint Analog Input



1 cFP Backplane
2 cFP Controller Module
3 cFP-AI-100
4 Captive Screws
5 Screw Holes

Figure 2. Installing the cFP-AI-100

Wiring the [c]FP-AI-100

The FP-TB-*x* terminal bases have connections for each of the eight input channels on the FP-AI-100 and for an external supply to power field devices. The cFP-CB-*x* connector blocks provide the same connections for the cFP-AI-100.

Table 1 lists the terminal assignments for the signals associated with each channel. The terminal assignments are the same for the FP-TB-*x* terminal bases and the cFP-CB-*x* connector blocks.

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Figur B.15: Data-ark FieldPoint Analog Input

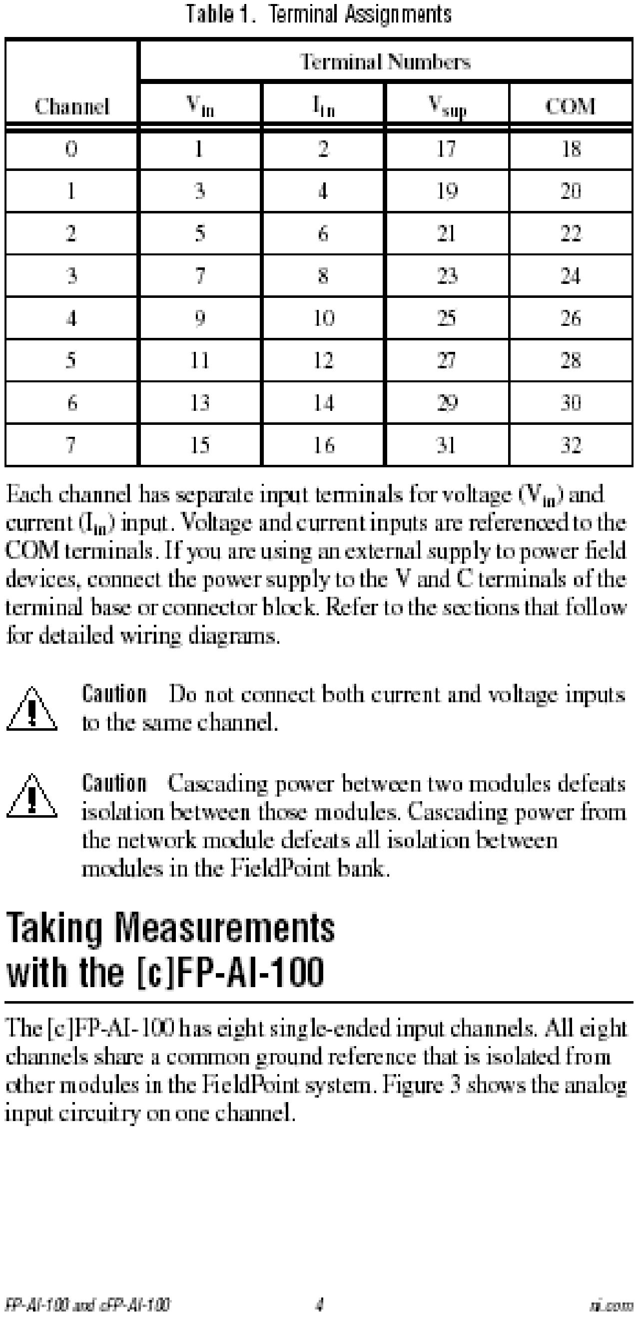

Table 1. Terminal Assignments

Channel	Terminal Numbers			
	V_{in}	I_{in}	V_{sup}	COM
0	1	2	17	18
1	3	4	19	20
2	5	6	21	22
3	7	8	23	24
4	9	10	25	26
5	11	12	27	28
6	13	14	29	30
7	15	16	31	32

Each channel has separate input terminals for voltage (V_{in}) and current (I_{in}) input. Voltage and current inputs are referenced to the COM terminals. If you are using an external supply to power field devices, connect the power supply to the V and C terminals of the terminal base or connector block. Refer to the sections that follow for detailed wiring diagrams.

⚠ **Caution** Do not connect both current and voltage inputs to the same channel.

⚠ **Caution** Cascading power between two modules defeats isolation between those modules. Cascading power from the network module defeats all isolation between modules in the FieldPoint bank.

Taking Measurements with the [c]FP-AI-100

The [c]FP-AI-100 has eight single-ended input channels. All eight channels share a common ground reference that is isolated from other modules in the FieldPoint system. Figure 3 shows the analog input circuitry on one channel.

FP-AI-100 and cFP-AI-100 *4* *ni.com*

Figur B.16: Data-ark FieldPoint Analog Input

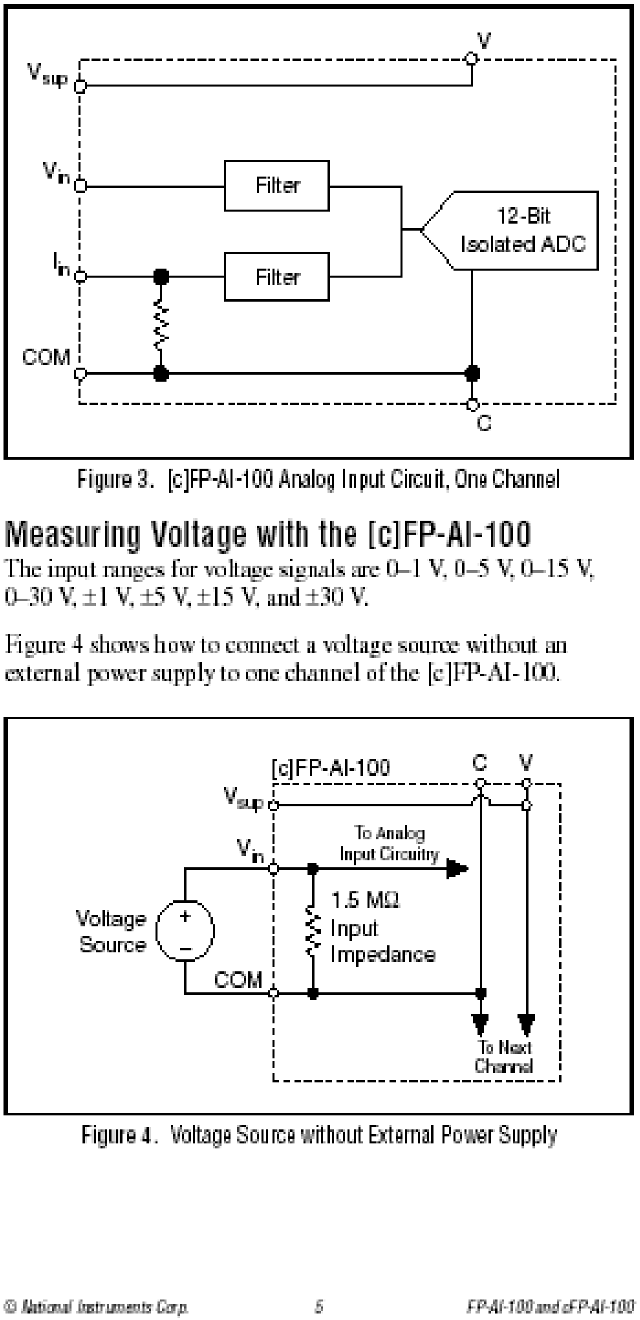

Figure 3. [c]FP-AI-100 Analog Input Circuit, One Channel

Measuring Voltage with the [c]FP-AI-100

The input ranges for voltage signals are 0–1 V, 0–5 V, 0–15 V, 0–30 V, ±1 V, ±5 V, ±15 V, and ±30 V.

Figure 4 shows how to connect a voltage source without an external power supply to one channel of the [c]FP-AI-100.

Figure 4. Voltage Source without External Power Supply

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Figur B.17: Data-ark FieldPoint Analog Input

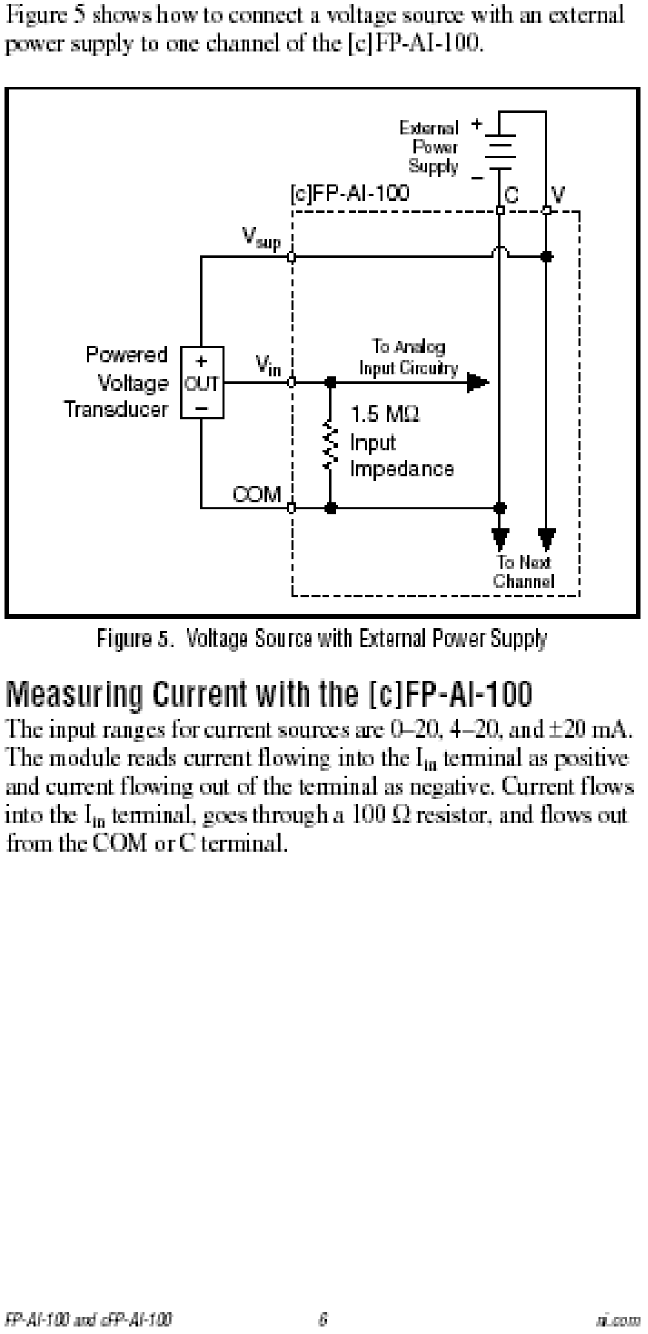

Figure 5 shows how to connect a voltage source with an external power supply to one channel of the [c]FP-AI-100.

Figure 5. Voltage Source with External Power Supply

Measuring Current with the [c]FP-AI-100

The input ranges for current sources are 0–20, 4–20, and ±20 mA. The module reads current flowing into the I_{in} terminal as positive and current flowing out of the terminal as negative. Current flows into the I_{in} terminal, goes through a 100 Ω resistor, and flows out from the COM or C terminal.

FP-AI-100 and cFP-AI-100 6 ni.com

Figur B.18: Data-ark FieldPoint Analog Input

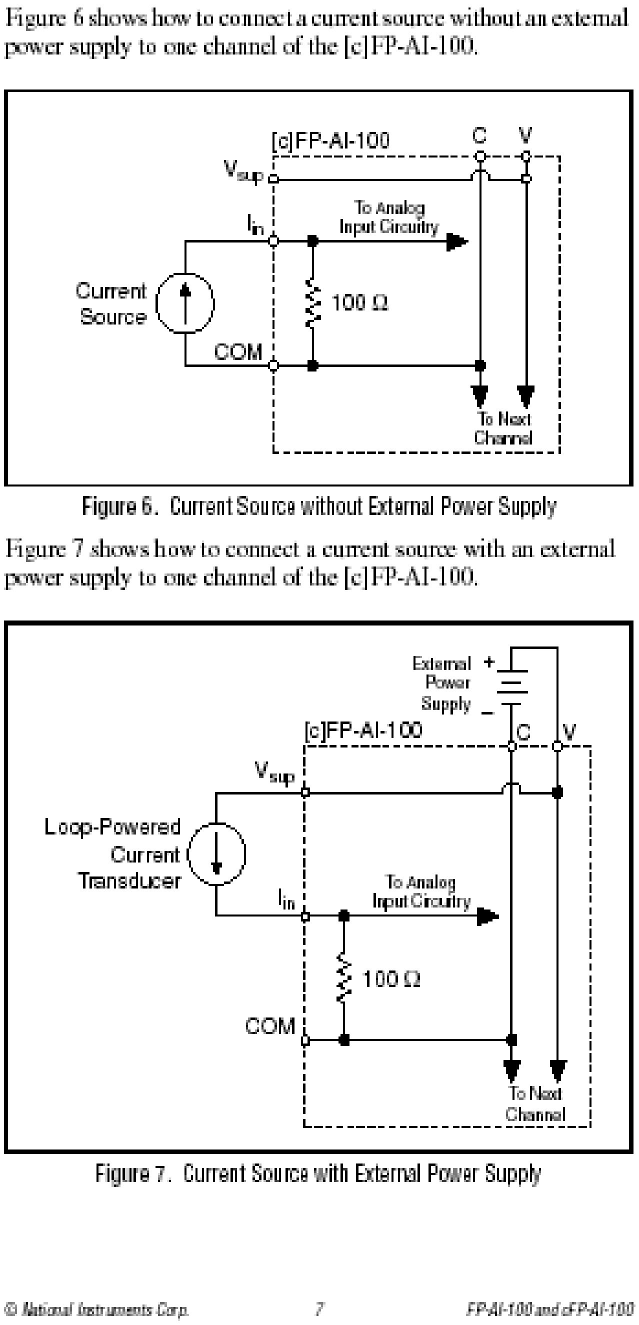

Figure 6 shows how to connect a current source without an external power supply to one channel of the [c]FP-AI-100.

Figure 6. Current Source without External Power Supply

Figure 7 shows how to connect a current source with an external power supply to one channel of the [c]FP-AI-100.

Figure 7. Current Source with External Power Supply

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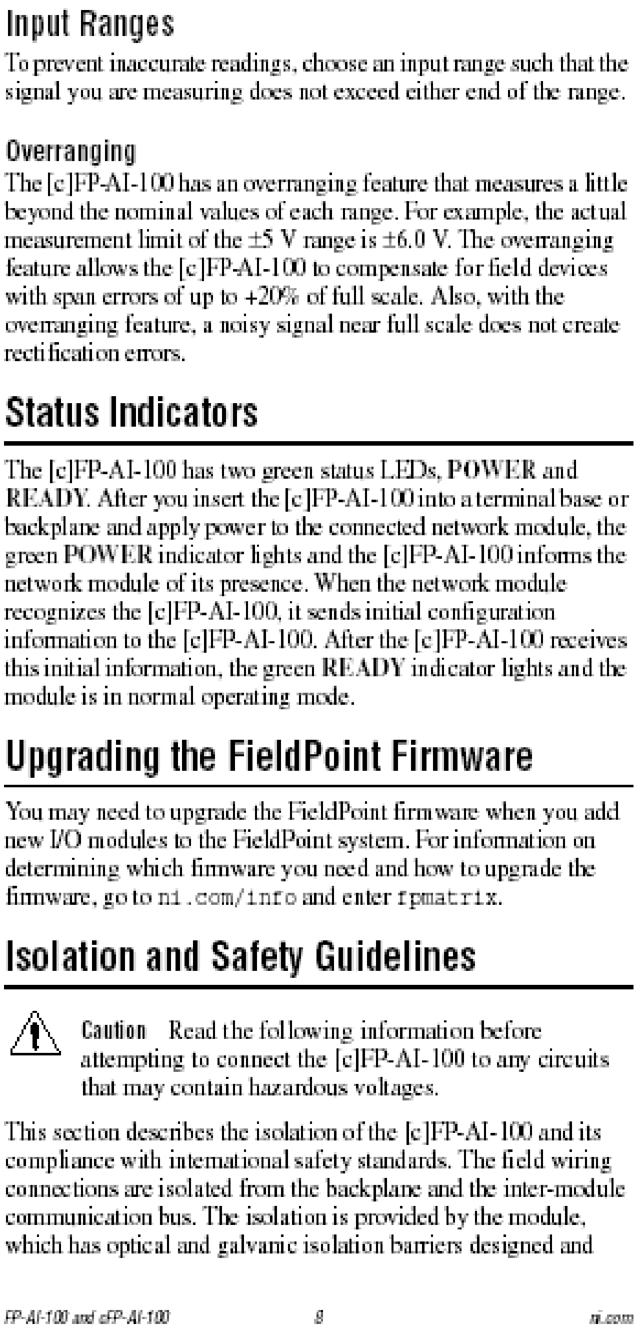
Figur B.19: Data-ark FieldPoint Analog Input



Input Ranges

To prevent inaccurate readings, choose an input range such that the signal you are measuring does not exceed either end of the range.

Overranging

The [c]FP-AI-100 has an overranging feature that measures a little beyond the nominal values of each range. For example, the actual measurement limit of the ±5 V range is ±6.0 V. The overranging feature allows the [c]FP-AI-100 to compensate for field devices with span errors of up to +20% of full scale. Also, with the overranging feature, a noisy signal near full scale does not create rectification errors.

Status Indicators

The [c]FP-AI-100 has two green status LEDs, **POWER** and **READY**. After you insert the [c]FP-AI-100 into a terminal base or backplane and apply power to the connected network module, the green **POWER** indicator lights and the [c]FP-AI-100 informs the network module of its presence. When the network module recognizes the [c]FP-AI-100, it sends initial configuration information to the [c]FP-AI-100. After the [c]FP-AI-100 receives this initial information, the green **READY** indicator lights and the module is in normal operating mode.

Upgrading the FieldPoint Firmware

You may need to upgrade the FieldPoint firmware when you add new I/O modules to the FieldPoint system. For information on determining which firmware you need and how to upgrade the firmware, go to `ni.com/info` and enter `fpmatrix`.

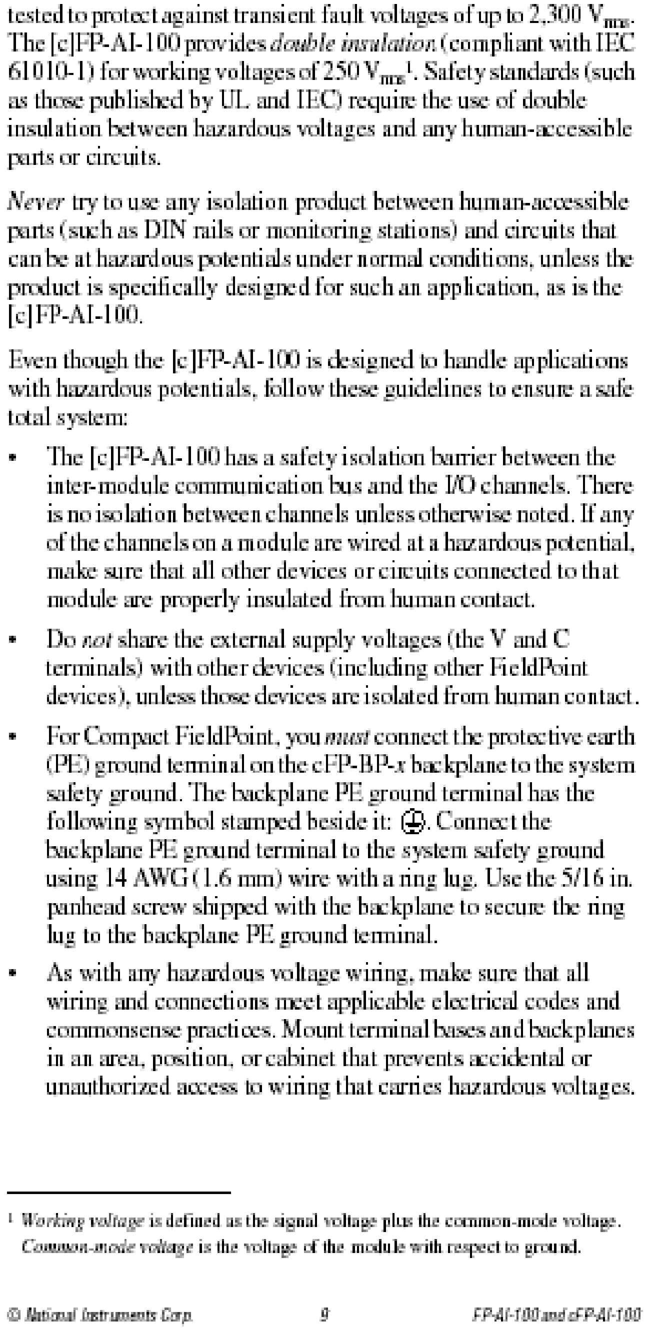
Isolation and Safety Guidelines

Caution Read the following information before attempting to connect the [c]FP-AI-100 to any circuits that may contain hazardous voltages.

This section describes the isolation of the [c]FP-AI-100 and its compliance with international safety standards. The field wiring connections are isolated from the backplane and the inter-module communication bus. The isolation is provided by the module, which has optical and galvanic isolation barriers designed and

FP-AI-100 and cFP-AI-100 8 *ni.com*

Figur B.20: Data-ark FieldPoint Analog Input



tested to protect against transient fault voltages of up to 2,300 V_{rms}. The [c]FP-AI-100 provides *double insulation* (compliant with IEC 61010-1) for working voltages of 250 V_{rms}[1]. Safety standards (such as those published by UL and IEC) require the use of double insulation between hazardous voltages and any human-accessible parts or circuits.

Never try to use any isolation product between human-accessible parts (such as DIN rails or monitoring stations) and circuits that can be at hazardous potentials under normal conditions, unless the product is specifically designed for such an application, as is the [c]FP-AI-100.

Even though the [c]FP-AI-100 is designed to handle applications with hazardous potentials, follow these guidelines to ensure a safe total system:

- The [c]FP-AI-100 has a safety isolation barrier between the inter-module communication bus and the I/O channels. There is no isolation between channels unless otherwise noted. If any of the channels on a module are wired at a hazardous potential, make sure that all other devices or circuits connected to that module are properly insulated from human contact.
- Do *not* share the external supply voltages (the V and C terminals) with other devices (including other FieldPoint devices), unless those devices are isolated from human contact.
- For Compact FieldPoint, you *must* connect the protective earth (PE) ground terminal on the cFP-BP-*x* backplane to the system safety ground. The backplane PE ground terminal has the following symbol stamped beside it: ⏚. Connect the backplane PE ground terminal to the system safety ground using 14 AWG (1.6 mm) wire with a ring lug. Use the 5/16 in. panhead screw shipped with the backplane to secure the ring lug to the backplane PE ground terminal.
- As with any hazardous voltage wiring, make sure that all wiring and connections meet applicable electrical codes and commonsense practices. Mount terminal bases and backplanes in an area, position, or cabinet that prevents accidental or unauthorized access to wiring that carries hazardous voltages.

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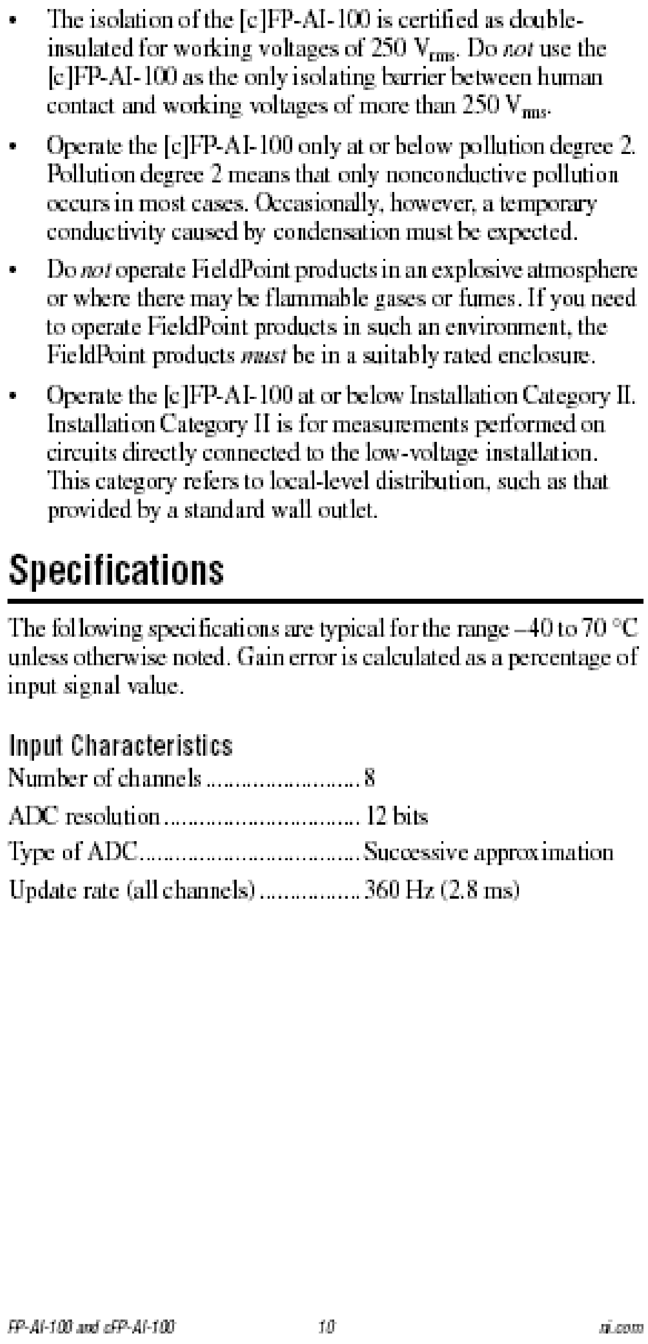
[1] *Working voltage* is defined as the signal voltage plus the common-mode voltage. *Common-mode voltage* is the voltage of the module with respect to ground.

Figur B.21: Data-ark FieldPoint Analog Input



- The isolation of the [c]FP-AI-100 is certified as double-insulated for working voltages of 250 V_{rms}. Do *not* use the [c]FP-AI-100 as the only isolating barrier between human contact and working voltages of more than 250 V_{rms}.
- Operate the [c]FP-AI-100 only at or below pollution degree 2. Pollution degree 2 means that only nonconductive pollution occurs in most cases. Occasionally, however, a temporary conductivity caused by condensation must be expected.
- Do *not* operate FieldPoint products in an explosive atmosphere or where there may be flammable gases or fumes. If you need to operate FieldPoint products in such an environment, the FieldPoint products *must* be in a suitably rated enclosure.
- Operate the [c]FP-AI-100 at or below Installation Category II. Installation Category II is for measurements performed on circuits directly connected to the low-voltage installation. This category refers to local-level distribution, such as that provided by a standard wall outlet.

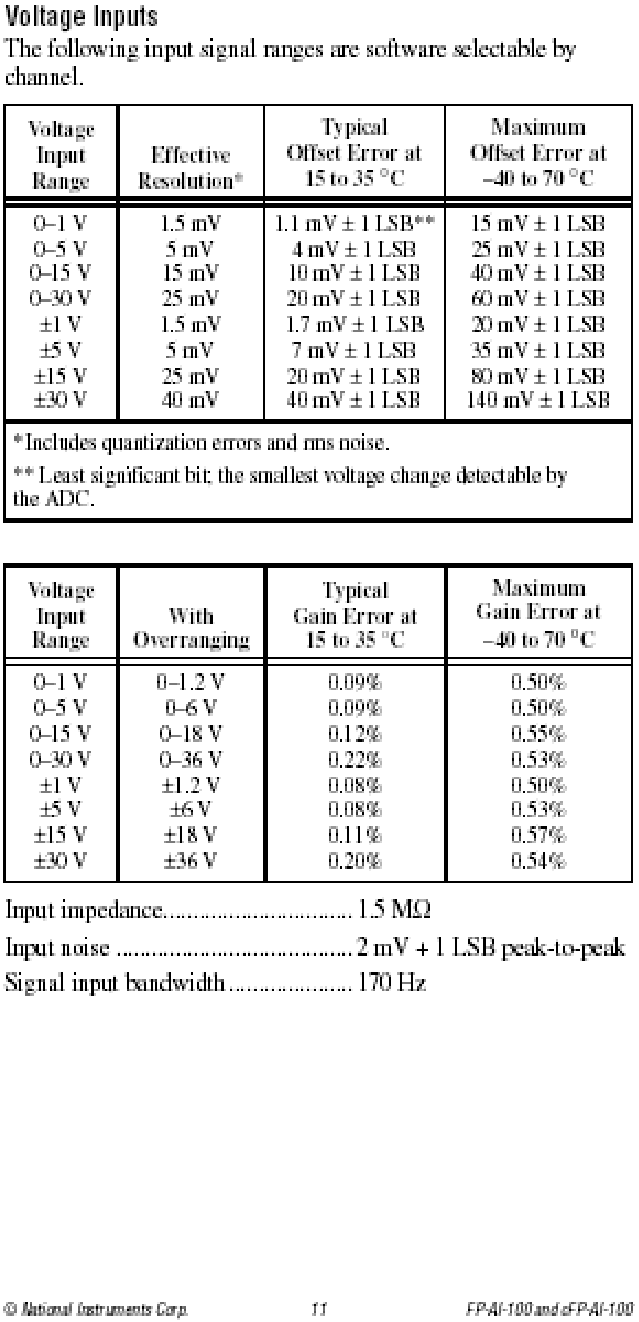
Specifications

The following specifications are typical for the range –40 to 70 °C unless otherwise noted. Gain error is calculated as a percentage of input signal value.

Input Characteristics

Number of channels	8
ADC resolution	12 bits
Type of ADC	Successive approximation
Update rate (all channels)	360 Hz (2.8 ms)

Figur B.22: Data-ark FieldPoint Analog Input



Voltage Inputs

The following input signal ranges are software selectable by channel.

Voltage Input Range	Effective Resolution*	Typical Offset Error at 15 to 35 °C	Maximum Offset Error at –40 to 70 °C
0–1 V	1.5 mV	1.1 mV ± 1 LSB**	15 mV ± 1 LSB
0–5 V	5 mV	4 mV ± 1 LSB	25 mV ± 1 LSB
0–15 V	15 mV	10 mV ± 1 LSB	40 mV ± 1 LSB
0–30 V	25 mV	20 mV ± 1 LSB	60 mV ± 1 LSB
±1 V	1.5 mV	1.7 mV ± 1 LSB	20 mV ± 1 LSB
±5 V	5 mV	7 mV ± 1 LSB	35 mV ± 1 LSB
±15 V	25 mV	20 mV ± 1 LSB	80 mV ± 1 LSB
±30 V	40 mV	40 mV ± 1 LSB	140 mV ± 1 LSB

*Includes quantization errors and rms noise.

** Least significant bit; the smallest voltage change detectable by the ADC.

Voltage Input Range	With Overranging	Typical Gain Error at 15 to 35 °C	Maximum Gain Error at –40 to 70 °C
0–1 V	0–1.2 V	0.09%	0.50%
0–5 V	0–6 V	0.09%	0.50%
0–15 V	0–18 V	0.12%	0.55%
0–30 V	0–36 V	0.22%	0.53%
±1 V	±1.2 V	0.08%	0.50%
±5 V	±6 V	0.08%	0.53%
±15 V	±18 V	0.11%	0.57%
±30 V	±36 V	0.20%	0.54%

Input impedance................................ 1.5 MΩ

Input noise .... 2 mV + 1 LSB peak-to-peak

Signal input bandwidth..................... 170 Hz

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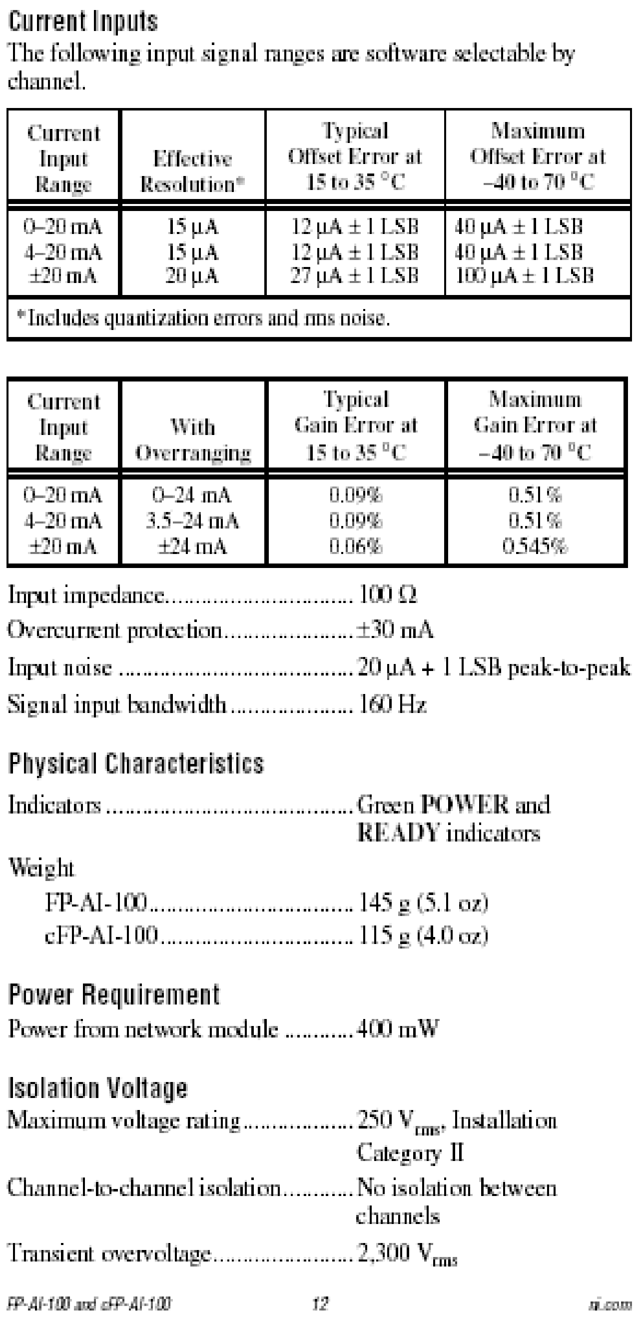
Figur B.23: Data-ark FieldPoint Analog Input



Current Inputs

The following input signal ranges are software selectable by channel.

Current Input Range	Effective Resolution*	Typical Offset Error at 15 to 35 °C	Maximum Offset Error at –40 to 70 °C
0–20 mA	15 µA	12 µA ± 1 LSB	40 µA ± 1 LSB
4–20 mA	15 µA	12 µA ± 1 LSB	40 µA ± 1 LSB
±20 mA	20 µA	27 µA ± 1 LSB	100 µA ± 1 LSB

*Includes quantization errors and rms noise.

Current Input Range	With Overranging	Typical Gain Error at 15 to 35 °C	Maximum Gain Error at –40 to 70 °C
0–20 mA	0–24 mA	0.09%	0.51%
4–20 mA	3.5–24 mA	0.09%	0.51%
±20 mA	±24 mA	0.06%	0.545%

Input impedance................................ 100 Ω

Overcurrent protection...................... ±30 mA

Input noise .... 20 µA + 1 LSB peak-to-peak

Signal input bandwidth .... 160 Hz

Physical Characteristics

Indicators .... Green POWER and READY indicators

Weight

- FP-AI-100.................................. 145 g (5.1 oz)
- cFP-AI-100................................. 115 g (4.0 oz)

Power Requirement

Power from network module .... 400 mW

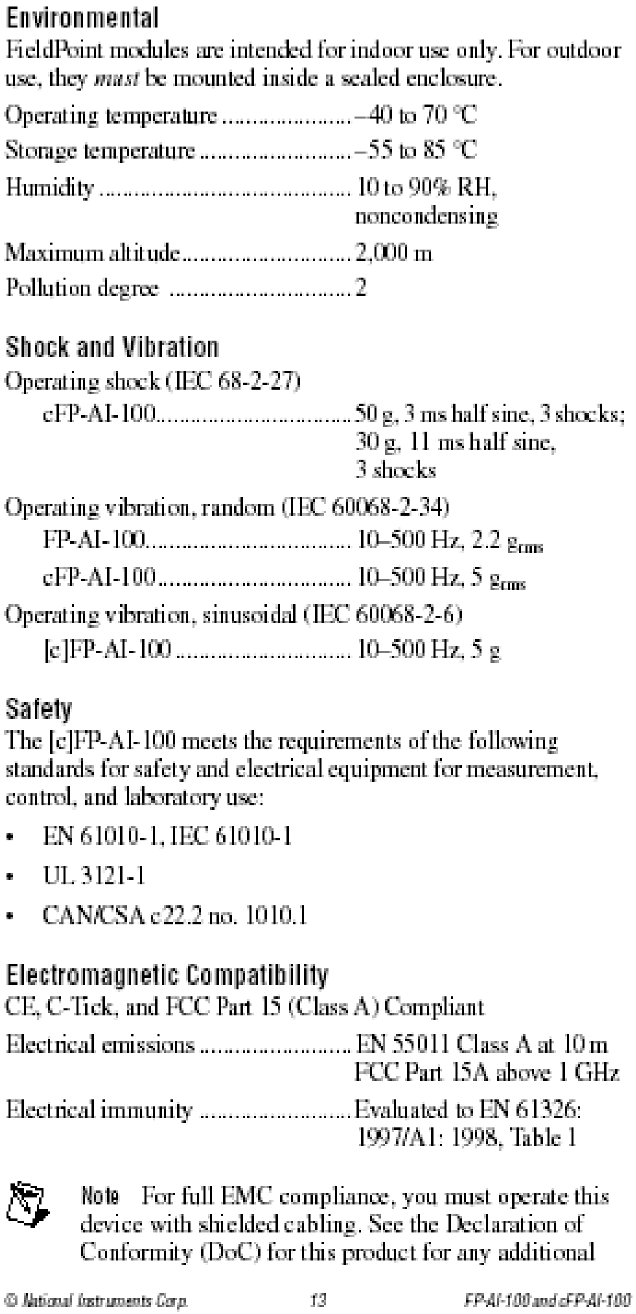
Isolation Voltage

Maximum voltage rating.................. 250 V_{rms}, Installation Category II

Channel-to-channel isolation........... No isolation between channels

Transient overvoltage....................... 2,300 V_{rms}

Figur B.24: Data-ark FieldPoint Analog Input



Environmental

FieldPoint modules are intended for indoor use only. For outdoor use, they *must* be mounted inside a sealed enclosure.

Operating temperature	–40 to 70 °C
Storage temperature	–55 to 85 °C
Humidity	10 to 90% RH, noncondensing
Maximum altitude	2,000 m
Pollution degree	2

Shock and Vibration

Operating shock (IEC 68-2-27)	
cFP-AI-100	50 g, 3 ms half sine, 3 shocks; 30 g, 11 ms half sine, 3 shocks
Operating vibration, random (IEC 60068-2-34)	
FP-AI-100	10–500 Hz, 2.2 g_{rms}
cFP-AI-100	10–500 Hz, 5 g_{rms}
Operating vibration, sinusoidal (IEC 60068-2-6)	
[c]FP-AI-100	10–500 Hz, 5 g

Safety

The [c]FP-AI-100 meets the requirements of the following standards for safety and electrical equipment for measurement, control, and laboratory use:

- EN 61010-1, IEC 61010-1
- UL 3121-1
- CAN/CSA c22.2 no. 1010.1

Electromagnetic Compatibility

CE, C-Tick, and FCC Part 15 (Class A) Compliant

Electrical emissions	EN 55011 Class A at 10 m FCC Part 15A above 1 GHz
Electrical immunity	Evaluated to EN 61326: 1997/A1: 1998, Table 1

Note For full EMC compliance, you must operate this device with shielded cabling. See the Declaration of Conformity (DoC) for this product for any additional

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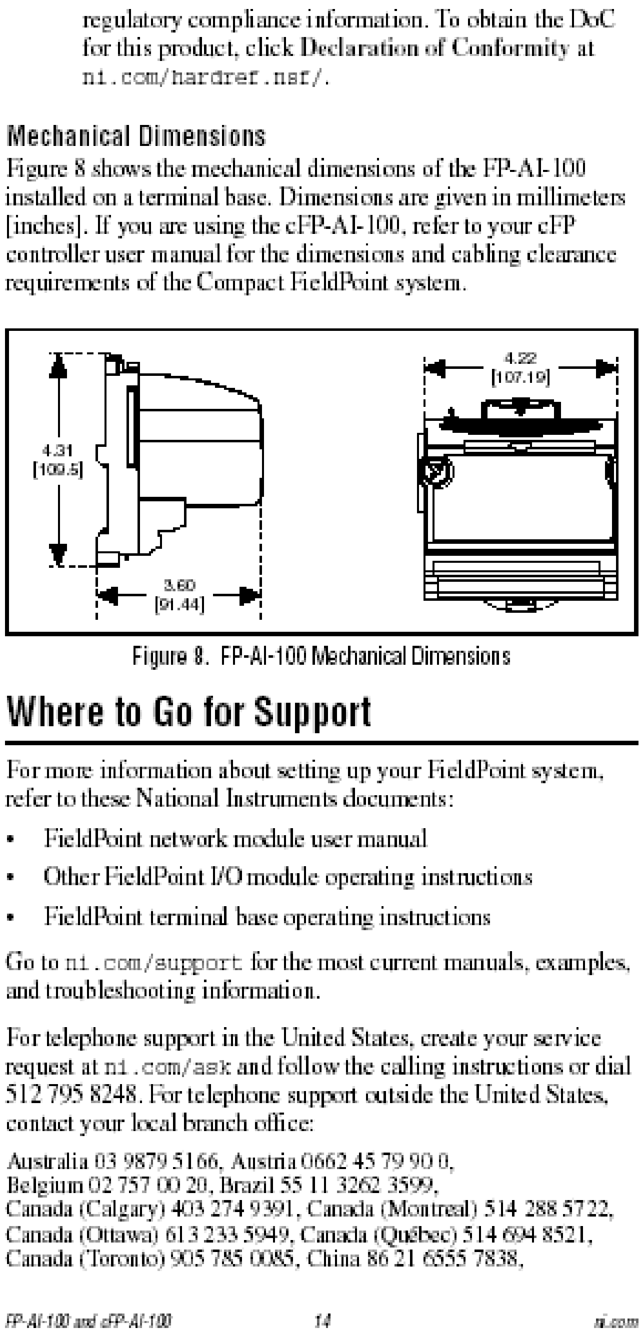
Figur B.25: Data-ark FieldPoint Analog Input



regulatory compliance information. To obtain the DoC for this product, click **Declaration of Conformity** at `ni.com/hardref.nsf/`.

Mechanical Dimensions

Figure 8 shows the mechanical dimensions of the FP-AI-100 installed on a terminal base. Dimensions are given in millimeters [inches]. If you are using the cFP-AI-100, refer to your cFP controller user manual for the dimensions and cabling clearance requirements of the Compact FieldPoint system.

Figure 8. FP-AI-100 Mechanical Dimensions

Where to Go for Support

For more information about setting up your FieldPoint system, refer to these National Instruments documents:

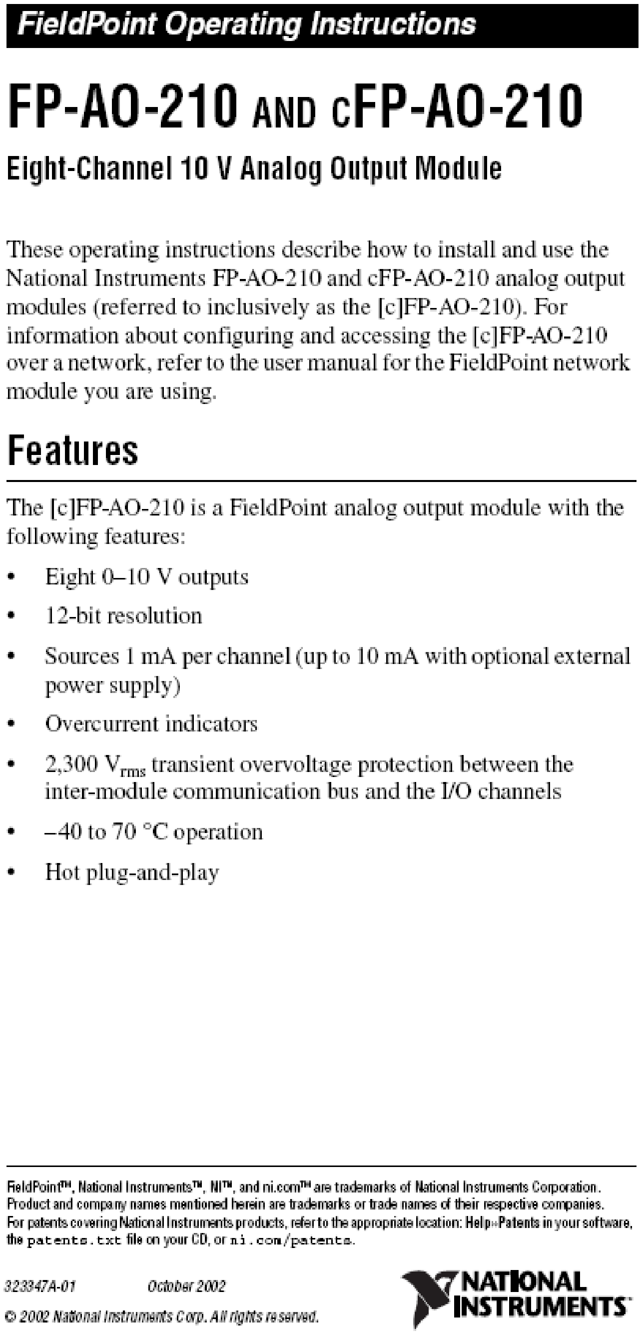
- FieldPoint network module user manual
- Other FieldPoint I/O module operating instructions
- FieldPoint terminal base operating instructions

Go to `ni.com/support` for the most current manuals, examples, and troubleshooting information.

For telephone support in the United States, create your service request at `ni.com/ask` and follow the calling instructions or dial 512 795 8248. For telephone support outside the United States, contact your local branch office:

Australia 03 9879 5166, Austria 0662 45 79 90 0,
Belgium 02 757 00 20, Brazil 55 11 3262 3599,
Canada (Calgary) 403 274 9391, Canada (Montreal) 514 288 5722,
Canada (Ottawa) 613 233 5949, Canada (Québec) 514 694 8521,
Canada (Toronto) 905 785 0085, China 86 21 6555 7838,

Figur B.26: Data-ark FieldPoint Analog Input



FieldPoint Operating Instructions

FP-AO-210 AND cFP-AO-210

Eight-Channel 10 V Analog Output Module

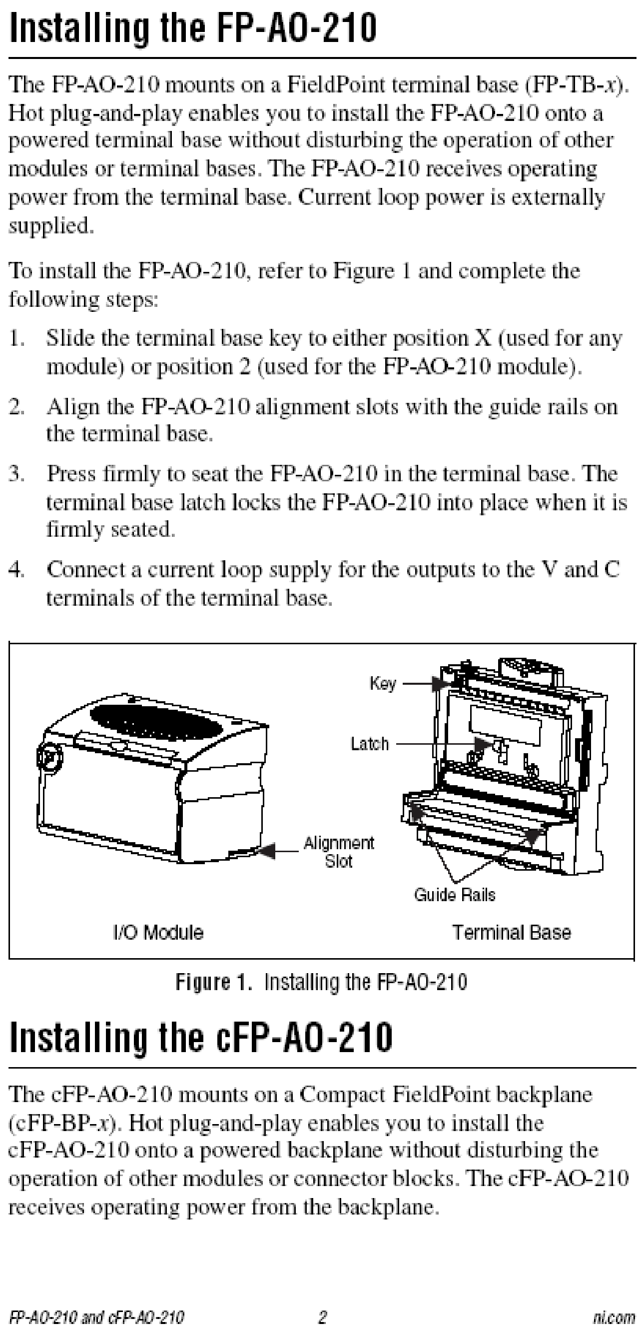
These operating instructions describe how to install and use the National Instruments FP-AO-210 and cFP-AO-210 analog output modules (referred to inclusively as the [c]FP-AO-210). For information about configuring and accessing the [c]FP-AO-210 over a network, refer to the user manual for the FieldPoint network module you are using.

Features

The [c]FP-AO-210 is a FieldPoint analog output module with the following features:

- Eight 0–10 V outputs
- 12-bit resolution
- Sources 1 mA per channel (up to 10 mA with optional external power supply)
- Overcurrent indicators
- 2,300 V_{rms} transient overvoltage protection between the inter-module communication bus and the I/O channels
- –40 to 70 °C operation
- Hot plug-and-play

Figur B.27: Data-ark FieldPoint Analog Output



Installing the FP-AO-210

The FP-AO-210 mounts on a FieldPoint terminal base (FP-TB-*x*). Hot plug-and-play enables you to install the FP-AO-210 onto a powered terminal base without disturbing the operation of other modules or terminal bases. The FP-AO-210 receives operating power from the terminal base. Current loop power is externally supplied.

To install the FP-AO-210, refer to Figure 1 and complete the following steps:

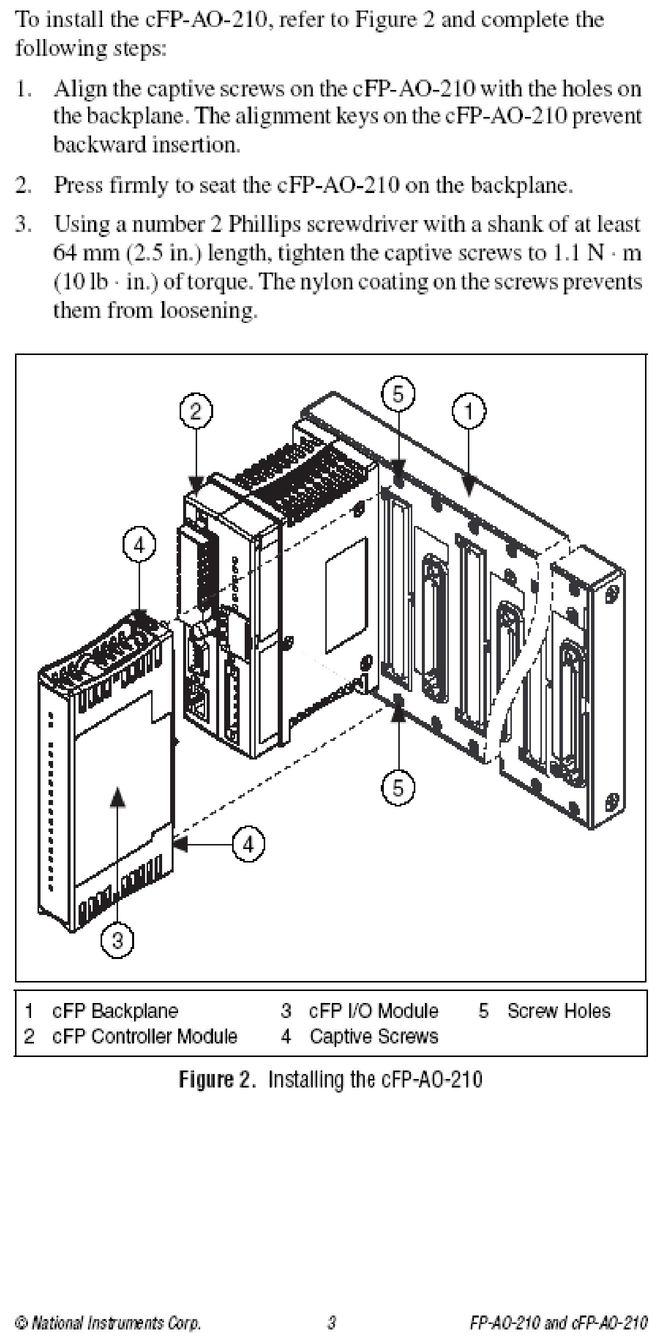
1. Slide the terminal base key to either position X (used for any module) or position 2 (used for the FP-AO-210 module).
2. Align the FP-AO-210 alignment slots with the guide rails on the terminal base.
3. Press firmly to seat the FP-AO-210 in the terminal base. The terminal base latch locks the FP-AO-210 into place when it is firmly seated.
4. Connect a current loop supply for the outputs to the V and C terminals of the terminal base.

Figure 1. Installing the FP-AO-210

Installing the cFP-AO-210

The cFP-AO-210 mounts on a Compact FieldPoint backplane (cFP-BP-*x*). Hot plug-and-play enables you to install the cFP-AO-210 onto a powered backplane without disturbing the operation of other modules or connector blocks. The cFP-AO-210 receives operating power from the backplane.

Figur B.28: Data-ark FieldPoint Analog Output



To install the cFP-AO-210, refer to Figure 2 and complete the following steps:

1. Align the captive screws on the cFP-AO-210 with the holes on the backplane. The alignment keys on the cFP-AO-210 prevent backward insertion.
2. Press firmly to seat the cFP-AO-210 on the backplane.
3. Using a number 2 Phillips screwdriver with a shank of at least 64 mm (2.5 in.) length, tighten the captive screws to 1.1 N · m (10 lb · in.) of torque. The nylon coating on the screws prevents them from loosening.

1	cFP Backplane	3	cFP I/O Module	5	Screw Holes
2	cFP Controller Module	4	Captive Screws		

Figure 2. Installing the cFP-AO-210

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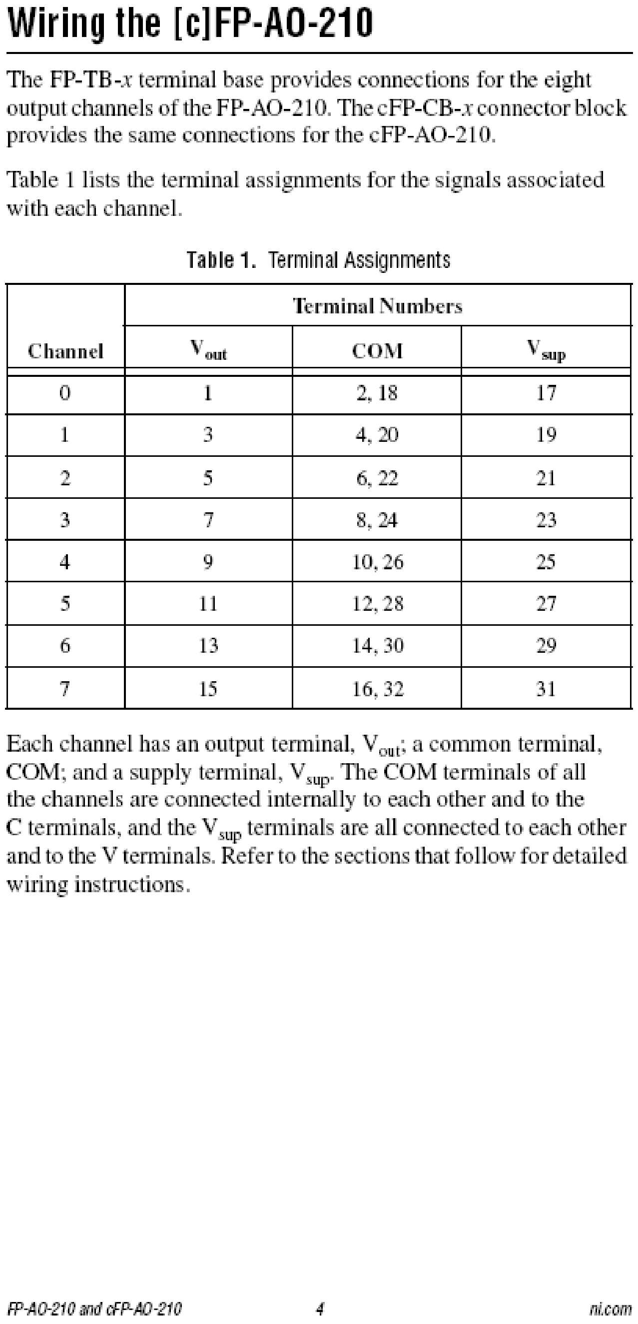
Figur B.29: Data-ark FieldPoint Analog Output



Wiring the [c]FP-AO-210

The FP-TB-*x* terminal base provides connections for the eight output channels of the FP-AO-210. The cFP-CB-*x* connector block provides the same connections for the cFP-AO-210.

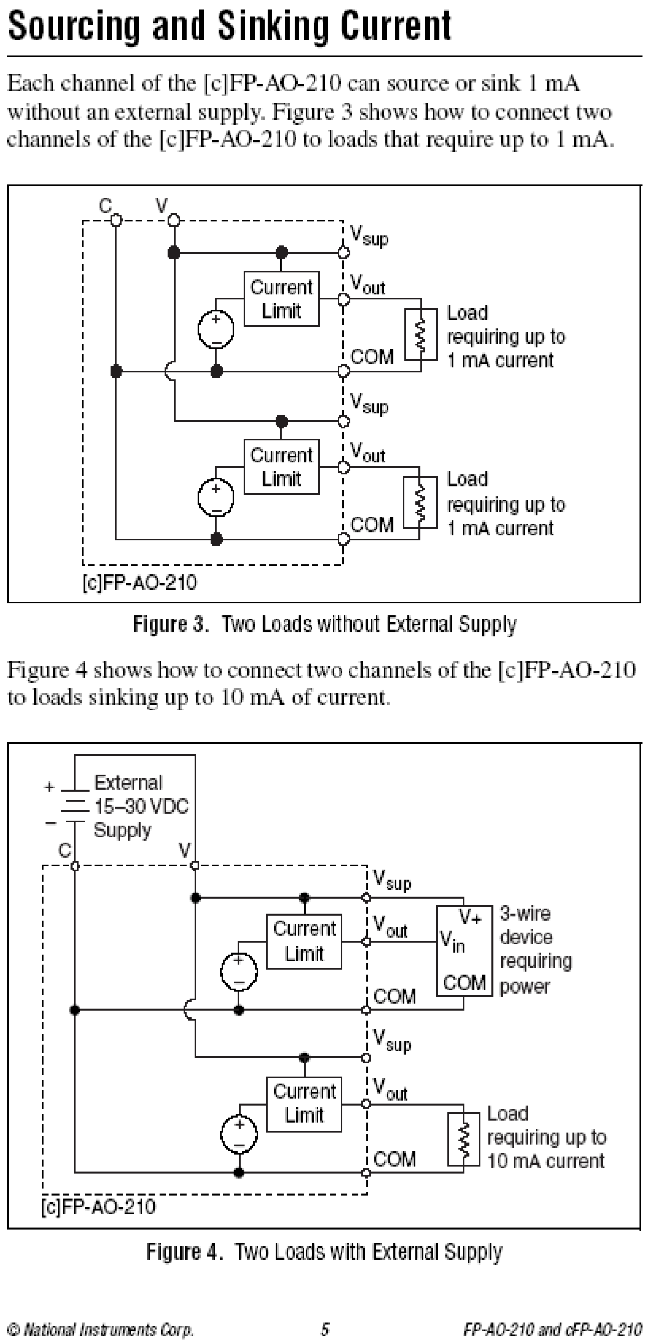
Table 1 lists the terminal assignments for the signals associated with each channel.

Table 1. Terminal Assignments

	Terminal Numbers		
Channel	V_{out}	COM	V_{sup}
0	1	2, 18	17
1	3	4, 20	19
2	5	6, 22	21
3	7	8, 24	23
4	9	10, 26	25
5	11	12, 28	27
6	13	14, 30	29
7	15	16, 32	31

Each channel has an output terminal, V_{out}; a common terminal, COM; and a supply terminal, V_{sup}. The COM terminals of all the channels are connected internally to each other and to the C terminals, and the V_{sup} terminals are all connected to each other and to the V terminals. Refer to the sections that follow for detailed wiring instructions.

Figur B.30: Data-ark FieldPoint Analog Output



Sourcing and Sinking Current

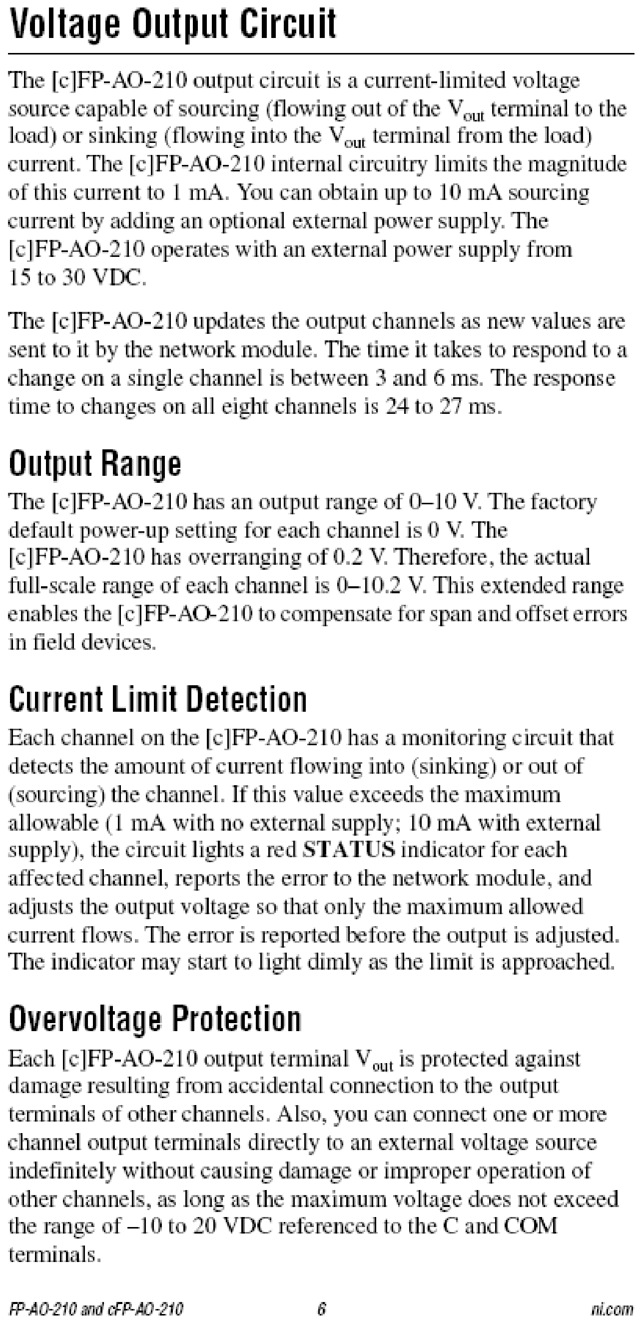
Each channel of the [c]FP-AO-210 can source or sink 1 mA without an external supply. Figure 3 shows how to connect two channels of the [c]FP-AO-210 to loads that require up to 1 mA.

Figure 3. Two Loads without External Supply

Figure 4 shows how to connect two channels of the [c]FP-AO-210 to loads sinking up to 10 mA of current.

Figure 4. Two Loads with External Supply

Figur B.31: Data-ark FieldPoint Analog Output



Voltage Output Circuit

The [c]FP-AO-210 output circuit is a current-limited voltage source capable of sourcing (flowing out of the V_{out} terminal to the load) or sinking (flowing into the V_{out} terminal from the load) current. The [c]FP-AO-210 internal circuitry limits the magnitude of this current to 1 mA. You can obtain up to 10 mA sourcing current by adding an optional external power supply. The [c]FP-AO-210 operates with an external power supply from 15 to 30 VDC.

The [c]FP-AO-210 updates the output channels as new values are sent to it by the network module. The time it takes to respond to a change on a single channel is between 3 and 6 ms. The response time to changes on all eight channels is 24 to 27 ms.

Output Range

The [c]FP-AO-210 has an output range of 0–10 V. The factory default power-up setting for each channel is 0 V. The [c]FP-AO-210 has overranging of 0.2 V. Therefore, the actual full-scale range of each channel is 0–10.2 V. This extended range enables the [c]FP-AO-210 to compensate for span and offset errors in field devices.

Current Limit Detection

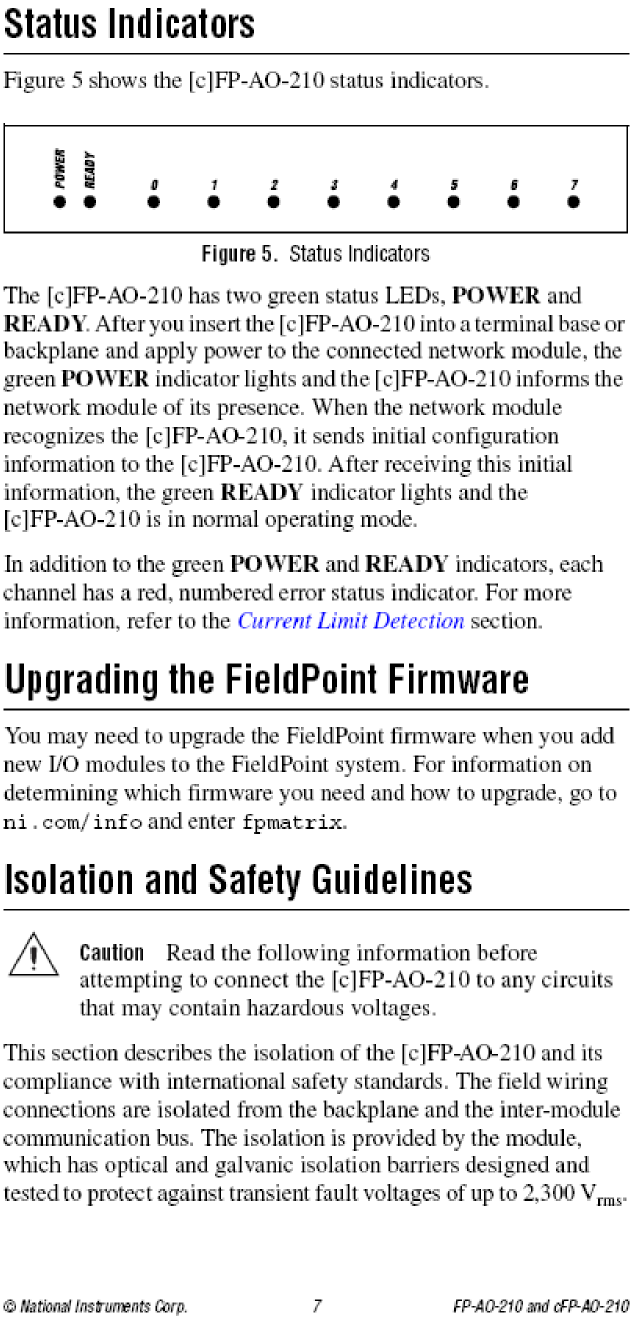
Each channel on the [c]FP-AO-210 has a monitoring circuit that detects the amount of current flowing into (sinking) or out of (sourcing) the channel. If this value exceeds the maximum allowable (1 mA with no external supply; 10 mA with external supply), the circuit lights a red **STATUS** indicator for each affected channel, reports the error to the network module, and adjusts the output voltage so that only the maximum allowed current flows. The error is reported before the output is adjusted. The indicator may start to light dimly as the limit is approached.

Overvoltage Protection

Each [c]FP-AO-210 output terminal V_{out} is protected against damage resulting from accidental connection to the output terminals of other channels. Also, you can connect one or more channel output terminals directly to an external voltage source indefinitely without causing damage or improper operation of other channels, as long as the maximum voltage does not exceed the range of –10 to 20 VDC referenced to the C and COM terminals.

FP-AO-210 and cFP-AO-210 *6* *ni.com*

Figur B.32: Data-ark FieldPoint Analog Output



Status Indicators

Figure 5 shows the [c]FP-AO-210 status indicators.

Figure 5. Status Indicators

The [c]FP-AO-210 has two green status LEDs, **POWER** and **READY**. After you insert the [c]FP-AO-210 into a terminal base or backplane and apply power to the connected network module, the green **POWER** indicator lights and the [c]FP-AO-210 informs the network module of its presence. When the network module recognizes the [c]FP-AO-210, it sends initial configuration information to the [c]FP-AO-210. After receiving this initial information, the green **READY** indicator lights and the [c]FP-AO-210 is in normal operating mode.

In addition to the green **POWER** and **READY** indicators, each channel has a red, numbered error status indicator. For more information, refer to the *Current Limit Detection* section.

Upgrading the FieldPoint Firmware

You may need to upgrade the FieldPoint firmware when you add new I/O modules to the FieldPoint system. For information on determining which firmware you need and how to upgrade, go to `ni.com/info` and enter `fpmatrix`.

Isolation and Safety Guidelines

⚠ **Caution** Read the following information before attempting to connect the [c]FP-AO-210 to any circuits that may contain hazardous voltages.

This section describes the isolation of the [c]FP-AO-210 and its compliance with international safety standards. The field wiring connections are isolated from the backplane and the inter-module communication bus. The isolation is provided by the module, which has optical and galvanic isolation barriers designed and tested to protect against transient fault voltages of up to 2,300 V_{rms}.

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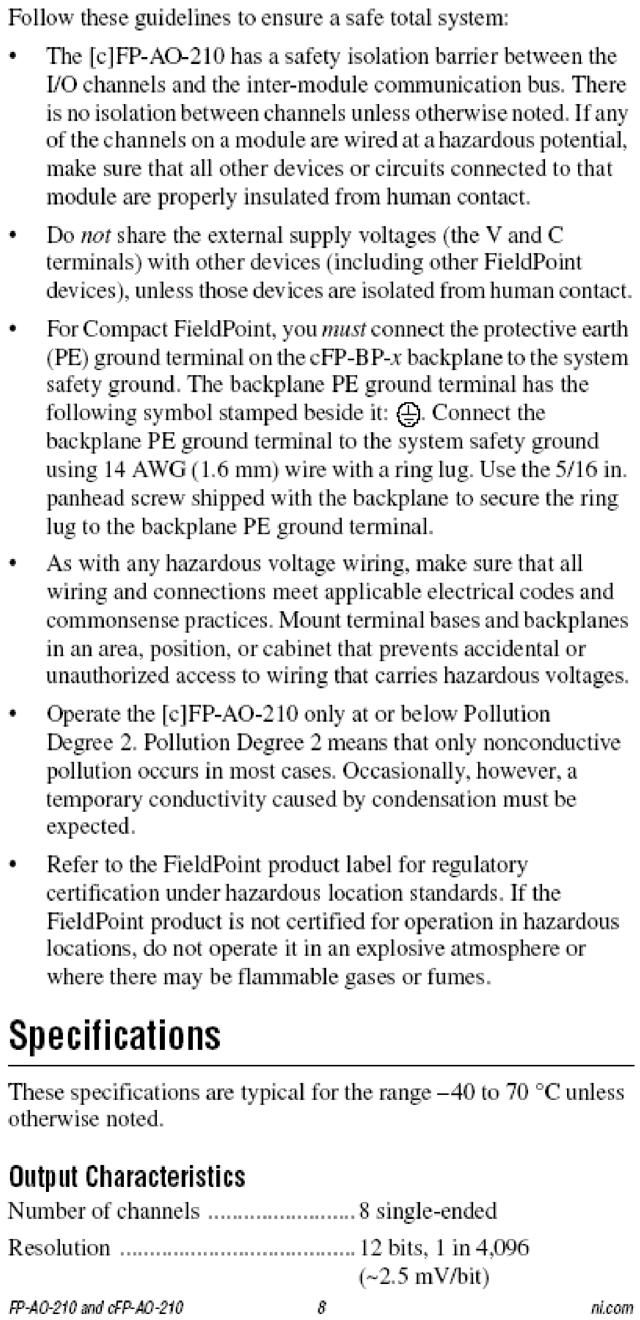
Figur B.33: Data-ark FieldPoint Analog Output



Follow these guidelines to ensure a safe total system:

- The [c]FP-AO-210 has a safety isolation barrier between the I/O channels and the inter-module communication bus. There is no isolation between channels unless otherwise noted. If any of the channels on a module are wired at a hazardous potential, make sure that all other devices or circuits connected to that module are properly insulated from human contact.
- Do *not* share the external supply voltages (the V and C terminals) with other devices (including other FieldPoint devices), unless those devices are isolated from human contact.
- For Compact FieldPoint, you *must* connect the protective earth (PE) ground terminal on the cFP-BP-*x* backplane to the system safety ground. The backplane PE ground terminal has the following symbol stamped beside it: ⏚. Connect the backplane PE ground terminal to the system safety ground using 14 AWG (1.6 mm) wire with a ring lug. Use the 5/16 in. panhead screw shipped with the backplane to secure the ring lug to the backplane PE ground terminal.
- As with any hazardous voltage wiring, make sure that all wiring and connections meet applicable electrical codes and commonsense practices. Mount terminal bases and backplanes in an area, position, or cabinet that prevents accidental or unauthorized access to wiring that carries hazardous voltages.
- Operate the [c]FP-AO-210 only at or below Pollution Degree 2. Pollution Degree 2 means that only nonconductive pollution occurs in most cases. Occasionally, however, a temporary conductivity caused by condensation must be expected.
- Refer to the FieldPoint product label for regulatory certification under hazardous location standards. If the FieldPoint product is not certified for operation in hazardous locations, do not operate it in an explosive atmosphere or where there may be flammable gases or fumes.

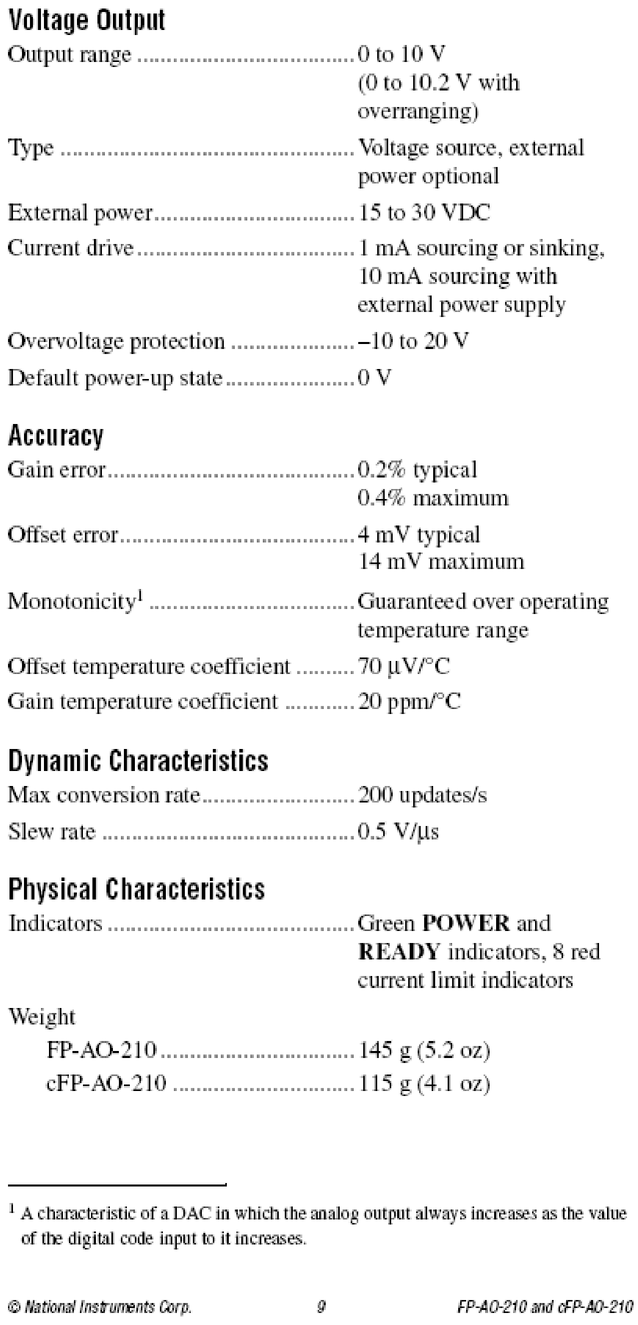
Specifications

These specifications are typical for the range –40 to 70 °C unless otherwise noted.

Output Characteristics

Number of channels	8 single-ended
Resolution	12 bits, 1 in 4,096 (~2.5 mV/bit)

Figur B.34: Data-ark FieldPoint Analog Output



Voltage Output

Output range	0 to 10 V (0 to 10.2 V with overranging)
Type	Voltage source, external power optional
External power	15 to 30 VDC
Current drive	1 mA sourcing or sinking, 10 mA sourcing with external power supply
Overvoltage protection	–10 to 20 V
Default power-up state	0 V

Accuracy

Gain error	0.2% typical 0.4% maximum
Offset error	4 mV typical 14 mV maximum
Monotonicity[1]	Guaranteed over operating temperature range
Offset temperature coefficient	70 µV/°C
Gain temperature coefficient	20 ppm/°C

Dynamic Characteristics

Max conversion rate	200 updates/s
Slew rate	0.5 V/µs

Physical Characteristics

Indicators	Green **POWER** and **READY** indicators, 8 red current limit indicators
Weight	
FP-AO-210	145 g (5.2 oz)
cFP-AO-210	115 g (4.1 oz)

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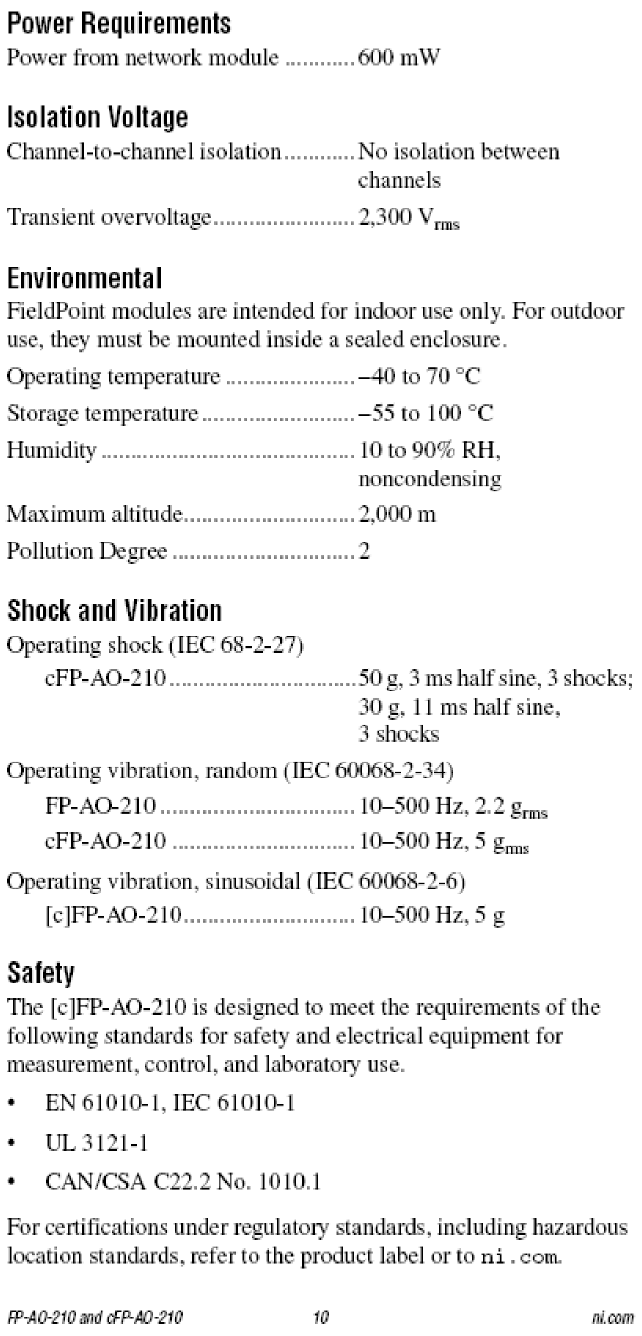
[1] A characteristic of a DAC in which the analog output always increases as the value of the digital code input to it increases.

Figur B.35: Data-ark FieldPoint Analog Output



Power Requirements

Power from network module	600 mW

Isolation Voltage

Channel-to-channel isolation	No isolation between channels
Transient overvoltage	2,300 V_{rms}

Environmental

FieldPoint modules are intended for indoor use only. For outdoor use, they must be mounted inside a sealed enclosure.

Operating temperature	–40 to 70 °C
Storage temperature	–55 to 100 °C
Humidity	10 to 90% RH, noncondensing
Maximum altitude	2,000 m
Pollution Degree	2

Shock and Vibration

Operating shock (IEC 68-2-27)

cFP-AO-210	50 g, 3 ms half sine, 3 shocks; 30 g, 11 ms half sine, 3 shocks

Operating vibration, random (IEC 60068-2-34)

FP-AO-210	10–500 Hz, 2.2 g_{rms}
cFP-AO-210	10–500 Hz, 5 g_{rms}

Operating vibration, sinusoidal (IEC 60068-2-6)

[c]FP-AO-210	10–500 Hz, 5 g

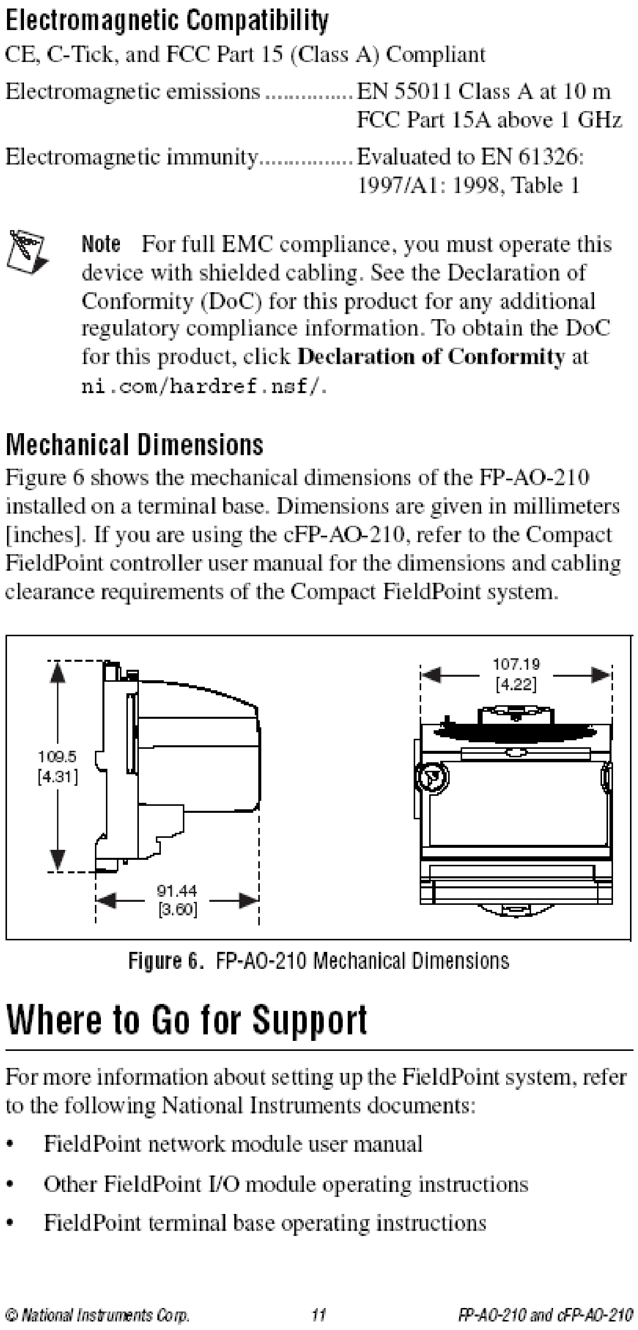
Safety

The [c]FP-AO-210 is designed to meet the requirements of the following standards for safety and electrical equipment for measurement, control, and laboratory use.

- EN 61010-1, IEC 61010-1
- UL 3121-1
- CAN/CSA C22.2 No. 1010.1

For certifications under regulatory standards, including hazardous location standards, refer to the product label or to `ni.com`.

Figur B.36: Data-ark FieldPoint Analog Output



Electromagnetic Compatibility

CE, C-Tick, and FCC Part 15 (Class A) Compliant

Electromagnetic emissions	EN 55011 Class A at 10 m FCC Part 15A above 1 GHz
Electromagnetic immunity	Evaluated to EN 61326: 1997/A1: 1998, Table 1

Note For full EMC compliance, you must operate this device with shielded cabling. See the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, click **Declaration of Conformity** at `ni.com/hardref.nsf/`.

Mechanical Dimensions

Figure 6 shows the mechanical dimensions of the FP-AO-210 installed on a terminal base. Dimensions are given in millimeters [inches]. If you are using the cFP-AO-210, refer to the Compact FieldPoint controller user manual for the dimensions and cabling clearance requirements of the Compact FieldPoint system.

Figure 6. FP-AO-210 Mechanical Dimensions

Where to Go for Support

For more information about setting up the FieldPoint system, refer to the following National Instruments documents:

- FieldPoint network module user manual
- Other FieldPoint I/O module operating instructions
- FieldPoint terminal base operating instructions

Figur B.37: Data-ark FieldPoint Analog Output

Go to `ni.com/support` for the most current manuals, examples, and troubleshooting information.

For telephone support in the United States, create your service request at `ni.com/ask` and follow the calling instructions or dial 512 795 8248. For telephone support outside the United States, contact your local branch office:

Australia 03 9879 5166, Austria 0662 45 79 90 0,
Belgium 02 757 00 20, Brazil 55 11 3262 3599,
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Canada (Montreal) 514 288 5722,
Canada (Ottawa) 613 233 5949, Canada (Québec) 514 694 8521,
Canada (Toronto) 905 785 0085, China 86 21 6555 7838,
Czech Republic 02 2423 5774, Denmark 45 76 26 00,
Finland 09 725 725 11, France 01 48 14 24 24,
Germany 089 741 31 30, Greece 01 42 96 427,
Hong Kong 2645 3186, India 91 80 4190000,
Israel 03 6393737, Italy 02 413091, Japan 03 5472 2970,
Korea 02 3451 3400, Malaysia 603 9596711,
Mexico 001 800 010 0793, Netherlands 0348 433466,
New Zealand 09 914 0488, Norway 32 27 73 00,
Poland 22 3390 150, Portugal 210 311 210, Russia 095 238 7139,
Singapore 65 6 226 5886, Slovenia 3 425 4200,
South Africa 11 805 8197, Spain 91 640 0085,
Sweden 08 587 895 00, Switzerland 056 200 51 51,
Taiwan 02 2528 7227, United Kingdom 01635 523545

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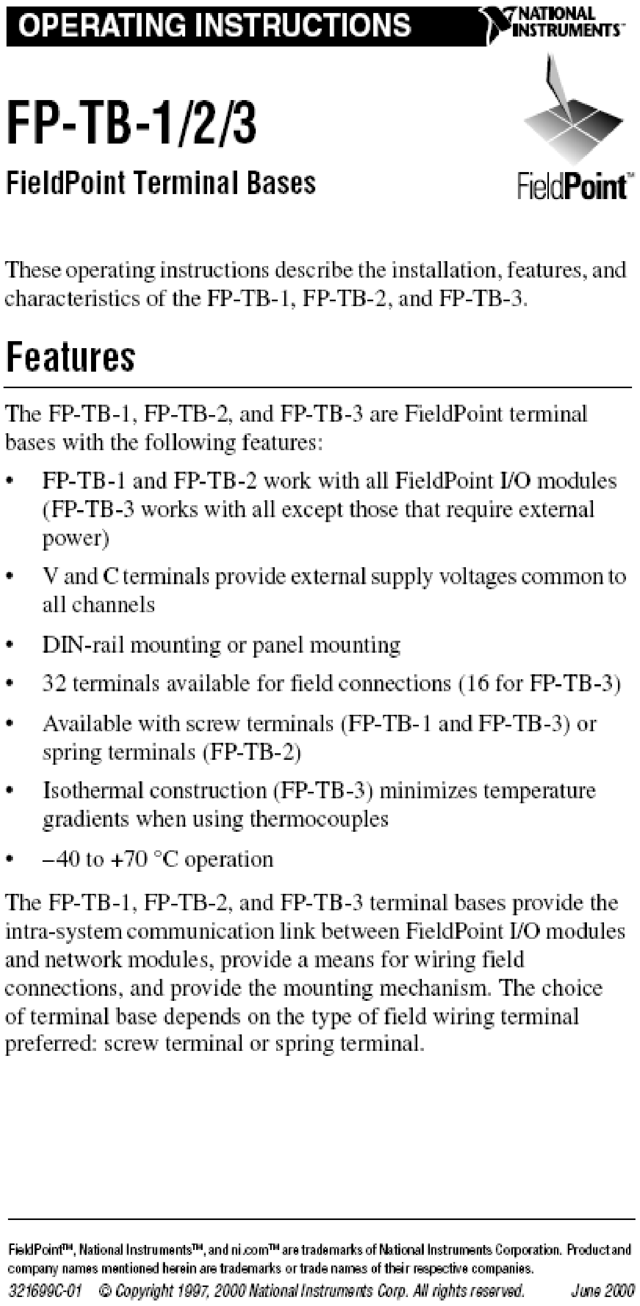
Figur B.38: Data-ark FieldPoint Analog Output



OPERATING INSTRUCTIONS

FP-TB-1/2/3

FieldPoint Terminal Bases

These operating instructions describe the installation, features, and characteristics of the FP-TB-1, FP-TB-2, and FP-TB-3.

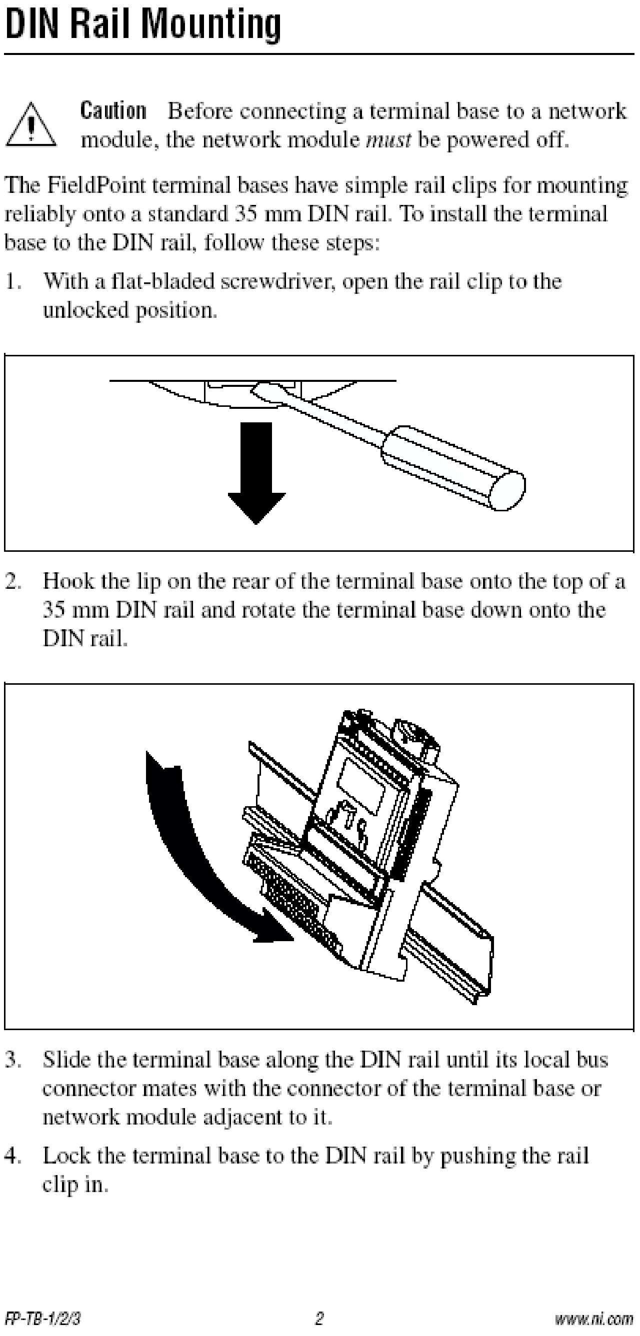
Features

The FP-TB-1, FP-TB-2, and FP-TB-3 are FieldPoint terminal bases with the following features:

- FP-TB-1 and FP-TB-2 work with all FieldPoint I/O modules (FP-TB-3 works with all except those that require external power)
- V and C terminals provide external supply voltages common to all channels
- DIN-rail mounting or panel mounting
- 32 terminals available for field connections (16 for FP-TB-3)
- Available with screw terminals (FP-TB-1 and FP-TB-3) or spring terminals (FP-TB-2)
- Isothermal construction (FP-TB-3) minimizes temperature gradients when using thermocouples
- −40 to +70 °C operation

The FP-TB-1, FP-TB-2, and FP-TB-3 terminal bases provide the intra-system communication link between FieldPoint I/O modules and network modules, provide a means for wiring field connections, and provide the mounting mechanism. The choice of terminal base depends on the type of field wiring terminal preferred: screw terminal or spring terminal.

Figur B.39: Data-ark FieldPoint Terminalbase



DIN Rail Mounting

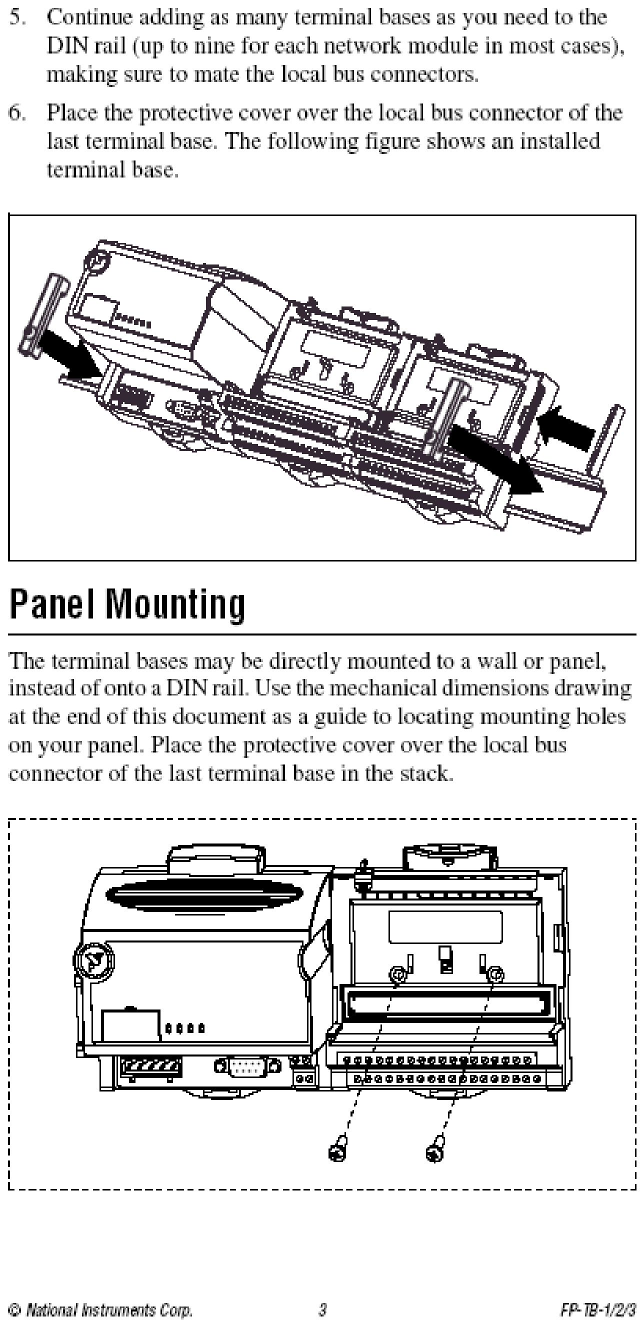
Caution Before connecting a terminal base to a network module, the network module *must* be powered off.

The FieldPoint terminal bases have simple rail clips for mounting reliably onto a standard 35 mm DIN rail. To install the terminal base to the DIN rail, follow these steps:

1. With a flat-bladed screwdriver, open the rail clip to the unlocked position.
2. Hook the lip on the rear of the terminal base onto the top of a 35 mm DIN rail and rotate the terminal base down onto the DIN rail.
3. Slide the terminal base along the DIN rail until its local bus connector mates with the connector of the terminal base or network module adjacent to it.
4. Lock the terminal base to the DIN rail by pushing the rail clip in.

FP-TB-1/2/3 2 www.ni.com

Figur B.40: Data-ark FieldPoint Terminalbase

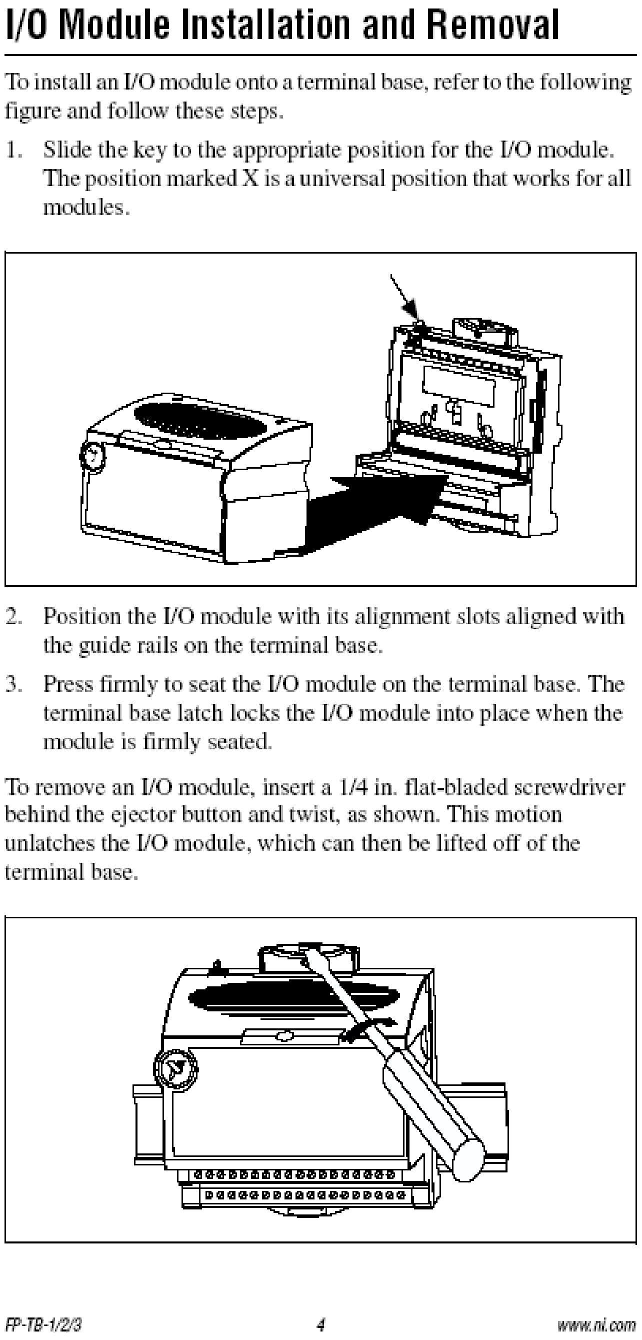


5. Continue adding as many terminal bases as you need to the DIN rail (up to nine for each network module in most cases), making sure to mate the local bus connectors.
6. Place the protective cover over the local bus connector of the last terminal base. The following figure shows an installed terminal base.

Panel Mounting

The terminal bases may be directly mounted to a wall or panel, instead of onto a DIN rail. Use the mechanical dimensions drawing at the end of this document as a guide to locating mounting holes on your panel. Place the protective cover over the local bus connector of the last terminal base in the stack.

Figur B.41: Data-ark FieldPoint Terminalbase



I/O Module Installation and Removal

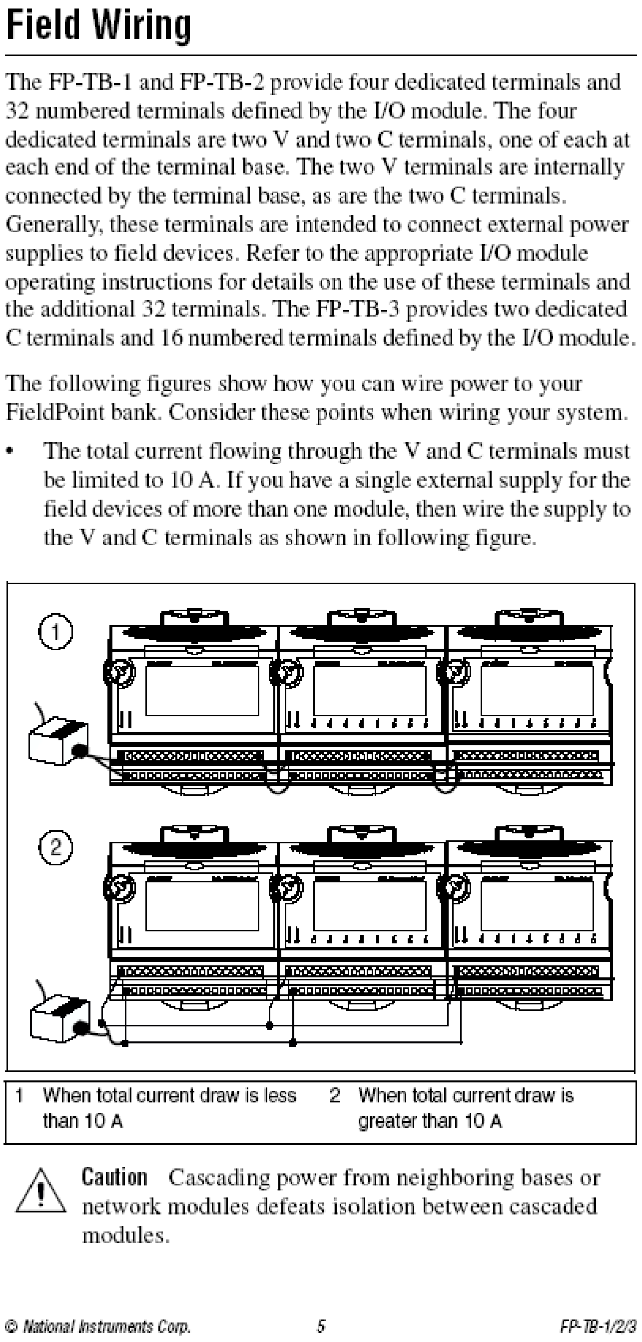
To install an I/O module onto a terminal base, refer to the following figure and follow these steps.

1. Slide the key to the appropriate position for the I/O module. The position marked X is a universal position that works for all modules.
2. Position the I/O module with its alignment slots aligned with the guide rails on the terminal base.
3. Press firmly to seat the I/O module on the terminal base. The terminal base latch locks the I/O module into place when the module is firmly seated.

To remove an I/O module, insert a 1/4 in. flat-bladed screwdriver behind the ejector button and twist, as shown. This motion unlatches the I/O module, which can then be lifted off of the terminal base.

FP-TB-1/2/3 *4* *www.ni.com*

Figur B.42: Data-ark FieldPoint Terminalbase



Field Wiring

The FP-TB-1 and FP-TB-2 provide four dedicated terminals and 32 numbered terminals defined by the I/O module. The four dedicated terminals are two V and two C terminals, one of each at each end of the terminal base. The two V terminals are internally connected by the terminal base, as are the two C terminals. Generally, these terminals are intended to connect external power supplies to field devices. Refer to the appropriate I/O module operating instructions for details on the use of these terminals and the additional 32 terminals. The FP-TB-3 provides two dedicated C terminals and 16 numbered terminals defined by the I/O module.

The following figures show how you can wire power to your FieldPoint bank. Consider these points when wiring your system.

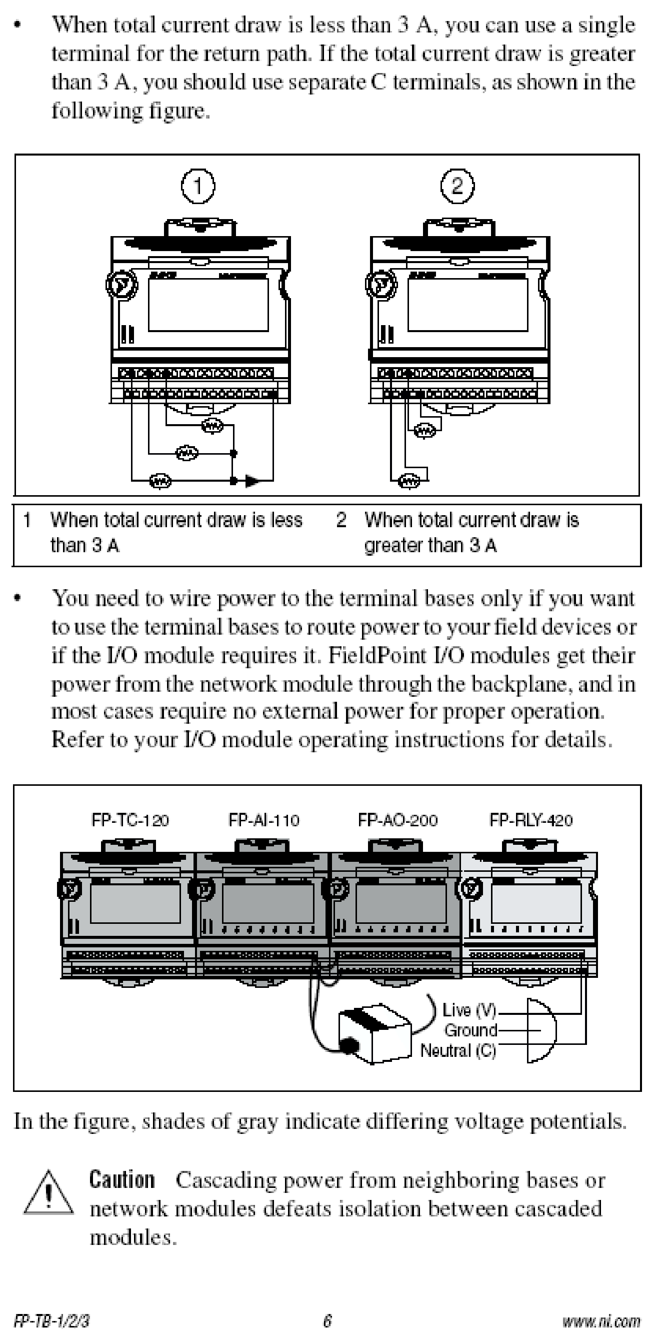
- The total current flowing through the V and C terminals must be limited to 10 A. If you have a single external supply for the field devices of more than one module, then wire the supply to the V and C terminals as shown in following figure.

1 When total current draw is less than 10 A

2 When total current draw is greater than 10 A

⚠ **Caution** Cascading power from neighboring bases or network modules defeats isolation between cascaded modules.

Figur B.43: Data-ark FieldPoint Terminalbase



- When total current draw is less than 3 A, you can use a single terminal for the return path. If the total current draw is greater than 3 A, you should use separate C terminals, as shown in the following figure.

1 When total current draw is less than 3 A
2 When total current draw is greater than 3 A

- You need to wire power to the terminal bases only if you want to use the terminal bases to route power to your field devices or if the I/O module requires it. FieldPoint I/O modules get their power from the network module through the backplane, and in most cases require no external power for proper operation. Refer to your I/O module operating instructions for details.

In the figure, shades of gray indicate differing voltage potentials.

⚠ **Caution** Cascading power from neighboring bases or network modules defeats isolation between cascaded modules.

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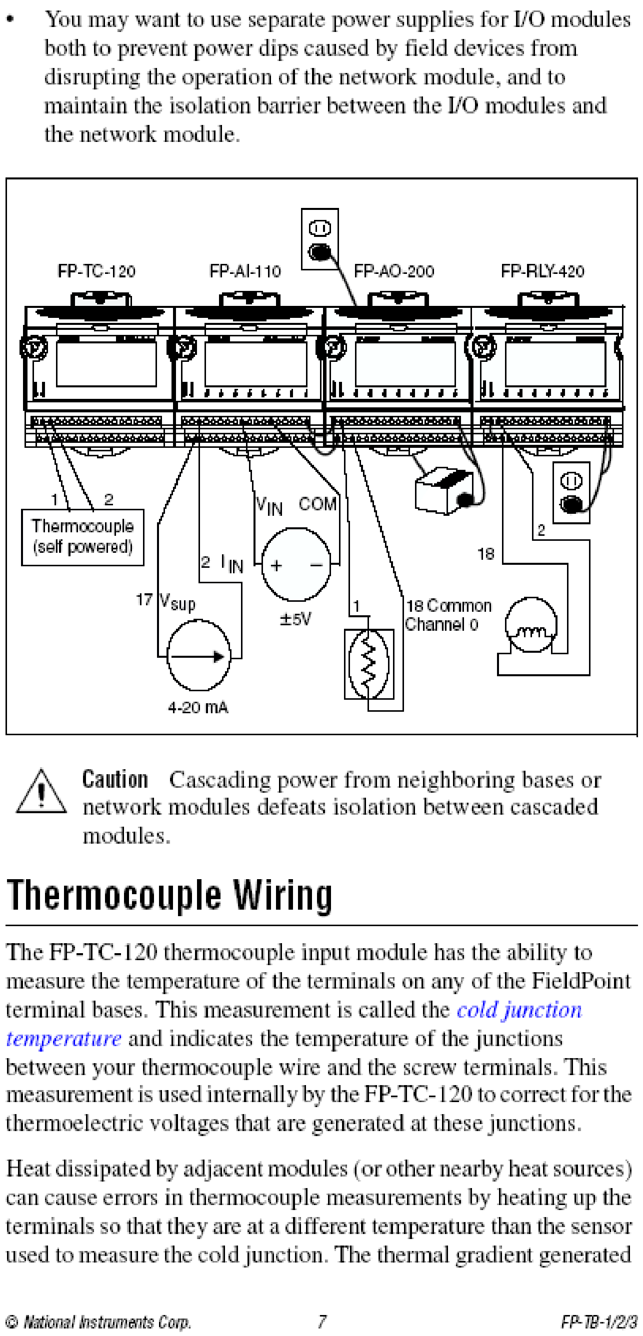
Figur B.44: Data-ark FieldPoint Terminalbase



- You may want to use separate power supplies for I/O modules both to prevent power dips caused by field devices from disrupting the operation of the network module, and to maintain the isolation barrier between the I/O modules and the network module.

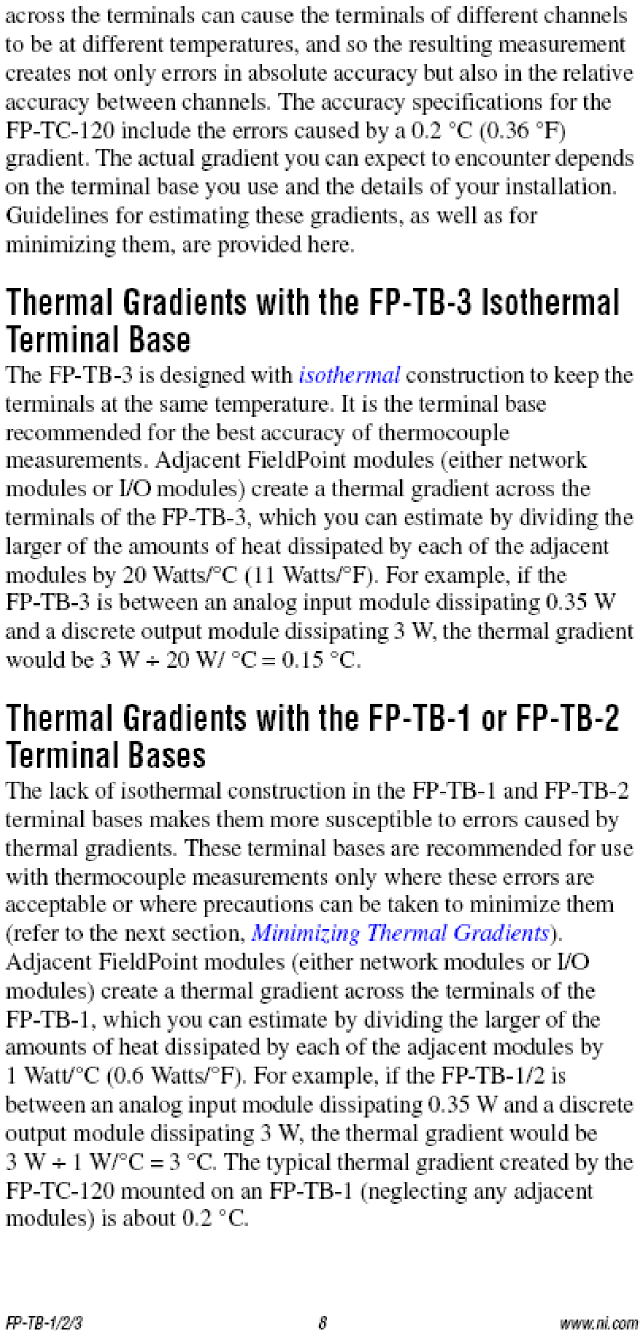
Caution Cascading power from neighboring bases or network modules defeats isolation between cascaded modules.

Thermocouple Wiring

The FP-TC-120 thermocouple input module has the ability to measure the temperature of the terminals on any of the FieldPoint terminal bases. This measurement is called the *cold junction temperature* and indicates the temperature of the junctions between your thermocouple wire and the screw terminals. This measurement is used internally by the FP-TC-120 to correct for the thermoelectric voltages that are generated at these junctions.

Heat dissipated by adjacent modules (or other nearby heat sources) can cause errors in thermocouple measurements by heating up the terminals so that they are at a different temperature than the sensor used to measure the cold junction. The thermal gradient generated

Figur B.45: Data-ark FieldPoint Terminalbase



across the terminals can cause the terminals of different channels to be at different temperatures, and so the resulting measurement creates not only errors in absolute accuracy but also in the relative accuracy between channels. The accuracy specifications for the FP-TC-120 include the errors caused by a 0.2 °C (0.36 °F) gradient. The actual gradient you can expect to encounter depends on the terminal base you use and the details of your installation. Guidelines for estimating these gradients, as well as for minimizing them, are provided here.

Thermal Gradients with the FP-TB-3 Isothermal Terminal Base

The FP-TB-3 is designed with *isothermal* construction to keep the terminals at the same temperature. It is the terminal base recommended for the best accuracy of thermocouple measurements. Adjacent FieldPoint modules (either network modules or I/O modules) create a thermal gradient across the terminals of the FP-TB-3, which you can estimate by dividing the larger of the amounts of heat dissipated by each of the adjacent modules by 20 Watts/°C (11 Watts/°F). For example, if the FP-TB-3 is between an analog input module dissipating 0.35 W and a discrete output module dissipating 3 W, the thermal gradient would be 3 W ÷ 20 W/ °C = 0.15 °C.

Thermal Gradients with the FP-TB-1 or FP-TB-2 Terminal Bases

The lack of isothermal construction in the FP-TB-1 and FP-TB-2 terminal bases makes them more susceptible to errors caused by thermal gradients. These terminal bases are recommended for use with thermocouple measurements only where these errors are acceptable or where precautions can be taken to minimize them (refer to the next section, *Minimizing Thermal Gradients*). Adjacent FieldPoint modules (either network modules or I/O modules) create a thermal gradient across the terminals of the FP-TB-1, which you can estimate by dividing the larger of the amounts of heat dissipated by each of the adjacent modules by 1 Watt/°C (0.6 Watts/°F). For example, if the FP-TB-1/2 is between an analog input module dissipating 0.35 W and a discrete output module dissipating 3 W, the thermal gradient would be 3 W ÷ 1 W/°C = 3 °C. The typical thermal gradient created by the FP-TC-120 mounted on an FP-TB-1 (neglecting any adjacent modules) is about 0.2 °C.

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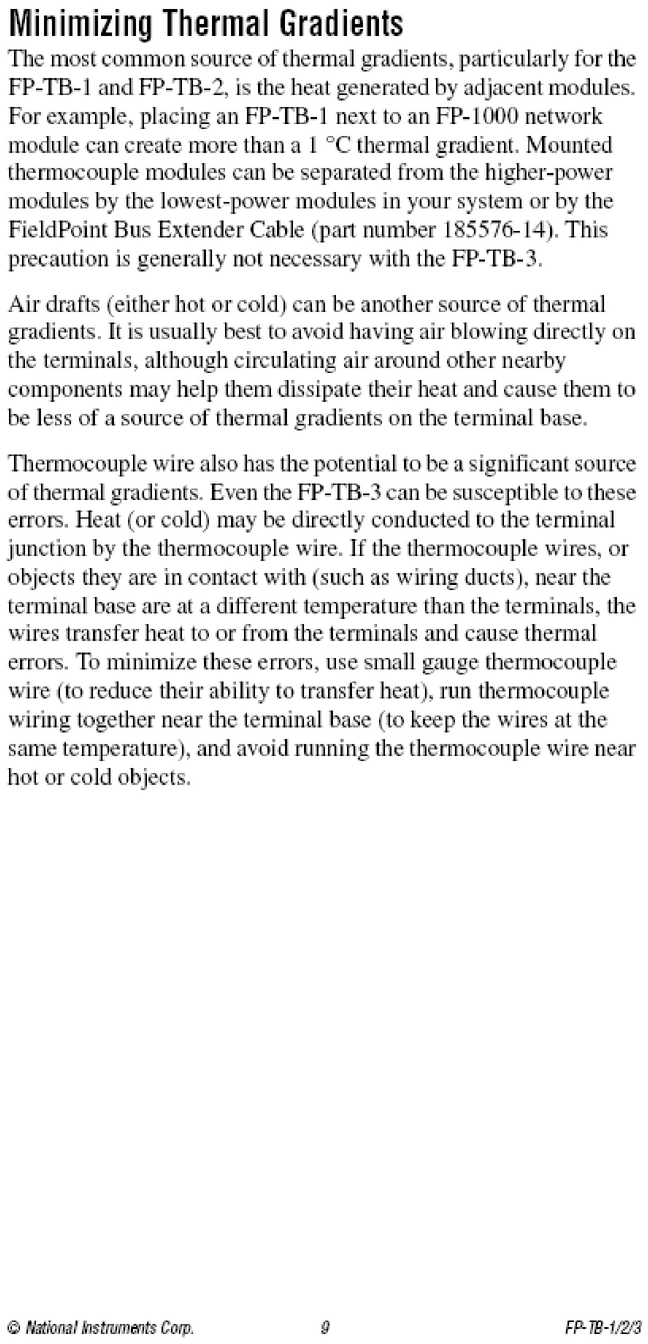
Figur B.46: Data-ark FieldPoint Terminalbase



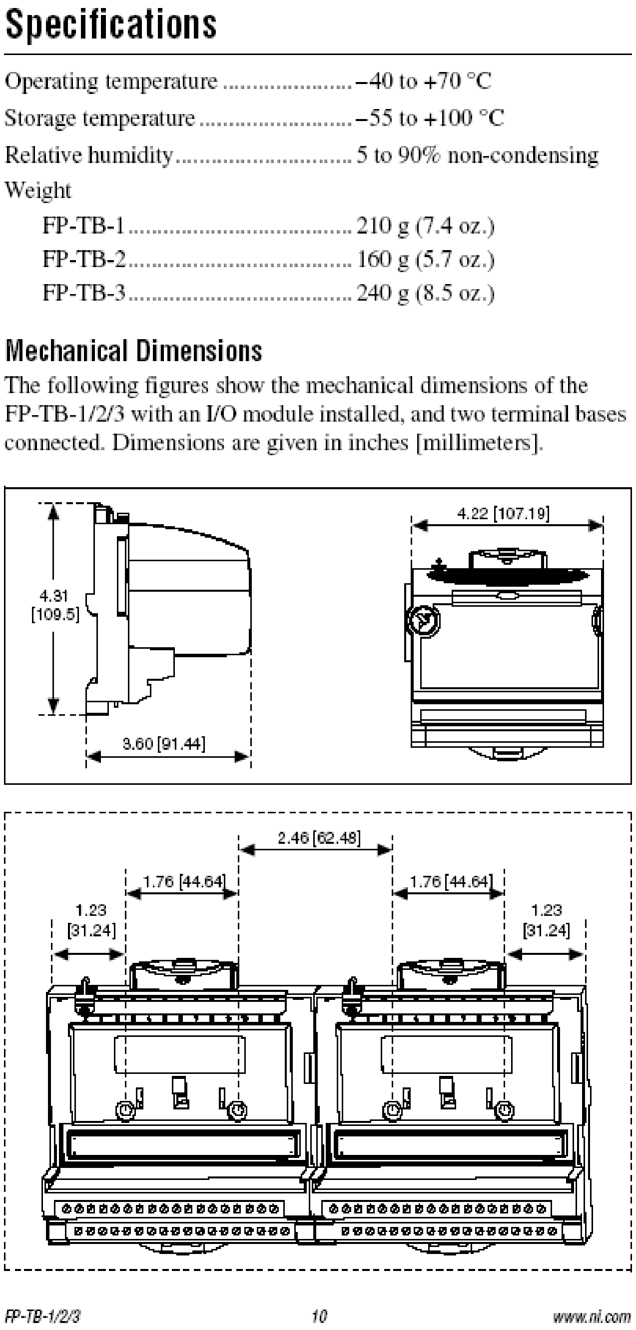
Minimizing Thermal Gradients

The most common source of thermal gradients, particularly for the FP-TB-1 and FP-TB-2, is the heat generated by adjacent modules. For example, placing an FP-TB-1 next to an FP-1000 network module can create more than a 1 °C thermal gradient. Mounted thermocouple modules can be separated from the higher-power modules by the lowest-power modules in your system or by the FieldPoint Bus Extender Cable (part number 185576-14). This precaution is generally not necessary with the FP-TB-3.

Air drafts (either hot or cold) can be another source of thermal gradients. It is usually best to avoid having air blowing directly on the terminals, although circulating air around other nearby components may help them dissipate their heat and cause them to be less of a source of thermal gradients on the terminal base.

Thermocouple wire also has the potential to be a significant source of thermal gradients. Even the FP-TB-3 can be susceptible to these errors. Heat (or cold) may be directly conducted to the terminal junction by the thermocouple wire. If the thermocouple wires, or objects they are in contact with (such as wiring ducts), near the terminal base are at a different temperature than the terminals, the wires transfer heat to or from the terminals and cause thermal errors. To minimize these errors, use small gauge thermocouple wire (to reduce their ability to transfer heat), run thermocouple wiring together near the terminal base (to keep the wires at the same temperature), and avoid running the thermocouple wire near hot or cold objects.

Figur B.47: Data-ark FieldPoint Terminalbase



Specifications

Operating temperature	–40 to +70 °C
Storage temperature	–55 to +100 °C
Relative humidity	5 to 90% non-condensing
Weight	
FP-TB-1	210 g (7.4 oz.)
FP-TB-2	160 g (5.7 oz.)
FP-TB-3	240 g (8.5 oz.)

Mechanical Dimensions

The following figures show the mechanical dimensions of the FP-TB-1/2/3 with an I/O module installed, and two terminal bases connected. Dimensions are given in inches [millimeters].

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Figur B.48: Data-ark FieldPoint Terminalbase