TRANSITRACE

A new approach for the timing of Speed Control Line models

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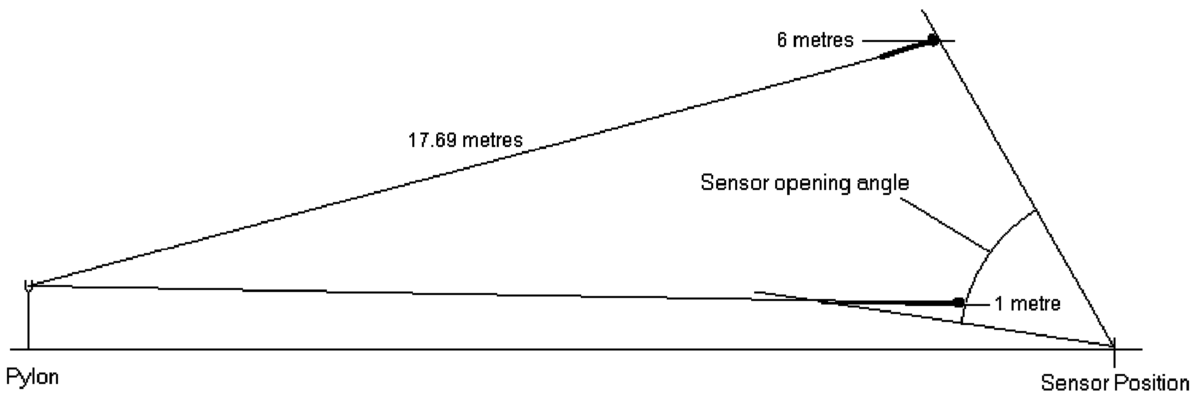
During a few busy months of the spring of 2000, an electronic system for the timekeeping of speed models was conceived, designed and tested. The system uses an optical principle that needs no light source, but employs existing light from the sky. This allows the sensor to be quite manageable and of a reasonable cost. The sensor employs a phototransistor for detecting the transits of models, and some circuitry for amplification and signal conditioning. An ordinary PC computer that connects to the sensor, equipped with application software, completes the system. If a laptop type PC is used, a system is at hand that is suitable for field use, independent of line power. The PC also provides the data handling required for running contests as well as practice sessions. The system is of low enough cost to be affordable by individual modellers, and provides means for recording and evaluating flight data in an entirely new way. The system allows an improvement in timing accuracy of at least an order of magnitude. The subjective and random effects that result from manual timekeeping, in spite of the best human efforts, can be eliminated.

A recent F2A rule amendment introduced the provision for electronic timekeeping. A working prototype of the system was prepared in time for the 2000 World Championships in Landres, France, with the aim to actually use it in official capacity. It turned out that the necessary confirmation to grant its official use at the World Championships could not be realised. Instead, the opportunity was used to thoroughly test and evaluate the system.

Description

The Sensor

The sensor is contained in a box with a vertical slit opening on one side. The box dimensions are: Height: 200 mm, width: 35 mm, and depth: 130 mm. The box stands on a small tripod. The phototransistor receives light from the part of the sky that is in view through the slit. The angle of view is from around 10° to 50° vertically, relative to the horizontal, and around 3° horizontally.
In operation the box should be placed on the ground with the slit pointing to the circle centre, outside the landing radius. Originally, the location was set to 20.5 metres from the centre for F2A, with a 17.69 metre line length. However, as the pilots at Landres felt uneasy with an object this close, the sensor geometry has later been modified to allow a distance of 1.2 times the line length, which means 21.2 m for F2A. At this distance the box will stay clear of landing models. The sensor and escaping dollies still need mutual protection, which can be arranged by a ramp cover.



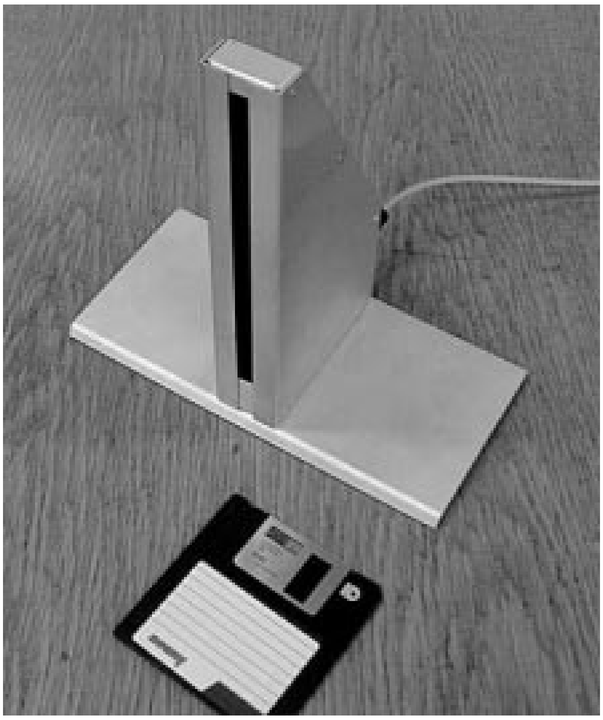
Relationship of model and sensor

The sensor location on the ground outside the circle allows it to be used without any special installations at the site. On the other hand, there is an obvious limitation from this: The field of view cannot extend to zero height, as objects near the ground would disturb. The bottom angle of 10° corresponds to around 1 metre flying height at the flight radius. The F2A rules set a lower limit of the flying height to 1 metre, but only ban lower flying if done for more than one lap. A model may fly low just when passing the sensor, and can escape detection, in spite of flying to the rules. On purpose made flying sites the sensor could be buried into the ground right under the flight path, which eliminates this limitation entirely. Just minor modifications to the design are necessary to allow such a use. The application program includes the handling of missed passes, which is discussed below.

The size of the phototransistor sensitive area is around 1 mm. The distance of the phototransistor to the slit is 100 - 150 mm. When an object passes in the field of view, and obscures part of the sky, the drop in light is detected by the circuitry, which outputs a pulse that is brought to the PC. The drop in light from a passing F2A model is less than 0.5% of the total, but this is well within the capability of the detecting circuitry.

Sensor Electronics

The circuit has four stages: Amplification of the phototransistor signal, filtering, thresholding and buffering. The phototransistor connects to an amplifier, designed to give an output proportional to the percentage change rather than the light in absolute terms. This way the operation becomes fairly independent of the sky brightness. The second stage is an amplifier with a bandpass filter, which blocks slow variations, as for instance from clouds, as well as fast variations, from internal noise. The third stage is a threshold circuit, which outputs a pulse when the output from the filter stage drops below a certain value. The threshold is adjustable, for optimising the response, depending on the model size. By means of these three stages, the sensor is matched to objects with the typical speeds and sizes of C/L models. The last stage is a buffer capable of driving the output pulse over a long cable that connects the sensor to a PC. It also drives a light-emitting diode indicator on the rear panel. This will blink when passes are detected. The unit is powered by a small 9 V battery. An alkaline battery will give at least 50 hours of operation.



Sensor prototype unit, used in Landres

The PC and the Application Program

A PC provides the timing, control, presentation and data logging of the Transitrace system. Almost any PC or laptop having a PC architecture can be used. A 486 CPU at 33 MHz is adequate. A cable connects the sensor to the standard parallel port of the PC. A length of 7 metres is used for practice, but for contest use the sensor and operator have to be separated by half a lap, so that the operator can team up with the judges and manual timekeepers. For this purpose a 75-metre extension cable is provided.

A quartz crystal controlled timer that is a standard item of the PC architecture is used for the timing. (This means that the system conforms to S/C rule B.7.10.) An application program has been developed, which handles the whole flight, starting from the attempt start signal. The program must run under MS-DOS, as Windows will interrupt program flow occasionally, which introduces timing errors.

During the flight, the time values of the internal timer are registered when pulses arrive from the sensor. For each pass of the model, the lap times in seconds, and the corresponding speeds are presented on the PC screen. When the pilot places the handle in the pylon, the operator will press the spacebar on the PC keyboard. The program will make the two lap down count, count the 9 laps of the timed flight, and then display the official result, ready for transfer to the contest protocol. At the same time, the flight data is recorded in a log file, for later reference. These records can be printed and be handed over to the competitors. A description and examples are found below. The program is also able to correct for a missed lap (due to underflying or any other reason) inside the laps 0 to 9. It also handles the sorting out of stray pulses due to, for instance, birds, butterflies or R/C models passing.

Accuracy

The nominal clock frequency of the PC timer is 1,193,046.5 Hz. (This rather odd value actually corresponds to 2^{32} cycles in one hour.) The actual frequency may differ in individual PCs, but by no more than 0.02%. A calibration program is provided for adapting to the PC timer if a more accurate reference is at hand. Due to the limited sampling rate of the software, the registered times get a random error. This will depend on the CPU speed, and for a 266 MHz CPU an error of around ±25 microseconds was found. Thus, the maximum error of the PC timing even if a slow PC is used, is no more than a couple of 1/10,000s of a second. The above figures have been verified by measurements using equipment traceable to atomic clock standards.
The sensor is designed to have a response time of around 1 millisecond.

The timing errors from the optical part of the system and the visual situation have not been possible to measure, in want of a better reference for timing C/L models, and here only an assessment can be made. Model speeds are between 70 and 80 metres per second. One millisecond corresponds to 70-80 mm travel, which is about equal to the chord of the wing. The width of the field of view at the flight radius is around 200 mm, which the model will travel in less than 3 milliseconds. How far into the field of view the model must travel before the sensor pulse is output will depend on the flying height and lighting conditions, and the threshold set in the sensor. Only if these conditions differ for the start and stop passes, there is a net timing error. It is a fair assumption that the distance flown into the field of view can vary no more than the distance from the model nose to the wing trailing edge, i.e. 250 mm, corresponding to a maximum timing error of around 3 milliseconds. In normal circumstances, the error is likely only fractions of a millisecond.

In all, this means that the overall accuracy of the Transitrace system can be projected to be <u>20 to 100</u> times better than that of manual timekeepers.

Design Limitations

The fact that the sensor uses light from the sky is a feature that allows for this very simple unit. It also, however, puts a limit on the dependability, as the light from the sky can be quite variable, in ways that cannot be foreseen. Brightness variations and changes are no problem at all as long as they are even across the field of view, thanks to the percentage drop response. Problems occur if the light is unevenly distributed, which can happen if there are dark and sunlit clouds in view simultaneously. If a model passes across the background of a dark cloud, while the rest of the sky in view is bright, the percentage drop will obviously be smaller. With this in mind, the threshold is set for a considerable margin, but as the sky cannot be predicted, there is a chance that passes will be missed under extreme circumstances. As mentioned, the software is often able to correct for missed passes inside the timed flight.
Another obvious limitation is that the sun must not be in the field of view. However, the sensor is remarkably tolerant to the sun shining down through the slit. It has been found to work with the sun's rays falling just millimetres away from the phototransistor.

Evaluation at the World Championships in Landres, France

By kind permission of the organisers at Landres, the Transitrace system could be tested during the competition. Its official use was abandoned, as some problems were seen in the tests on the practice days, and the bad weather prevented all chances of establishing the reliability of the system. It was, however, tested during the second and third rounds of the competition. During the event a lot of support was received from Jo and Peter Halman, who, in spite of being busy as official and competitor, respectively, found time to assist with the operation and evaluation. Also, Darlene Brown, wife of US competitor Tom, assisted as an operator. Jean-Paul Perret, as well as all in the contest organisation were very supportive. The author sends a warm thanks to all those who helped.

There are flight records from 46 timed flights out of the contest total of 102, which provides a good material for comparison between the official results and those produced by the system. The reason that not all flights were recorded is that the first round was used only for a few preparatory tests, and that sometimes no operator was available. The sensor was located in alignment with the timer mark used by the manual timekeepers. The distance to the circle centre was 21.5 instead of 20.5 metres. The reason was to guarantee clearance of landing models under all circumstances. The sensor was, however, designed and aligned for the shorter distance. Another metre seems small, but the set-up is extremely sensitive to the distance, and this change reduces the solid angle of the model, seen from the sensor, into less than half.

The operator was positioned approximately 1/3 lap after the officials, with no means of communication between them. This meant that the judging of when the handle was put in the pylon fork was done independently, and from different outlook points. Therefore, shifts in the start lap compared to the official timing were quite common, which was obvious when looking at the data. As the flight record file gives the times for all passes, the results for alternative starting laps can be calculated later. Many flights ended in slowing speed, and the results could be fit only if the starting lap was shifted by plus or minus one lap. Faced by this ambiguity, the choice was made to make the comparison between the manual and electronic results after a shift to the laps that gave the smallest difference was applied. This has the disadvantage that lap shifts might be done when they actually should not, and large but real differences between the manual and electronic result become concealed. The number of such cases is probably quite small, though, but the data presented should be treated with this in mind.

The results of the evaluation are shown in the appended table. A few explanations to the table: Flights are shown in the order they appear in the flight log. “Manual Result” is the official speed. The electronic result speeds are given for three alternative start laps, “-1 lap” is one lap before the lap the system chose after the two lap down count from the operator handle-in-pylon decision, and so on. The “Best Fit Diff. Man-El” column shows the difference between the manual result and the one of the three alternative electronic results which gives the smallest difference. In one case it was necessary to shift laps to one later to find a fit, which is denoted. At the bottom the calculated mean values and the standard deviation for the difference are shown.

One point of concern regarding the use of electronic timekeeping has been that if there is a bias between the manual and the electronic result, and the electronic system occasionally fails, the affected competitors would be at a disadvantage, or an unfair advantage. However, the data now collected show clearly that there is only a very small bias between the manual and electronic results. The mean difference is only 0.13 km/h, close to being statistically insignificant. If we suspect that the lap fitting has influenced the outcome, we can drop it, and choose the “0 lap” column for comparison. Still the difference remains low. There is, however, a random deviation, shown by the standard deviation of 0.61 km/h, corresponding to 0.03 seconds. As explained above, the method of lap fitting may conceal some differences, and the true value could be larger. As the projected error of the electronic timing is much smaller, it is a fair assumption that the deviation seen is largely due to errors in the manual timekeeping. These findings go in line with earlier studies on the spread of stopwatch times, such as the one done by the author using the records from Norrköping in 1996. In a few cases the difference exceeds 1 km/h, and if the electronic system had been used, it would have affected the placing. We must state clearly, however, that such speculation would be unfair, as the record is far from complete, and the problem with lap synchronisation makes it ambiguous.

There were a total of three flights where laps were missed. In two flights the misses occurred inside the timed flight. The system corrected for this and presented correct results except in one case. The process can be seen in the flight log example below for the miss outside the timed flight. In the case not corrected there were a total of three missed laps. Inside the timed flight there was a missed lap, one registered, and then one missed again. The software was not equipped to handle this case, and the system presented a wrong result. The correct result could, however, be calculated manually from the flight log, and this is the result presented in the table. The third missed lap was the one after the nominal stop lap, and therefore no lap fitting was done here. The reason for the missed laps is not clear. No low flying was reported by the operators. The system is still under development, and it should be possible to eliminate lap misses for causes other than low flying and, possibly, extreme lighting conditions. The increased distance to the circle, which was not tested before, and outside the design prerequisites, may have contributed.

The testing at Landres represents something like a tenfold increase in overall operating experience of the system. That it was able to give a trustworthy result in all 46 flights except one, and in this case a manual correction could be done successfully, must be considered a great leap forward. The test also represents a first study of timekeeper performance against another standard. With the PC and operator situated in the main spectator area, public interest was big, and gave the system a better exposure than had it been used officially, and in view of the operators only.

Pilot Series and Future Developments

There were quite a number of people interested in acquiring a system, and their interest has formed the base for a pilot run of about 20 units, which is currently underway. Hopefully, delivery can start within a few months. The software is being developed in many ways, also for use in other speed classes, where line lengths and lap counts differ. A program for F2C practice is also under development. The system's suitability for R/C pylon racing will also be tested.

Cost

The cost is still not determined. The original indication was US$100 for the sensor, short cable and software, but this may have to be increased. Suitable second hand laptop PCs could probably be acquired for less than US$500.

The Flight Log File

The Transitrace program generates a log file, where all relevant data is retained for later use. A few examples are given here to clarify the system operation. The file format is “plain text”, allowing it to be viewed by applications such as MS-DOS Edit and Windows Notepad. The data items are separated by tabs, to allow convenient import into MS Office and most other applications. The file is organised into records, one for each flight. These are separated by page breaks, making the flights appear on separate pages if printouts are made.

The flight log file from Landres has been made public on the Internet. It has been manually edited to include the competitors’ names and a few comments. It can be found here:

http://www.plasma.kth.se/~olsson/wch00f2alog.txt

Below are three examples of flight records taken from this log file. The comments to the right are added here.

The “Ticks” column shows the “raw data”, i.e. readings of the PC internal timer, obtained when passage pulses arrive from the sensor. The timer of the PC used in Landres has a clock tick rate of 1,193,253 per second. To get the time in seconds between any two events, subtract the tick values of the events and divide by the clock tick rate. This allows the calculation of timings in retrospect, with the full resolution of the system.

Examples from the Flight Log

The first flight record shows a pilot that takes off, lands and takes off again during the three minutes period, while the timing proceeds. It also shows the correction of a missed lap.

F2A, Round 3, Competitor 7, Attempt 2			Ron Peters, CAN	
				Round, competitor and attempt numbers are entered by the operator. The name has been added afterwards.
Monday, 17 July, 2000, 14:11:04				The time of day is given to positively
Timed Flight				identify the flight.
First	Last	Time (s)	Speed (km/h)	The official result, with lap numbers
13	21	13.4045	268.5	for the timed laps.
(Top km Speed:				The fastest kilometre is also found
11	19	12.9332	278.353)	and presented.
Individual laps:				
Lap	Time	Speed	Ticks	
1	2.6516	150.854	831986743	Speeds are shown for every individual lap
2	2.5689	155.708	835052111	
3	3.8382	104.215	839632069	
4	8.9246	44.820	850281394	
5	6.4951	61.585	858031639	
6	9.4747	42.217	869337421	
7	66.4010	6.024	948570646	Landed and took off again within 66 seconds
8	2.2005	181.781	951196345	
9	1.5808	253.031	953082679	
10	1.4575	274.447	954821820	
11	1.4575	274.447	956560960	Missed lap corrected.
12	1.4401	277.762	958279370	
13	1.4338	278.970	959990288	
14	1.4304	279.646	961697096	
15	1.4301	279.706	963403535	
16	1.4303	279.653	965110299	
17	1.4322	279.294	966819255	
18	1.4351	278.719	968531741	
19	1.4437	277.071	970254407	
20	1.4841	269.515	972025371	
21	1.8847	212.231	974274347	
22	3.5006	114.265	978451506	

If the lap time suddenly becomes roughly twice the normal, the software assumes that a lap has been missed. Unfortunately, the program did not include a clear indication of such events in the log file. This is revealed anyway by a closer look, as two consecutive laps get exactly the same lap time. The time of the missed lap is reconstructed by repeating the previous value. The software to handle missed laps is still under development, and only a primitive version was used in Landres.

The second example shows the benefits of having each lap timed with high accuracy, and recorded. This flight record is chosen as it is reveals quite an astonishing speed consistency, attained by Gordon Isles in his third flight. The lap times of laps 10, 11 and 12 are equal to within 15 millionths of a second!! Extra decimals have been added afterwards so that the difference gets resolved. Talk about running like clockwork!

F2A, Round 3, Competitor 22, Attempt 1			Gordon Isles, GBR
Monday, 17 July, 2000, 10:03:22			
Timed Flight			
First	Last	Time (s)	Speed (km/h)
7	15	12.3240	292.1
(Top km Speed:			
9	17	12.3116	292.408)
Individual laps:			

Lap	Time	Speed	Ticks	
1	2.6905	148.673	290579815	
2	1.7235	232.085	292636397	
3	1.4548	274.944	294372393	
4	1.4117	283.349	296056891	
5	1.3905	287.657	297716163	
6	1.3799	289.880	299362710	
7	1.3743	291.067	301002543	
8	1.3731	291.309	302641016	
9	1.3711	291.740	304277069	
10	1.3695	292.070	305911269	
11	1.3678885	292.422	307543506	Added decimals are calculated afterwards.
12	1.3678952	292.420	309175751	
13	1.3678801	292.424	310807978	
14	1.3663	292.752	312438371	
15	1.3660	292.824	314068365	
16	1.3664	292.735	315698853	
17	1.3685	292.289	317331830	
18	1.4042	284.853	319007439	
19	1.4742	271.331	320766553	

The third example shows how the flight record looks if no official flight is made. The fastest kilometre is still found, on condition that nine laps are completed.

F2A, Round 3, Competitor 12, Attempt 1 Luis Parramon, ESP
Monday, 17 July, 2000, 09:49:18
(Top km Speed:
4 12 21.6023 166.649)
Individual laps:

Lap	Time	Speed	Ticks
1	18.8662	21.202	3690169367
2	3.9259	101.887	3694853974
3	3.1253	127.987	3698583267
4	2.4803	161.274	3701542843
5	1.9999	200.010	3703929233
6	1.9919	200.818	3706306018
7	2.7540	145.242	3709592276
8	2.5141	159.102	3712592242
9	1.9787	202.152	3714953342
10	2.3981	166.799	3717814883
11	2.8045	142.627	3721161392
12	2.6809	149.205	3724360353
13	2.6856	148.945	3727564903
14	2.7118	147.502	3730800799
15	2.9433	135.903	3734312871
16	2.7233	146.879	3737562486

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