auto-tuning controller

system 6000

6355

product specification

Auto-tuning controller: Features

- Enhanced version of 6350 Process Controller.
- Continuous on-line plant identification.
- Automatic selection of plant identification sampling rate.
- Optional generation of Setpoint perturbations between programmable limits.
- Confidence factor for plant model.
- Computation of optimum PI, PD or PID parameters.
- Front-panel indication when Controller is not optimally tuned.
- Remote monitoring and supervision via a simple serial data link.

Description

The 6355 Auto-Tuning Controller has all the features of the 6350 Process Controller plus on-line plant identification and computation of the optimum 2 or 3-term control terms.

Plant identification is carried out by sampling the Process Actuation and Measured Variable in normal operation and forming a model of the plant's dynamic characteristics. New data gradually refines the model, and a "confidence factor" is calculated from how closely it predicts the actual Process Variable.

A good model requires adequate information in the Actuation and Process Variable signals and a correct sampling rate. The 6355 continuously calculates a recommended sample time from its model, allowing an initial estimate to converge to the optimum value. Sufficient Process Variable "activity" ensures that the process dynamics can be measured, and a random setpoint disturbance, programmable between user-defined limits, can be generated to assist plant modelling.

The optimum control terms are calculated from this model. A full range of P, P+D, P+I, or P+I+D terms can be selected by the user. Both actual and recommended parameters are displayed on the Hand-held terminal which can update the control parameters with those recommended. Indication of a discrepancy between operational and recommended parameters is optionally provided by flashing the front panel Digital Readout

Signal inputs and outputs can be 4–20mA, from plant-mounted equipment, or 0–10V from the System 6000 range of signal conditioners and output drivers.

The 6355 has the same control loop parameters as the 6350, with the addition of absolute alarms and a second page of auto-tuning parameters. A serial RS422 data link allows remote monitoring and supervision of the controller using a standard ANSI protocol.

The 6355 is plug compatible with the 6350 controller and can be used wherever PID control is appropriate. All features of Manual, Remote and Ratio operation are retained, with the benefit of bumpless transfer, integral de-saturation, etc. provided by the TCS 3-term algorithm.

Operator displays and controls

Operator displays

Digital Readout
(for process variable, setpoint, 3-Term Output and measured power indication) 4-digit, orange LED display with sign and decimal point. Flashes when PID parameters are not optimum.

Error Indication
Vertical red LED bargraphs with 8 segments for positive and negative error in 1% steps.

Alarm Indication
High or low alarms indicated by flashing positive or negative error bargraphs.

Zero Error and Power-on Indication
Green LED in centre of error bargraph.

3-Term Output or Measured Power Display
Horizontal yellow LED bargraph with 10 segments to indicate 0–100% output.

Status Indicators
2 yellow rectangular LEDs to indicate TRACK and HOLD status

Operator controls

Control Mode Selection
3 illuminated push-buttons:
Manual (M) with integral yellow LED.
Local Auto (A) with integral green LED.
Remote Auto or Ratio (R) with integral green LED.

Function Selection
2 non-illuminated push-buttons.
Raise (▲) increments the output when Manual (M) is pressed, or increments the setpoint when (SP) is pressed.
Lower (▼) decrements the output when Manual (M) is pressed, or decrements the setpoint when (SP) is pressed.

Display Selection
1 non-illuminated push-button (SP) causes the digital readout to display the current setpoint while pressed.

NOTE: Pressing the Manual, Auto or Remote buttons causes the digital readout to display the current output level or the measured power.

Applications

Gas pressure control
Extruder control
Boiler control
Brewing vessel control
Environmental chambers
Turbine test beds
Ethylene oxide plant
Hydrofluoric acid plant
Glass manufacture
Paper production
Cement production
Blast furnaces
Reheat furnaces
Adhesive coating line control
Paint oven control
Oil production platforms
Viscose yarn production
Glycerine manufacture

The 6350 single loop controller has already found application in all of the above processes and industries. To its flexibility is now added the capability to automatically calculate the correct PID parameters for the process, thus ensuring that loops may be maintained under close control even though the process may change due to operating point or load variations.

Example

A typical example is a glass furnace where the response time may change considerably due to the size of the load. Such furnaces often require re-tuning for each new load, and with a response time of several hours, such tuning can be tedious and time consuming even for a skilled operator. The 6355, by an automatic analysis of the dynamic response of the process, can calculate PID parameters very much more quickly than manual tuning methods, and without the need for graphical analysis of chart records of plant response.

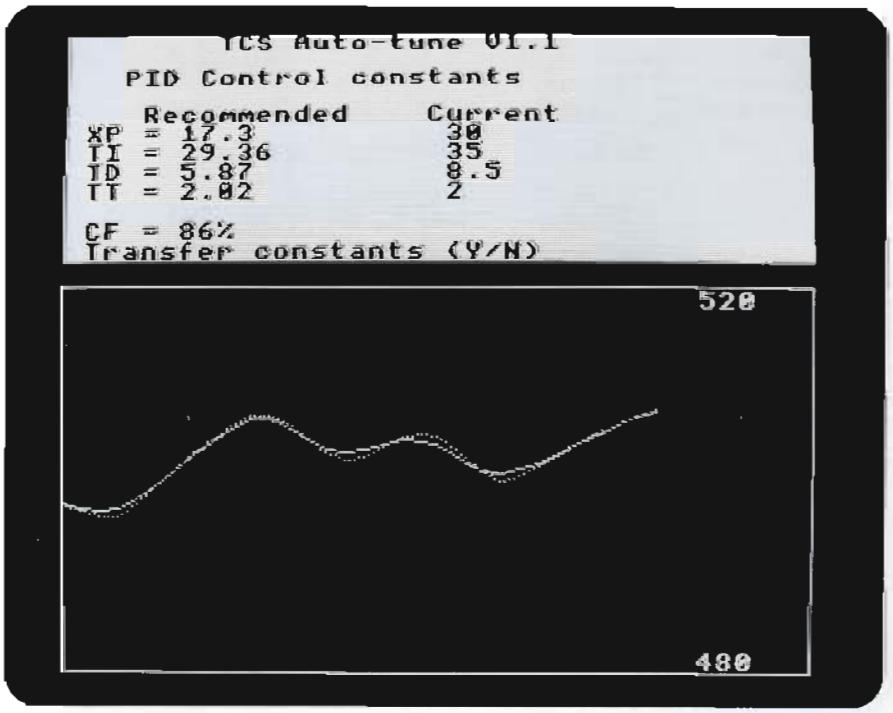
Commissioning Procedures:

On a new, or unknown plant, some initial estimates of plant response must be obtained before even trial PID parameters can be entered. The 6355 caters for this by an "initial test" sequence, in which the plant is operated manually, and automatically stepped between operator defined limits. From this initial test, estimates are obtained of a suitable sample time, and any dead time in the process. Once these are available, the on-line process modelling begins, and evaluates an initial set of PID parameters, which may be entered to allow closed-loop operation of the plant. Typically, these initial values will have a low confidence value, because of the limited data used to derive them, but the operator may choose to perturb the plant manually for a further period in order to improve the model, before accepting the PID terms and putting the 6355 into "Auto" (i.e. closed-loop) mode.

Re-Tuning:

Continuation of the modelling procedure will result in a better fit between model and process variables. This fit is reflected in an increased confidence factor, but can also be assessed in graphical form if an intelligent VDU terminal is available in place of the hand-held terminal. The 6355 maintains an internal record of 64 previous data samples, and these, together with the model output, can be displayed using a communication program developed by TCS for the BBC micro-computer. Such a display provides valuable information as to the progress of the tuning, particularly for slow loops, and a typical display, showing a 1% FSD setpoint perturbation, is shown in the accompanying photograph.

The policy adopted in the 6355 is that the auto-tuning should act in an advisory capacity only, and that acceptance of new control parameters should only be performed by the operator or engineer. If the process operating point or load conditions are changed significantly, then a re-tuning of the PID parameters can be initiated by the operator. Alternatively, if gradual changes in the plant cause consistent errors between the model and the process variable, then a more rapid adaptation of the model will automatically occur, and new PID terms will be calculated. If these differ by more than a user-defined percentage from those currently in use, and if the confidence factor is also above a selected value, then the Digital Readout will flash to inform the operator that the control constants require updating.



Limitations:

In the majority of situations correct tuning of single-loop controllers can result in significant improvements in the control of the process, and in these cases the 6355 is a valuable tool. However, in certain processes, strong interaction between several process variables, or large, unmeasured disturbances to the plant, will mean that single-loop controllers, however well tuned, are unable to achieve the desired level of control. In these situations, a more complex control system design device can advise on individual requirements.

Communications

Every System 6000 microprocessor based instrument is fitted with an RS232 port and an RS422 port for serial data communications. The RS232 port is available via a front-panel socket and is used for the 8260 Hand-held programming terminal. The RS422 port is available on the module rear connector pins and is bussed onto the supervisory data link common to all modules. All parameters that can be monitored via the 8260 terminal can also be accessed and updated via the supervisory data link.

Hand-held terminal

Each System 6000 instrument can be set up using a plug-in 8260 Hand-held terminal. Every parameter is accessed by means of a simple 2 character command mnemonic and all data is entered directly in engineering units This technique ensures the accuracy and security of parameter settings.

Specification

Transmission Standard
2-wire RS232/V24 (± 12V)

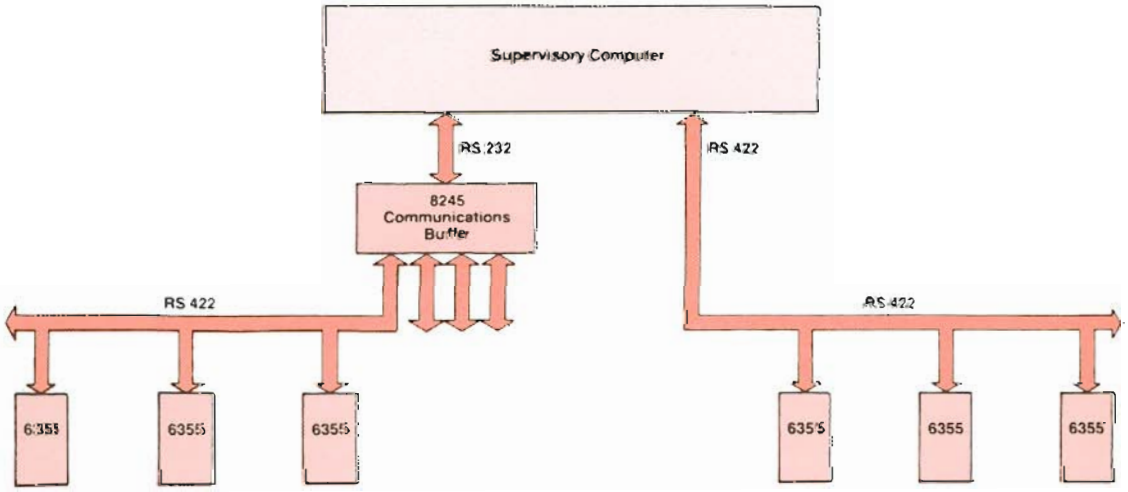
Data Rate
Selectable from
300, 1200, 2400, or 9600 baud.

Character Length
10 bits made up of:
1 start + 7 data + 1 parity (even)
+ 1 stop.

The photograph shows an 8260 terminal plugged into the front panel of a 6355 controller A full list of the available command parameters is given in the 6355 Facts Card

Multi-drop supervisory link

Every System 6000 instrument contains an RS422 communications port which enables it to send and receive command parameters over a simple four-wire link connected to other intelligent devices The use of RS422 and the transmission of information in ASCII or Binary data format makes it particularly easy to communicate with the 6355 controller To hook the 6355 into a distributed control system requires no modification to the instrument and no further expenditure on options. The four-wire link is simply connected up so that the 6355 becomes part of the distributed control system The illustration shows how an array of 6355s can be directly connected to a supervisory computer which has an RS422 serial port. If the computer only has an RS232 serial port then an 8245 Communications Buffer Unit can be used to carry out the required RS232 to RS422 Conversion as shown.



Specification

Transmission Standard
4-wire RS422 (0-5V)

Line Impedance
120-240Ω twisted pair.

Line Length
4000 ft max. (at 9600 baud).

Number of Units/Line
16.

Data Rate
Selectable from 300, 1200, 2400, or 9600 baud.

Character Length (ASCII/Binary)
10/11 bits — 300 to 9600 baud.

Protocol

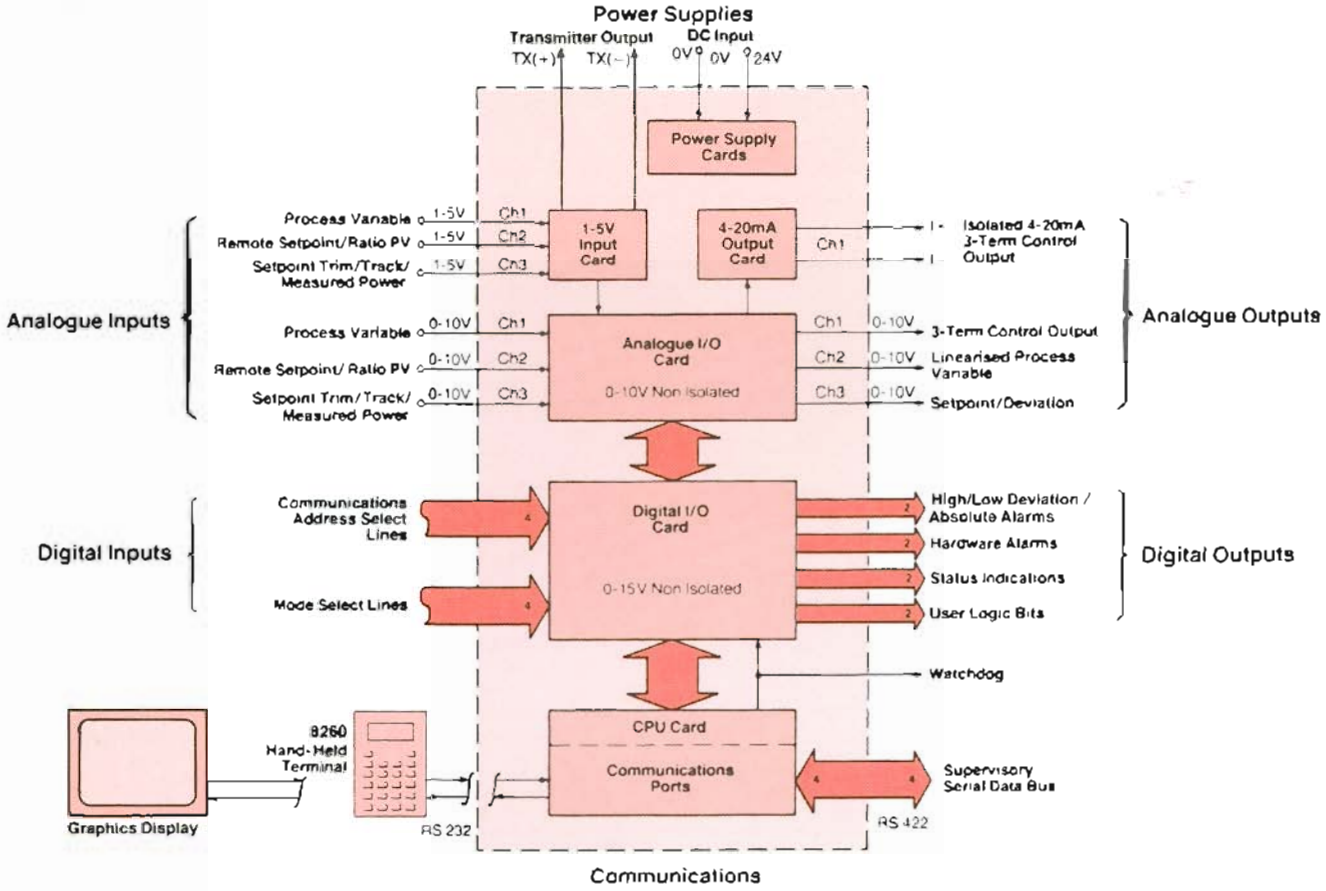
All microprocessor based instruments in the System 6000 range employ a standard ANSI protocol known as BI-SYNCH. The exact form of BI-SYNCH implemented within System 6000 corresponds with the American National Standard specification:

ANSI – X3.28 – 2.5 – A4 Revision 1976

TCS have implemented both an ASCII and Binary version of this protocol within each instrument.

The ASCII mode is simplest to use as all data is transmitted in ASCII characters. The Binary mode offers a 4 to 1 increase in transmission speed by compressing the data into a binary format, and also supports additional features like Multi-Parameter and Enquiry Polling.

Input/Output signals



Analogue inputs

Number of Channels
3 direct non-isolated inputs or 3 conditioned non-isolated inputs.

Channel Functions
Channel 1=Proces Variable input.
Channel 2=Remote Setpoint/Ratio Process variable input.
Channel 3=Setpoint or Ratio Trim/ Track/Measured Power input.

Input Signal Levels
Direct inputs are 0-10V range
Conditioned inputs are 1-5V or 4-20mA range with external sense resistors

Resolution
12 bit binary ADC (.250%) hardware applied to inputs.
15 bit binary representation obtained after digital input filtering and signal averaging giving resolution of 1 digit in ± 9999.

Accuracy
± 1 LSB max. over 0-50°C range for hardware.
± 1 digit of reading for 0-4000 range,
± 2 digits of reading for 0-8000 range,
± 3 digits of reading for 0-9999 range, after input filtering.

Sampling Rate
ADC samples 1 channel every 12ms, i.e. any one channel is sampled once every 36ms

Input Impedance
1MΩ pull-down to −5V on channel 1.
1MΩ pull-down to 0V on channels 2 and 3.

Input Signal Processing
Linear (normal or inverse).
Normalised square root.
Type J, K, T, S, R, E, B thermocouples.
Platinum resistance thermometers.
User specified linearisation function.

Analogue outputs

Number of channels
3 direct non-isolated outputs plus 1 isolated output.

Channel Functions
Channel 1=3-Term control output.
Channel 2=Process Variable output.
Channel 3=Setpoint output or amplified deviation (error).

Output Signal Levels
Direct outputs are 0-10V range.
Isolated output is 4-20mA (channel 1 only).

Output Circuit Type
Medium-term analogue sample-and-hold circuits preceded by DAC.

Output Resolution
12 bit binary (.025%) giving minimum analogue voltage steps of 2.5mV.

0-10V Output Accuracy
± 1 LSB max. over 0-50° C range.

Isolated Output Accuracy
± 0.5% of full scale.

Sample and Hold
DAC updates 1 channel every 12ms, i.e. any one channel is refreshed once every 36ms.

Output Drift Rate Under Watchdog Failure Conditions
½mV/sec maximum (equivalent to 1% of full scale in 3 minutes).

Output Drive Capability
± 5mA for direct voltage outputs.

Isolation Voltage
± 50V minimum with respect to system ground.

Digital inputs

Number of Inputs
8 external non-isolated inputs.

Inputs Functions
4 communications unit address select lines.
4 mode select lines.

Input Voltage Levels
15V = logic one.
5V = logic zero.

Input Impedance
100k Ω pull-down to 0V (gives 150µ A logic one current.

Digital outputs

Number of Outputs
8 external non-isolated outputs plus Watchdog

Output Functions
2 deviation or absolute alarms
2 hardware alarms.
2 status indications.
2 user logic bits.

Output Voltage Levels
15V = logic one.
0V = logic zero.

Output Drive Capability
2k2 open-collector pull-up to +15V supply, maximum logic zero sink current = 16mA.

3-term control characteristics

Algorithm Sampling Period
36ms to 1.56s dependent upon integral and derivative times.

Setpoint
Range — low, high −9999 to +9999.
Limits — low, high −9999 to +9999.

Setpoint Trim
Range – low, high −9999 to +9999 in engineering units.

Alarm Limits (absolute or deviation)
Low, high −0 to 9999 with hysterisis of ½% of setpoint span.

Input Filter Range (all inputs)
0 to 99.99 sec (first order).

Control Output
Range – 0 to 99.99% = 0-10V or 4-20mA (Ch1).
Limits — low, high — 0 to 99.99%.
Polarity — inverse output mode switch selectable.
Raise/lower rate in manual – 0 to 99.99% in 10 sec with accelerating action.

Proportional Band Range
0 to 999.9%.

Integral Time Constant Range
0.04 to 99.99 sec. or 0.01 to 99.99 min.
0 = off.

Derivative Time Constant Range
0.04 to 99.99 sec. or 0.01 to 99 99 min.
0 = off.

Power supplies

Input Voltage
(May be unsmoothed, full-wave rectified AC).
20-30V DC recommended operating range.
19-35V DC absolute maximum input limits.

Input Fuse Rating
2A.

Input Current
550mA without hand-held terminal.
650mA with hand-held terminal.

Power Failure Detect Threshold
When input voltage falls below 16.5 ± 0.5V.

Remote Transmitter Supply
26V ± 1.5V at 4mA output.
30V ± 0.5V at 20mA output.
± 50V minimum isolation with respect to system ground.

Memory Standby Battery
3.0V Lithium type.
160mAh rating.
8-10 year shelf life
5 year life minimum on continuous standby.

Mechanical details

All System 6000 microprocessor based instruments are supplied in 72mm wide metal housings fitted with front-panel fascias and catch handles for module retention. These may be used with a wide variety of rack and panel mounting hardware as illustrated in the examples below.

7000 series racks

Up to six 6355 controllers may be fitted into a 7000 series 19 inch rack as shown. Interconnections between instruments are made by wire wrapping while external connections may be brought out to 2 rows of 64 way screw terminal blocks fitted to the hinge down rear door. The 7000 series rack is also available with a panel mounting option, and a 10 inch half rack version for mounting up to three 6355s can also be supplied.

7900 powered sleeves

The powered sleeve allows a 6355 to be mounted with a mains power unit. This is incorporated in the associated 7355 Rear Termination Assembly which is also fitted with alarm relays and gives access to all module connections via screw terminals. The 7900 assembly is available in single, 3 way or 6 way versions for mounting in panels from 1.5mm to 6.5mm thick. A 6 way 19 inch rack mounting version can also be supplied.

Overall dimensions in mm of housings illustrated:

	7000 rack	7900 sleeve
width:	482	105
height:	177	177
depth:	380	423

Panel cut-out dimensions in mm.

	7000 rack	7900 sleeve
width:	448.2	88.2
height:	166.3	166.3

Details

For further details refer to:

6355 Auto-Tuning Controller technical manual.

6355 Facts Card.

7355 Auto-tuning Controller rear termination assembly.

7900 Single or multi-way sleeve assembly for microprocessor based instrumentation.

TCS
Advanced Instrumentation

Turnbull Control Systems Limited
Broadwater Trading Estate
Worthing, West Sussex, BN14 8NW
Telephone: Worthing (0903) 205277 Telex: 87437

HA075750U001
Issue 1/1 June 1984